

## ***REGISTRIRANJE I DODJELA CERTIFIKATA OSOBLJU KOJE RADI NA KVALITETU PO SHEMA EOQ***

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### ***REZIME***

*U radu su predstavljene neke od najvažnijih prednosti uskladene sheme Evropske organizacije za kvalitet (EOQ-a) za registriranje i dodjelu certifikata osoblju koje radi na kvalitetu, kao i procedura priznavanja SZK, kao zastupnika EOQ-a. Predstavljena su također i naša prva iskustva u obuci i dodjeli certifikata osoblju koje će raditi kao menadžeri sistema kvaliteta EOQ-a (čija će odgovornost biti stvaranje i provođenje sistema kvaliteta unutar firme ili organizacije).*

***Ključne riječi:*** obuka, dodjela certifikata, shema EOQ, osoblje koje radi na kvalitetu

## ***REGISTRATION AND CERTIFICATION OF QUALITY PERSONNEL ACCORDING TO THE EOQ SCHEME***

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### ***SUMMARY***

*At the paper some of the main advantages of the EOQ harmonized scheme for the registration and certification of quality personnel are discussed together with recognition procedure for SZK as EOQ agent. Also our first experiences in training and certification of personal for EOQ quality systems manager (who holds the responsibility for the creation and implementation of a quality system within a company or organization) are presented.*

***Keywords:*** training, certification, EOQ scheme, quality personnel,

### ***1. UVOD***

U većini evropskih organizacija dobivena je bitka koja je vođena kako bi se kvalitet priznao kao osnovni predmet menadžmenta. Stručnjaci su danas pokretniji nego ikad prije, posebno s obzirom na težnje ka većoj harmonizaciji poslovne prakse unutar Evropske unije, a i šire, postoji istinska potreba za jednim evropskim sistemom obuke i sposobljavanja iz oblasti kvaliteta. Stoga se središte pomjerilo ka iskustvu, obuci, sposobnostima i priznavanju osoblja koje će raditi na kvalitetu. Samo postojanje ljudi koji imaju određene odgovornosti da rade na kvalitetu nije garancija da je to osoblje i kvalitetno.

Takav sistem postoji u obliku Uskladene sheme za sposobljavanje i registriranje osoblja koje radi na kvalitetu pri EOQ. Evropska organizacija za kvalitet (EOQ) je uspostavila ovu shemu kao dio svoje misije na jačanju evropskog ekonomskog sistema putem promoviranja poboljšanja u svim aspektima kvaliteta – od razvoja upravljanja sistemima kvaliteta do korištenja kvaliteta kao sile na konkurentnom tržištu tako što će se predviđati potrebe i stvarati povjerenje kod kupaca.

### ***1. INTRODUCTION***

*In most European organizations, the battle to have quality recognized as a fundamental management discipline has been won. Professionals are now more mobile than ever and, with moves towards greater harmonization of business practices within the European Union and beyond; there is a real demand for a European system of quality training and qualifications. The focus has therefore now shifted to the experience, training, qualifications and recognition of quality personnel. Merely having people with specific responsibilities for quality does not guarantee that you have quality personnel. Such a system exists in the shape of the EOQ Harmonized Scheme for the Qualification and Registration of Quality Personnel. The European Organization for Quality (EOQ) established the scheme as part of its mission to strengthen Europe's economic system by promoting improvement in all aspects of quality - from developments in quality systems management through to the use of quality as a competitive market force by anticipating customer needs and creating customer confidence.*

Usklađena shema za osposobljavanje i registriranje kvalitetnog osoblja EOQ-a, koja je predstavljena 1994. godine, koristi sheme obuke i osposobljavanja koje već postoje u većini zemalja članica EOQ-a i jača ih usklađivanjem relevantnih procedura. Međutim, shema EOQ-a ne propisuje način na koji bi trebalo voditi obuku i osposobljavanje osoblja. Cilj EOQ-a jeste da postigne uzajamno priznavanje kvalifikacija unutar sheme, te time i registriranje i dodjelu certifikata osoblju koje radi na kvalitetu.

## **2. SHEMA REGISTRIRANJA OSOBLJA EOQ-A**

Evropska organizacija za kvalitet, EOQ, je nezavisno, neprofitno udruženje u skladu s belgijskim zakonom. Kao tijelo za koordiniranje i kataliziranje za svoje 34 organizacije članice (FMO-ove), EOQ ima jedinstven pogled na doprinos koji kvalitet daje organizacijama svih vrsta, u svim sektorima širom Europe. EOQ je uspostavljena 1956. godine, a njeno trenutno članstvo čine 34 evropske organizacije za kvalitet na državnom nivou, jednakom kao i institucije, kompanije i pojedinci iz cijelog svijeta.

Ideja o stvaranju "evropskog inžinjera kvaliteta" nije nova. Komisija za edukaciju i obuku EOQ-a razmatrala je tu ideju još prije deset godina, međutim, u to vrijeme, zahtjevi nisu bili jasni. Priličan broj organizacija, punopravnih članica EOQ-a (Full Member Organisations - FMOs) obavilo je kurseve obuke za različite ciljne grupe, od kojih su najvažnije bili ispektori i inžinjeri kvaliteta. U to vrijeme su postojale neke druge poteškoće. Jedna od njih bili su različiti jezici u zemljama iz kojih su poticale Organizacije, punopravne članice, a druga je bila nedostatak zajedničkih uputstava za sisteme kvaliteta.

Situacija se promjenila kad su ISO Standardi, serija 9000 prihvaćeni, objavljeni i stupili na snagu kao usklađeni Evropski standardi serija EN 29000 do 29004. Industrijski kupci usluga nisu više bili zadovoljni certifikatima proizvoda, oznakama i obilježjima kvaliteta, tražili su znak, svjedoka i dokaz o sposobnosti da se proizvede kvalitet, odnosno informaciju koja bi se mogla dobiti prije snabdijevanja proizvodima, pa čak i prije samog poručivanja.

Certifikat, odnosno potvrda koja pokazuje sposobnost o kvalitetu bila je logična posljedica.

The EOQ Harmonized Scheme for the Qualification and Registration of Quality Personnel, introduced in 1994, uses the training and qualification schemes that already exist in most of the EOQ's member countries and strengthens them by harmonizing the relevant procedures. But the EOQ scheme does not prescribe how the training of quality personnel should be conducted. The EOQ's goal is to achieve mutual recognition of qualifications within the scheme and, hence, the registration and/or certification of quality personnel.

## **2. THE EOQ PERSONNEL REGISTRATION SCHEME**

The European Organization for Quality, EOQ, is an autonomous, non-profit making association under Belgian law. As the co-coordinating body and catalyst for its 34 national full member organizations (FMO's), the EOQ has a unique outlook on the contribution that quality makes to organizations of all types, in all sectors, right across Europe. The EOQ was established in 1956 and its present membership is comprised of 34 national European quality organizations, as well as institutions, companies and individuals from all over the world.

The idea of creating the "European Quality Engineer" is not new. The Education and Training Committee of the EOQ discussed this idea already more than ten years ago. However, at that time the requirements were not very clear. Quite a number of EOQ Full Member Organizations (FMOs) performed training courses for different target groups; the most important were Quality Inspectors and Engineers. There were certain other difficulties at that time: the different languages in the FMO countries was one, the not yet existing common guideline for Quality Systems was the other.

The situation changed when the ISO Standards Series 9000 were accepted, published and put in force as a harmonized European Standard Series EN 29000 to 29004. Industrial customers were no longer satisfied with product certificates and quality marks, they asked for an indication, a witness and a proof of the capability to produce quality / an information which could be gained prior to the supply of the products and even prior to the time of placing an order .

The certificate demonstrating the quality capability was the logical consequence.

*U tom kontekstu, državne organizacije koje su radile na dodjeli certifikata o sistemima kvaliteta, s ciljem međunarodnog priznavanja certifikata za sisteme kvaliteta i evropskih organizacija koje su težile uzajamnom prihvaćanju certifikata, Evropska mreža za ocjenu i dodjelu certifikata za sisteme kvaliteta (the European Network for Quality System Assessment and Certification - E-Q-Net), na bilateralnoj osnovi i radi multilateralnog prihvatanja certifikata, Evropski komitet za procjenu i dodjelu certifikata za kvalitet (the European Committee for Quality Assessment and Certification - EQS), tražio je jedinstveno i usklađeno osposobljavanje relevantnih ocjenjivača kvaliteta.*

*Evropska organizacija za kvalitet (EOQ), kao nadležna organizacija, zajedno sa Organizacijama punopravnim članicama (FMO), koje su već vršile obuku iz oblasti upravljanja i provjere kvaliteta priznala je da je njen zadatak da postane aktivna. Evropska organizacija za kvalitet je isprva bila svjesna da se kod obuke i educiranja ocjenjivača kvaliteta nije radilo o kratkim seminarima. Obuka ocjenjivača kvaliteta može se zasnivati samo na znanju iz oblasti upravljanja kvalitetom i na iskustvu u radu sa sistemima kvaliteta, te sredstvima i metodama za postizanje kvaliteta.*

*Komisija za edukaciju i obuku (The Education and Training Committee), na prijedlog izvršne i generalne skupštine EOQ-a, započela je anketiranje kako bi saznala više o obuci koja se nudi u Zemljama punopravnim članicama EOQ-a. Rezultat je pokazao da skoro sve zemlje punopravne članice organiziraju kurseve obuke za različite nivoje ciljnih grupa, od kojih su neki namijenjeni posebno ocjenjivačima. Ankete je također potvrdilo da obuka ocjenjivača ne može biti i nije izolirana obuka iz oblasti kvaliteta. Slijedi kratka historija uspostavljanja usklađene sheme EOQ-a:*

- 1985.-1990. Komisija za edukaciju i obuku EOQ-a definira znanje i iskustva stručnjaka koji se bavi kvalitetom
- 1990.-1993. EOQ izrađuje svoju Usklađenu shemu za osoblje
- 13. juna 1993. u Helsinkiju, Generalna skupština EOQ-a usvaja Memorandum o razumjevanju za uspostavljanje usklađene sheme EOQ-a za osposobljavanje i registriranje osoblja koje se bavi kvalitetom
- 1. januar 1994. zvanični datum lansiranja EOQ PRS
- avgust 1994. SAQ dobija prvu akreditaciju EOQ-a kao zastupnik EOQ-a za registriranje osoblja
- 19. januar 1995. DGQ dobija certifikat kojim se potvrđuje da je zastupnik EOQ-a za registriranje osoblja

*In this context the national organizations dealing with the certification of quality systems with the aim of an international recognition of the quality system certificate and the European Organizations striving for mutual acceptance of certificates, the European Network for Quality System Assessment and Certification (E-Q-Net) on a bilateral basis and for multilateral acceptance of certificates the European Committee for Quality assessment and Certification (EQS) asked for a unified or harmonized qualification of relevant auditors.*

*The EOQ as the competent organization with FMOs performing already training in the field of quality engineering and auditing recognized that it was its task to become active. The EOQ was aware right from the beginning that the training and education of quality auditors was not a matter of training in a short seminar. Training of auditors can only be based on a sound knowledge of quality engineering and experience with quality systems, quality tools and methods.*

*The Education and Training Committee, on proposal of the EOQ Executive and the General Assembly) started a survey in order to learn more about the training offered by the FMOs of EOQ in their countries. The result showed that in almost all countries the FMOs perform training courses for different levels of target groups, some specifically for auditors. The survey also proved that training of auditors cannot be and is not an isolated training in the Quality field. A brief history of establishing EOQ Harmonized Scheme is:*

- 1985-1990 The EOQ Education and Training committee defines the Knowledge and experience of Quality Professional.
- 1990-1993 EOQ builds the EOQ Personnel Harmonized Scheme
- June 13, 1993 in Helsinki EOQ General Assembly accepts the Memorandum of understanding for establishing an EOQ Harmonized Scheme for the Qualification and Registration of Quality Personnel.
- January 1, 1994 Official date of launching of the EOQ PRS
- August 1994, SAQ receives the first EOQ accreditation as agent of EOQ for registration of Personnel
- January 19, 1995 DGQ receives the recognition certificate as agent of EOQ for registration of Personnel

- 30. oktobar 1996. EOQ-ova Shema za osoblje je upisana u dokument *Evropska politika promoviranja kvaliteta s ciljem unapređenja konkurentnosti u Evropi* (Poglavlje III, 2, e) : "Jedna od najvažnijih metoda kojima će se uvesti dosljednost u svijetu kvaliteta ... jeste osiguranje da programi obuke razviju slične pristupe... U tom takmičenju, posao koji su tijela Evropske organizacije za kvalitet (EOQ) već uradila, a to je razvoj uskladene sheme na nivou Europe... mogao bi poslužiti kao primjer nečeg vrijednog."
- 1. juni 2003. SQA (SZK - Slovensko združenje za kakovost) dobija certifikat kojim se potvrđuje da je EOQ-ov zastupnik za registriranje osoblja.

Uskladena pravila i procedure EOQ-a uspostavljene su i za ospozobljavanje i za registriranje osoblja koje se bavi kvalitetom. Ova pravila i procedure se zasnivaju na "Općim kriterijima za organe za dodjelu certifikata osoblju", EN 45013, i novom ISO standardu 17024 "Opći uslovi za organe koji provode sheme za dodjelu certifikata". Uslovi koje bi Organizacije punopravne članice EOQ-a trebalo da ispune su državna akreditacija, davanje na uvid priručnika o kvalitetu u organizaciji i izjava o usklađivanju sa standardima EN 45014 i ISO 17024. Procedura za priznavanje Organizacije punopravne članice (FMO), koja ima Shemu za registriranje osoblja (Personnel Registration Scheme - PRS) jednaku EOQ-ovoj predstavljena je na *slici 1*.

Da bi uspostavila svoju uskladenu shemu, EOQ je prije svega postigla dogovor s Organizacijama punopravnim članicama koje su učestvovale o uslovima koje je bilo potrebno ispuniti da bi se postigla usklađenost na međunarodnom nivou. Tada su uspostavljana Uskladena pravila i procedure EOQ-a i za ospozobljavanje i za registriranje osoblja koje radi na kvalitetu. Da bi jedna Organizacija punopravna članica bila priznata kao zastupnik, ona mora ili dokazati da je akreditirana kao organ za dodjeljivanje certifikata od strane svog državnog organa ovlaštenog za akreditiranje ili mora proći proces strogog ocjenjivanja na kolegialnoj osnovi, i to od strane ocjenjivača koje u tu svhu dodijeli EOQ.

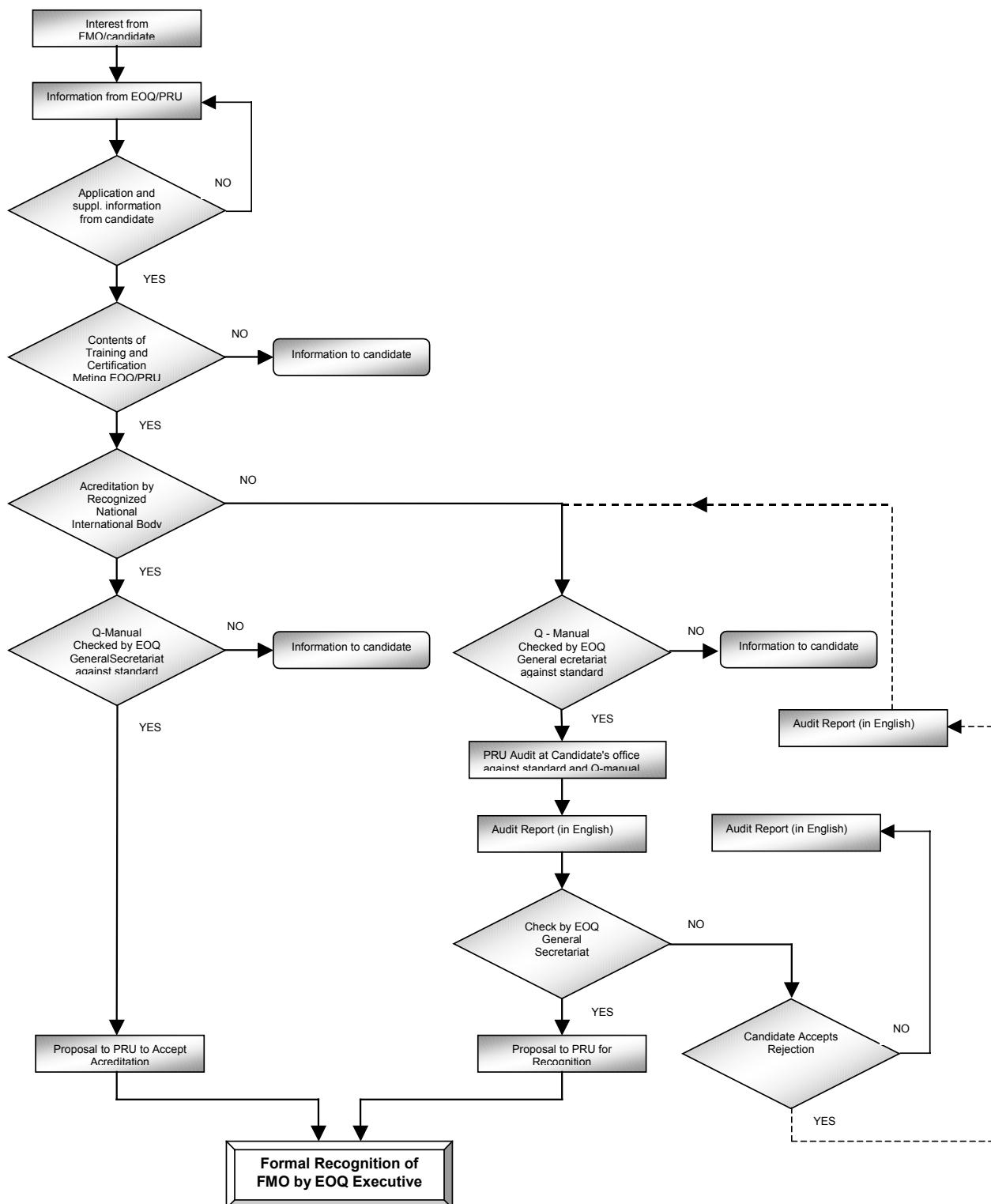
EOQ također vrši periodično ocjenjivanje svih priznatih Organizacija punopravnih članica. Organizacije punopravne članice koje učestvuju u tome moraju prilikom svakog ocjenjivanja zadovoljiti uslove uskladene sheme. Organizacije punopravne članice također moraju priznati obuku i dodjelu certifikata koje pružaju i drugi organi u njihovoj zemlji, dok god one zadovoljavaju pravila i uslove EOQ-ove sheme.

- October 30, 1996 The EOQ Personnel Scheme is recorded in the document A European Quality promotion policy for improving European Competitiveness (Ch III, 2, e) : "One of the main methods of bringing coherence to the quality world ..would be to ensure that training programs develop similar approaches..In this contest, the work already carried out by bodies such as the European Organization for Quality (EOQ), which has developed harmonized scheme, at European level.could be of exemplary value."
- June 1, 2003, SQA (SZK - Slovensko združenje za kakovost) receives the recognition certificate as agent of EOQ for registration of Personnel.

Harmonized EOQ rules and procedures were established for both the qualification and the registration of quality personnel. These rules and procedures are based on EN 45013 "General Criteria for Bodies Operating Certification of Personnel" and the new ISO 17024 standard "General requirements for bodies operating certification schemes for persons". The requirements to be fulfilled by the EOQ FMOs are national accreditation, the submission of the organizations quality manual and a declaration of conformity in accordance with EN 45014 and ISO 17024. Procedure for the recognition of Full Member Organization (FMO) sharing the EOQ Personal Registration Scheme (PRS) is presented in *Figure 1*.

To set up its harmonized scheme, the EOQ first agreed with its participating FMOs on the requirements needed to achieve international conformity. Harmonized EOQ rules and procedures were then established for both the qualification and the registration of quality personnel. For an FMO to be recognized as an agent, it must either prove that it is accredited as a certification body by its national accreditation authority or undergo a rigorous peer evaluation by auditors appointed by the EOQ for that purpose.

All recognized FMOs are also audited periodically by the EOQ. Participating FMOs must satisfy the EOQ at all times that national procedures meet the requirements of the harmonized scheme. FMOs are also obliged to recognize the training and certification provided by other bodies in their countries, so long as they meet the EOQ scheme's rules and requirements.



Slika 1: Procedura priznavanja Organizacija punopravnih članica koje imaju PRS jednak EOQ-ovom  
 Figure 1: Procedure for the recognition of FMO sharing the EOQ PRS

Svaka organizacija punopravna članica nudi Generalnom sekretarijetu EOQ-a uspješne kandidate (koje sama obuči ili koje obuče drugi državni organi koji su osposoljeni i registrirani za to) za pet kategorija, što je središnja tačka za registriranje i dodjelu certifikata. Svako registriranje i svaki certifikat nose jedinstveni identifikacijski broj, što znači da za svaki postoji evidencija, kojoj se može lako ući u trag i koja se po potrebi može ažurirati.

Danas postoji 17 zemalja koje su priznate kao zastupnici EOQ-a: Austrija, Češka Republika, Danska, Njemačka, Mađarska, Italija, Holandija, Norveška, Poljska, Rumunija, Slovenija, Slovačka, Španija, Švicarska, Turkska, Ukrajina i Velika Britanija.

### **3. KATEGORIJE SHEME EVROPSKE ORGANIZACIJE ZA KVALITET**

EOQ-ova shema je pozdravljenja kao istinski evropska, dobila je pohvale za svoju otvorenost, transparentnost i kredibilitet u očima širokog spektra korisnika. EOQ-ova shema sadrži jedanaest kategorija osoblja koje rade na kvalitetu:

- **EOQ-ov stručnjak za kvalitet** je, naprimjer, inžinjer za kvalitet koji je odgovoran za izradu i primjenu kvalitetnih tehnika.
- **EOQ-ov menadžer sistema kvaliteta** ima odgovornost za stvaranje i primjenu sistema kvaliteta u kompaniji ili organizaciji.
- **EOQ-ov ocjenjivač kvaliteta** je osoba osposobljena za vođenje procesa vanjskog ocjenjivanja kvaliteta (od strane treće strane).
- **EOQ-ov TQM ocjenjivač** je osposobljen za vršenje samoprocjene (unutrašnje ocjene) i/ili procjene (vanjske procjene) od strane treće strane. On također ima pravo da učestvuje u procesu procjene radi dodjele državnih nagrada za kvalitet. Procjene se vrše u skladu s modelima Poslovne izvrsnosti, evropskim ili nekim drugim ekvivalentnim modelom.
- **EOQ-ov menadžer za sisteme okoliša** je odgovoran za stvaranje i provođenje daljeg razvoja Sistema upravljanja okolišom.
- **EOQ-ov ocjenjivač za okoliš** je osposobljen za vođenje ocjena kvaliteta koje se odnose na okoliš (ocjene od strane druge ili treće strane).
- **EOQ-ov TQM lider** je osposobljen za vođenje, podučavanje i podršku menadžmentu i osoblju organizacije iz oblasti menadžmenta s ciljem uvođenja promjena ka TQM-u, u skladu s TQM/Modelima izvrsnosti, bilo evropskim ili nekim drugim ekvivalentnim modelom.

Each FMO offers up successful candidates (trained by themselves or by other qualifying and registered national bodies) in the five categories to the EOQ General Secretariat, which is the central point for registration and the issuing of certificates. Each registration and certificate carries an exclusive identification number, which ensures that each record is dedicated and can easily be traced and updated as necessary.

There are today 17 countries recognized as EOQ agent: Austria, Czech Republic, Denmark, Germany, Hungary, Italy, Netherlands, Norway, Poland, Romania, Slovenia, Slovakia, Spain, Switzerland, Turkey, Ukraine and the United Kingdom.

### **3. CATEGORIES OF EOQ SCHEME**

The EOQ scheme has been welcomed as being genuinely European and has been commended for its openness, transparency and credibility in the eyes of a wide range of users. Eleven categories of quality personnel are identified by the EOQ scheme:

- An **EOQ quality professional** is, for example, a quality engineer with responsibilities for devising and applying quality techniques.
- An **EOQ quality systems manager** holds the responsibility for the creation and implementation of a quality system within a company or organization.
- An **EOQ quality auditor** is a person qualified to conduct external (third party) audits.
- An **EOQ TQM assessor** is qualified to perform self-assessments (internal assessments) and/or third party assessments (external assessments). He is also eligible to take part in the assessment process for the national quality awards. The assessments are performed according to Business Excellence models, European or equivalents.
- An **EOQ environmental systems manager** holds the responsibility for the creation and implementation and further development of an Environmental Management System.
- An **EOQ environmental auditor** is qualified to perform environmental audits (2nd and 3rd party audits).
- An **EOQ TQM leader** is qualified to lead, coach and support in a professional manner management and staff of an organization in the management of change towards TQM, in accordance with TQM/Excellence models, either European or equivalents.

- EOQ-ov menadžer sistema za zdravlje i sigurnost je sposobljen za stvaranje i provođenje Sistema upravljanja zdravljem i sigurnosti (Health And Safety Management System - HSMS). EOQ-ov ocjenjivač zdravlja i sigurnosti je sposobljen za vršenje procesa ocjene sistema zdravlja i sigurnosti (ocjene od strane druge ili strane).
- EOQ-ov menadžer procesa je sposobljen da bude koordinator i multiplikator načina razmišljanja u organizaciji usmjerenog na proces, identificiranja, upravljanja i poboljšanja procesa u organizaciji, prepoznavanja potencijala za optimiziranje, promoviranje sistematskog realiziranja organizacijske strategije.
- EOQ-ov konsultant za sisteme menadžmenta je u stanju da razumije i da daje pojašnjenja, da ukaže na relevantne metode, da pomaže pri njihovoj primjeni i da upravlja procesom i sadržajem konsultantskog projekta, da elaborira i integrira relevantne metode, da moderira i interpretira rezultate konsultantskih projekata i da generira mjerljive dobrobiti.
- An EOQ Health and Safety Systems Manager is qualified to hold the responsibility for the creation and implementation of a Health And Safety Management System (HSMS) An EOQ Health and Safety Auditor is qualified to perform health and safety system audits (2nd and 3rd arty audits)
- An EOQ Process Manager is qualified to be a co-coordinator and multiplier of the: process oriented way of thinking in the organization, identification, management and improvement of the organization's processes, recognition of optimization potentials, promotion of the systematic realization of the organization's strategy
- An EOQ management system consultant is capable of understand and to be able to explain, to indicate relevant methods, help to apply them and to manage the process and content of consultancy project, to elaborate and integrate relevant methods, to moderate and interpret the results of consultancy project and to generate measurable benefit

#### **4. MENADŽERI SISTEMA KVALITETA EOQ-A**

EOQ-ovi menadžeri sistema kvaliteta moraju imati sposobnost da uvedu sisteme kvaliteta koji zadovoljavaju uslove kompanije bilo koje veličine, te da djeluju kao predstavnici menadžmenta. Moraju biti u stanju da vrše ocjene proizvoda i procesa, da djeluju kao unutrašnji ocjenjivači i da budu partneri u procesu ocjene radi dodjele certifikata. Kandidati za kategoriju EOQ-ovih menadžera sistema kvaliteta bi trebalo da posjeduju univerzitetsku ili njoj ekvivalentnu diplomu, koja je relevantna za oblast u kojoj rade.

Još jednom, definicija ekvivalentnosti je stvar zastupnika Organizacije punopravne članice. Sažetak uslova za edukaciju i obuku EOQ-ovih menadžera sistema kvaliteta (Quality Systems Managers -QSM) predstavljen je na slici 2.

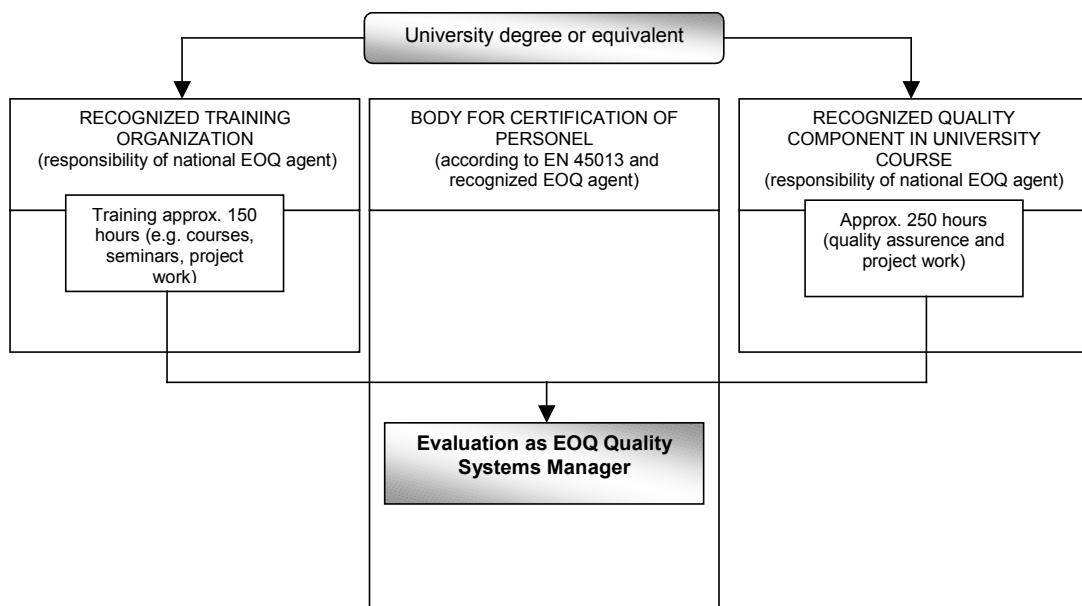
Prije nego što se sposobne za menadžere sistema kvaliteta, kandidati bi trebalo da su akumulirali odgovarajuću obuku i iskustvo na radnom mjestu u periodu od najmanje dvije godine. Pored toga, trebalo bi da posjeduju najmanje dvije godine praktičnog iskustva iz oblasti osiguranja kvaliteta, a dio toga tog iskustva bi trebalo da se odnosi na upravljanje sistemima kvaliteta. EOQ-ovi menadžeri sistema kvaliteta bi trebalo da budu otvoreni, orijentirani ka kvalitetu, iskreni, odani, da posjeduju odgovarajuće vještine, i da su spremni da prihvate i nauče nove tehnike. Trebalo bi da posjeduju menadžerske sposobnosti, da demonstriraju sposobnost da rade u timu, te da budu svjesni troškova.

#### **4. EOQ QUALITY SYSTEM MANAGERS**

EOQ quality systems managers must have the ability to install quality systems that meet the requirements of any size of company and to act as the management representative. They must be able to perform product and process audits, to act as internal auditors and to be partners for certification audits. Candidates for the EOQ quality systems manager category should hold a university degree or equivalent, relevant to their fields of employment.

Again, the definition of equivalence is a matter for the agent FMO. Summary of the education and training requirements for the EOQ Quality Systems Managers (QSM) is presented in Figure 2.

Before qualifying as a quality systems manager, the candidates should have accumulated appropriate practical workplace training and experience over a minimum period of two years. In addition they should have at least two years' practical experience in quality assurance, part of which should be in quality systems management. EOQ quality systems managers should be open-minded, quality-minded, honest, loyal, skilled and ready to accept and to learn new techniques. They should have managerial abilities, demonstrate the ability to work in teams and should be cost-conscious.



Slika 2: Uslovi za EOQ-ove menadžere sistema kvaliteta koji se odnose na edukaciju i obuku

Figure 2: Education and training requirements for EOQ-QSM

EOQ-ovi menadžeri sistema kvaliteta moraju biti kompetentni u svim tehnikama upravljanja kvalitetom, a to su:

- načela sistema kvaliteta,
- pregled i evaluiranje troškova koji se odnose na kvalitet,
- sistemi troškova koji se odnose na kvalitet,
- informacijski sistemi/sistemi komunikacija s podacima o kvalitetu,
- dokumentacija i evidencija koja se odnosi na kvalitet,
- sigurnost i odgovornost koja se odnosi na proizvod,
- zapošljavanje osoblja, edukacija i obuka koja se odnosi na kvalitet,
- evaluiranje statističkih metoda,
- postupanje sa nepridržavanjem,
- programi korektivnih mjera,
- održavanje i unapređenje sistema kvaliteta,
- ocjena dobavljača,
- upravljanje mjeranjem i testiranjem opreme,
- upravljanjem inspekcionim za kvalitet i osiguranje kvaliteta u svim elementima faza,
- Pokretanje motiviranja na kvalitet i programa poboljšanja kvaliteta,
- Napredne metode upravljanja kvalitetom,
- Razvoj programa ocjene kvaliteta.

The EOQ quality systems managers must be competent in all quality management techniques:

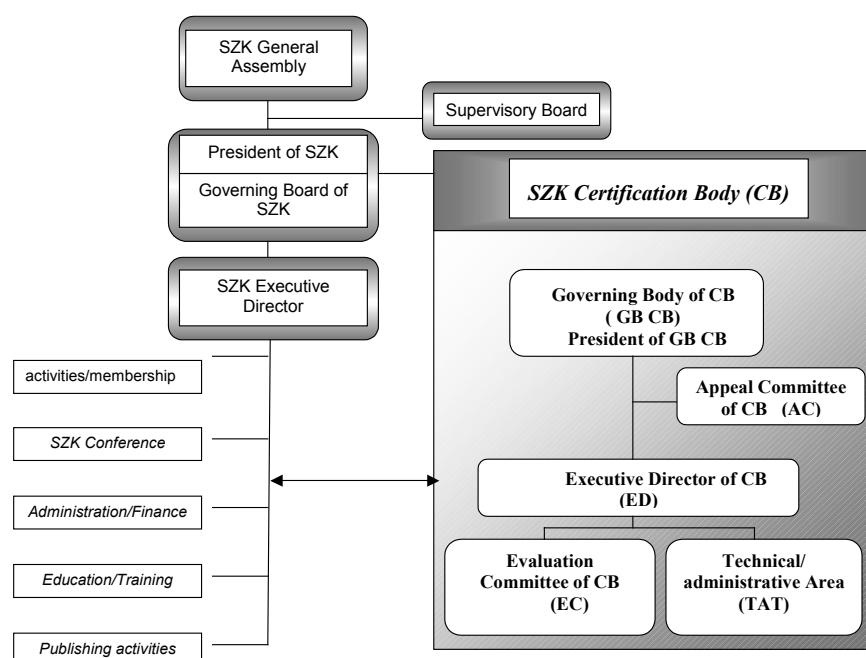
- Quality system principles,
- Review and evaluation of quality related costs considerations,
- Quality costs systems,
- Quality data information systems/communications,
- Quality documentation and records,
- Product safety and liability,
- Personnel recruitment, education and training related to quality,
- Evaluation of statistical methods,
- Treatment of non-conformance,
- Corrective action programs,
- Maintenance and improvement of quality systems,
- Supplier evaluation,
- Management of measuring and testing equipment,
- Management of quality inspection and quality assurance in each phase element,
- Initiating quality motivation and quality improvement programs,
- Advanced quality management methods,
- Development of quality audit programs.

## 5. ORGAN ZA DODJELU CERTIFIKATA SLOVENAČKOG UDRUŽENJA ZA KVALITET – CB SZK

SZK je pravno lice uspostavljeno u skladu sa Zakonom o društvu, UL SRS 37/74, 42/86. Udrženje je neprofitna organizacija, koju predstavlja njen predsjednik. Udrženje je osnovano 1991. i danas ima 1000 članova. Članovi udruženja su pojedinci koji aktivno učestvuju u sistematskom upravljanju kvalitetom u svom okruženju. SZK je započela projekt uspostavljanja svih formalnosti kako bi postala Organizacija punopravna članica EOQ-a početkom 2001. godine (Organ za dodjelu certifikata unutar strukture SZK predstavljen je na *slici 3*).

## 5. SLOVENIAN QUALITY ASSOCIATION CERTIFICATION BODY – CB SZK

SZK is a legal entity established in accordance with the Association Act (Zakon o Drustvih, UL SRS 37/74, 42/86). The association is a non-profit organisation, which is represented by its president. The association was founded in 1991 with 1000 members today. Members of the association are individuals who take an active part in systematic quality management in their environment. SZK started with the project of setting-up all formalities to become an EOQ FMO at the beginning of 2001 (CB within the structure of the SZK is presented in *Figure 3*).



*Slika 3: Struktura Slovenskog udruženja za kvalitet*  
*Figure 3: The structure of the Slovenian Quality Association*

Dodjelom certifikata za ekspertizu i integriranjem ovake ekspertize u poslovne strukture različitih organizacija, SZK želi dati značajan doprinos širenju i uspostavljanju ideje kvaliteta. Time slijedimo viziju "aktivnog učestvovanja u proširivanju znanja na praksi" i "međunarodnog povezivanja". Politika i ciljevi dobivanja certifikata, definirani u Priručniku za kvalitet, su sljedeći:

- Ispunjavanje zahtjeva i očekivanja klijenata koji se odnose na dodjelu certifikata
- Dodjela certifikata je osigurana svakom zainteresiranom licu pod jednakim uslovima. To mogu biti kandidati koji su prošli obuku iz stručne oblasti koja je predmetom dodjele certifikata, ili kandidati koji su tu stručnost stekli na neki drugi način

With the certification of expertise and with the integration of this kind of expertise into business structures of various organisations, SZK wish to contribute significantly to the expansion and establishment of the idea of quality. With this we follow the vision of "taking an active part in extending knowledge to practise" and "being internationally connected". Policy and objectives of certification, defined at Quality Manual, are as follows:

- Fulfilling demands and expectations of clients for certification.
- The certification is ensured to every interested party under equal conditions. These can be applicants who have passed training in the field of expertise that is the subject of certification, or applicants who have obtained this expertise in some other way.

- Nezavisnost, nepristrasnost i objektivnost u procesu dodjele certifikata. Osobe koje su učestvovale u evaluiranju neće donositi odluke o dodjeli certifikata
- Osiguranje povjerljivosti informacija o dodjeli certifikata kandidatima, te informacija koje se dobiju u toku procesa dodjele certifikata, u skladu sa Zakonom o zaštiti ličnih informacija
- Profesionalno obavljanje dužnosti; osiguranje potrebnih izvora; finansiranje i kompetentnost onih koji vrše dodjelu certifikata
- Poštivanje svih zahtjeva i vanjskih dokumenata
- Dodjela certifikata će se uvijek vršiti u cijelosti i neće biti ograničena zbog nedospjelih finansijskih, kadrovskih, organizacijskih ili nekih drugih limitirajućih okolnosti, prijašnjeg statusa kandidata, te raznih certifikata o pohađanju kurseva obuke
- Efikasno i odgovorno vršenje dužnosti; uz pomoć priručnika, svim zainteresiranim stranama je data prilika da imaju uvid u shemu dodjele certifikata
- Profesionalno (lagovremeno, nezavisno, nepristrasno i objektivno) rješavanje mogućih žalbi, pritužbi ili drugih oblika nezadovoljstva koje klijenti izraze.
- Independence, impartiality and objectivity in the process of certification. Persons who have participated in the evaluation will not make the decisions on certification.
- Safeguarding confidentiality of certification candidates' information, obtained during the course of certification; respecting the Law on Security of Personal Information. -
- Professional execution; ensured necessary sources; financing and competent certification executants
- Respecting all demands of external documents
- Certification will always be carried out in entirety and will not be restricted on the grounds of undue financial, cadre, organizational or other limited conditions, candidate's priority status, and various certificates attending training courses.
- Effective and responsible execution. With the manual, all interested parties are given the opportunity of an insight into the certification scheme.
- Professional (up-to-date, independent, impartial and objective) resolution of eventual appeals, complaints or other forms of dissatisfaction expressed by clients.

Certifikat osigurava kvalifikacije koje su u skladu s uslovima uskladene sheme Evropske organizacije za kvalitet. Priznat je u svim zemljama u kojima su organizacije članice EOQ-a (primjer EOQ-ovog certifikata o priznanju i ukupnog broja izdatis certifikata iz svih kategorija EOQ-ove sheme – više od 30,000 – predstavljen je na slici 4).

The certificate ensures the qualification that is compatible with the requirements of the European Quality Organisation harmonised scheme. It is also recognized and acknowledged in all countries in which their organisations are members of the EOQ (an example of EOQ recognition certificate and the total number of issued certificates from all categories of EOQ scheme – more than 30.000 – is presented in Figure 4).

## 6. ZAKLJUČAK

Uspostavljanjem nezavisnog Organa za dodjelu certifikata (CB) unutar organizacijske strukture SZK i priznanje organizacije kao punopravne članice sa Shemom registriranja osoblja jednakom EOQ-ovoju (akreditacija od strane EOQ-a u skladu s EN 45013 i ISO 17024 1. juna 2003.), CB - SZK je započeo s izdavanjem certifikata za EOQ-ove menadžere sistema kvaliteta (dosad je certifikat dobio 31 menadžer sistema kvaliteta).

Po završetku projekta teško je procijeniti dobrobiti uvođenja EOQ-ove Sheme za dodjelu certifikata osoblju koje radi na kvalitetu u slovenačkom okruženju kvaliteta (a posebno uslijed visokog nivoa postojećeg znanja, vještina i iskustva stručnjaka za kvalitet). Bilo kako bilo, mišljenja naše prve generacije menadžera sistema kvaliteta su jako pozitivna, a slijedi nekoliko važnijih:

## 6. CONCLUSION

Establishing independent Certification Body inside the organizational structure of SZK and being recognized as a Full Member Organization sharing EOQ Personal Registration Scheme (accreditation by EOQ according to the EN 45013 and ISO 17024 at 1<sup>st</sup> of June 2003), CB -SZK firstly started with issuing certificate for EOQ quality systems managers. (31 Quality system managers have been certified until now).

After concluding the project it is difficult to estimate the benefit of the introducing EOQ Scheme for certification of quality personnel into the Slovenian quality environment (moreover due to the very high level of existing knowledge, skills and experiences of quality professionals). However general opinion from our first generation of Quality Systems Managers has been very positive, some important thoughts are as follows:

Na mnoštvu seminara, sredstava, modela ... iz oblasti kvaliteta, nastavni materijal, njegova profesionalna prezentacija i, konačno, ispit i dodjela certifikata je jedini pravi metod ka postizanju potpunog kvaliteta, što je neophodno za trenutne menadžere kvaliteta koji moraju uspostaviti i održati sistem upravljanja kvalitetom u organizaciji.

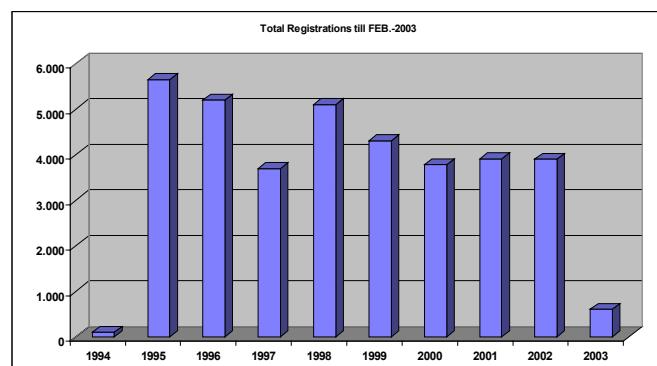
Gledajući unazad, na početak svoje obuke, kad sam, kao potpuni početnik u oblasti kvaliteta, počeo da shvatam šta će biti poljem moga rada u budućnosti, teško je povjerovati da je moguće proći kroz tako veliku transformaciju. U toku ovog četverosedmičnog perioda učenja, nеприменим инжењер електротехнике који је имао пotešкоћа с приватанjem новина, промјенио се у особу која непрестано razmišља о промјенама и njihovima utjecajima na troškove.

Ubijedjen sam da je ovakvo osposobljavanje potrebno ne samo slovenačkim organizacijama, nego i cijeloj Sloveniji. Neko sam vrijeme dobivao potvrde od strane svojih kolega i prijatelja o tome da u mnogim stvarima nismo tako dobri, a mi smo čak i značajno bolji od nekih priznatih stranih kompanija.

*At abundance of seminars, tools, models... in the field of quality, the teaching material, its professional presentation and finally the exam and certification is the only proper method towards the achievement of total quality, which is necessary for present quality manager who have to establish and maintain the system of quality management in the organization.*

*Looking back to the beginning of my training, when, as a complete greenhorn in the field of quality, I began to perceive my future field of work, it is difficult to believe, that it is possible to go through such a big transformation. During this four-week learning period inadaptable electrical engineer, having difficulties to accept novelties, changed into a person, who continually thinks about changes and their influences on the costs.*

*I am convinced that not only Slovenian organizations but also the whole of Slovenia needs this qualification. For some time I have been receiving confirmations from my colleagues and friends that in many places we are not only as good as, but even significantly better than well established and recognized foreign companies.*



Slika 4: EOQ certifikat o priznanju za EOQ-PRS i ukupna registracija u februaru 2003. godine  
Figure 4: EOQ recognition certificate for EOQ-PRS and total registration on February 2003

## **EFEKTIVNO ŠIRENJE ZNANJA U ORGANIZACIJAMA KOJE UČE**

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### **REZIME**

Kvalitet je sada prihvaćen kao sine qua non za poslovni uspjeh, te time predstavlja očigledan dio organizacije koja uči. Kompanije koje su usmjerene na Potpuno upravljanje kvalitetom (Total Quality Management - TQM) teže kontinuiranom poboljšanju i imaju dosta zajedničkog s organizacijama koje uče. Mnogo toga je napisano o važnosti razvijanja kulture učenja, međutim, malo se pažnje posvećuje praktičnom razumijevanju osobina organizacije koje uče i načina na koje kompanije mogu poboljšati svoje sisteme učenja. Ovaj rad istražuje osobine učenja u organizaciji i efektivnog širenja znanja. Također potvrđuje da znanje nema granica i da se može jednako lako širiti i van granica jedne države i postati vlasništvo onih koji su sposobni da ga koriste. Ovo razumijevanje je posebno važno za bivše socijalističke zemlje koje nastoje da prebrode decenije nedovoljnog ekonomskog razvoja.

**Ključne riječi:** upravljanje promjenama, upravljanje znanjem, kultura učenja, učenje u organizaciji, efektivnost upravljanja, radnik znalač

## **EFFECTIVE KNOWLEDGE DIFFUSION WITHIN LEARNING ORGANISATIONS**

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### **SUMMARY**

Quality is now accepted as a sine qua non for business success and thus is an obvious part of a learning organisation. Companies having a Total Quality Management (TQM) focus strive for continuous improvement and such companies have much in common with learning organisations. However, while much has been written on the importance of evolving a learning culture, less attention has been given to understanding in a practical way the characteristics of learning organisations and the ways in which companies can improve their learning systems. This paper explores the characteristics of organisational learning and effective knowledge diffusion. It also recognizes that knowledge has no boundaries and can just as easily be diffused across national borders and become the property of those who are capable of using it. This understanding is especially important for former socialist countries that are endeavouring to overcome decades of economic under development.

**Key Words:** Change Management, Knowledge Management, Learning culture, Organisational Learning, Management Effectiveness, Knowledge Worker

### **1. UVOD**

Stvarnost globalne konkurenčije i povećane sofisticiranosti kupca usmjerila je pažnju organizacije na potrebu da se razvije proces organizacije koja uči. Neki komentatori tvrde da težnja da se postane organizacija koja uči nije samo neophodna nego i suštinska za dugoročno prezivaljavanje [9,10]. Također tvrde [2] da stopa kojom pojedinci i organizacije uče može postati jedina održiva konkurentna prednost. Ovu ideju je podržao i Schein [5] kad je rekao da nam trenutne okolnosti govore da učenje više nije izbor nego nužnost.

### **1. INTRODUCTION**

The realities of global competition and increased customer sophistication have focused organisational attention on the need to develop a learning organisation process. Some commentators argue that the aspiration of becoming a learning organisation is not only necessary but essential for long-term survival [9,10] and contended [2] that the rate at which individuals and organisations learn may become the only sustainable competitive advantage. This notion is supported by Schein [5] when he stated that current circumstances tell us that learning is no longer a choice but a necessity.

Potpuno upravljanje kvalitetom (TQM) nastoji da stvori kulturu u kojoj će se provoditi stalna unapređenja kvaliteta u cijeloj organizaciji. Ono je usmjereno na ukupnost sistema, a ne na njegove pojedinačne dijelove, nastojeći da utvrdi koji su to uzroci neuspjeha, a ne samo činjenicu da neuspjeh postoji. Velik naglasak je na timskom radu, vodenju, motiviranju uposlenika i direktnom uključivanju radnika u rješavanje tehničkih poteškoća i zabrinutosti koje se odnose na ponašanje. Doista, na potpuno upravljanje kvalitetom se može gledati kao na prethodnice učenja organizacije ili kao na prve probne korake firme ka tome da postane organizacija koja uči.

## 2. MODEL UČENJA

Iz opširnog pregleda literature [29,30] identificirano je sljedećih sedam osobina učenja u organizaciji:

1. Prethodnice učenja
2. Inovativno okruženje
3. Uočena potreba i mehanizmi učenja
4. Izazov/procesi učenja za rukovodstvo
5. Kulturološki imperativ pribavljanja resursa za učenje
6. Učenje u cijeloj organizaciji
7. Organizacija koja uči

Total Quality Management (TQM) strives to create a culture, which is conducive to continuous quality improvements throughout the organisation. It focuses on the totality of the system rather than its individual parts, seeking to identify the causes of failure rather than the simple fact that failure has occurred. Much emphasis is placed on teamwork, leadership, employee motivation and the direct involvement of workers in solving technical difficulties and behavioural concerns. Indeed, in some respects, TQM may be seen as the precursor of organisational learning or a firm's tentative first steps towards becoming a learning organisation.

## 2. LEARNING MODEL

Seven characteristics of organisational learning have been identified from an extensive review of the literature [29,30], which are as follows.

1. Learning antecedents
2. Environment of innovation
3. Perceived need & learning mechanisms
4. Executive challenge/learning processes
5. Cultural imperative of resourcing learning
6. Organisational wide learning
7. Learning organisation



Slika 1: Model učenja  
Figure 1: Learning model

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## **2.1. Prethodnice učenja**

Opseg ovog rada omogućava autorima da daju detaljni pregled samo prve osobine učenja organizacije, budući da ograničenje stranica koje su odredili organizatori konferencije sprečava opširniji pregled procesa učenja. U radu se aludira na značaj ostalih osobina, međutim njihovo detaljnije ispitivanje se ostavlja za neku drugu priliku.

### **2.1.1. Kultura reagiranja na potrebe kupaca**

Sinkula [20] tvrdi da kultura organizacije vodi cjelokupan sistem vrijednosti i postavlja dobra pravila za razmjjenjivanje informacija i usaglašavanju o njihovom značenju. Day [17] to razrađuje, pa laže: *Kultura učenja koja se rukovodi kupcem podržava vrijednost potpune tržišne inteligencije i nužnost funkcionalnog koordiniranja radnji usmjerenih ka dostizanju konkurentne prednosti. Svojim vanjskim naglaskom na razvijanje razumijevanja koje se odnosi na kupce i konkurenće, organizacija koja uči i koja se povodi tržištem u dobroj je poziciji da predviđi potrebe svojih kupaca koje se razvijaju i da na njih odgovori dodavanjem inovativnih proizvoda i usluga.* Zato je fokus na kupca važan aspekt usmjerenosti učenja. Usko izgrađena kultura bi dovela do učenja samo unutar tradicionalnih granica. Da bi razvila čvrste temelje za dalekosežno učenje, organizacija mora svim akterima omogućavati stvaralačko učenje.

### **2.1.2. Antropomorfizam u organizacijama**

Antropomorfizam znači pripisivanje ljudskog oblika ili osobina neljudskom. Trenutno prihvaćanje učenja u organizaciji uključuje antropomorfizam, budući da poznata teorija izbjegava razmatranje načina i razloga zbog kojih organizacije uče, što nije uvijek očigledno samo po sebi. Argyris & Schon [7] zaključuju da se prema učenju u organizaciji ne može i ne treba odnositi kao prema proširenju učenja pojedница, slažući se s tim da učenje proizvodi znanje i da organizacije i njihovi članovi često znaju ili steknu znanje o raznim stvarima. Mada se učenje u organizaciji javlja kroz pojedince, bilo bi pogrešno zaključiti da učenje u organizaciji nije ništa drugo nego kumulativni rezultat učenja njenih članova. Organizacije nemaju mozak, ali imaju kognitivne sisteme i pamćenje. Kako pojedinci vremenom razvijaju svoju ličnost i uvjerenja, tako i organizacije razvijaju svoja gledišta i ideologije.

### **2.1.3. Intelektualni kapital**

Sve do nedavno su se proizvodni resursi određivali na osnovu kapitala, zemljišta i poslovne oštromosti. Nastupanjem modernog tehnološkog razvoja, nove prakse upravljanja i sistematskih inicijativa na razvoju osoblja smanjuje se važnost kapitala i zemljišta.

## **2.1. Learning Antecedents**

However, the scope of this paper only allows the authors to review the first organisational learning characteristic in any detail as the page restraint imposed by the conference organisers prevents a more comprehensive review of the learning process. The significance of the remaining characteristics is alluded to but a more detailed examination awaits another opportunity.

### **2.1.1. Customer Responsive Culture**

Sinkula [20] argue the organisation's culture drives the overall value system providing strong norms for sharing of information and reaching a consensus on its meaning. Day [17] elaborates: A customer driven learning culture supports the value of thorough market intelligence and the necessity of functionally co-ordinated actions directed at gaining a competitive advantage. With its external emphasis on developing understanding with regard to customers and competitors, the market-driven learning organisation is well positioned to anticipate the developing needs of its customers and respond through the addition of innovative products and services. Thus, a customer focus is an important aspect of a learning orientation. A narrow construction of culture would lead to learning only within traditional boundaries. To develop a powerful foundation for extensive learning, the organisation must provide the opportunity for generative learning by all stakeholders.

### **2.1.2. Anthropomorphism within Organisations**

Anthropomorphism is the attribution of human form or qualities to non-human entities. The current, acceptance of organisational learning involves anthropomorphism as the known theory glosses over the how and why organisations learn, which is not always self-evident. The argument that organisational learning cannot and should not be treated as an extension of individual learning was made by Argyris & Schon [7], understanding that learning produces knowledge, organisations and their members often know, or come to know, different things. Although organisational learning occurs through individuals, it would be a mistake to conclude that organisational learning is nothing but the cumulative result of members' learning. Organisations do not have brains, but they have cognitive systems and memories. As individuals develop their personalities and beliefs over time, so too will organisations develop their views and ideologies.

### **2.1.3. Intellectual Capital**

Up until recently manufacturing resources were determined on the basis of capital, land, and business acumen. With the advent of modern technological developments, new management practices and systematic staff development initiatives, the importance of capital and land is diminishing.

S druge strane, istovremeno, rad, posebno intelektualni rad, je izvršio veoma velik utjecaj na sve medije, pa čak i na sektor visoke tehnologije. Graham [21] ja tvrdio su posmatrači društvenih promjena u svijetu koji daju najbolja predviđanja zapravo predviđjeli dolazak nove ekonomije, u kojoj će intelektualna odvažnost, a ne sposobnost mašina predstavljati presudni resurs. Dok je Drucker [8] dobio zasluge za predviđanje pada kapitalizma, Peters i Waterman [1] su uspostavili organizacijski značaj svakog uposlenika u kompaniji, bez obzira na njenu veličinu. Oni ukazuju na to da se u izvrsnim kompanijama kao glavni resurs identificiraju uposlenici. Njihovo istraživanje je pokazalo da su izvrsne kompanije bile, prije svega, sjajne u osnovnim stvarima. Alat nije zamjenio razmišljanje. Intelekt nije nadvladao mudrost. Analiza nije kočila djelovanje, nego su ove organizacije radile naporno na tome da održe stvari jednostavnim u jednom složenom svijetu. Intelektualni kapital pojedinaca se mora oslobođiti ako organizacija želi da ima imalo šanse da dugoročno preživi, budući da je radna snaga prvenstveni pokretač organizacijskog uspjeha. Istovremeno, radnici znalci, zajednički predstavljaju nove kapitaliste jer zajednički posjeduju sredstva za proizvodnju [11].

#### **2.1.4. Nezadovoljstvo tradicionalnom paradigmom upravljanja**

Drucker Š9,11Č se protivi ideji o potrebi za kontrolom u modernim organizacijama s obzirom na razvoj informacijskih tehnologija i sve veći broj «uposlenika znalaca», koji baš i ne reagiraju na autokratsko upravljanje. Umjesto toga, on vidi uposlenike koji traže priliku za izazovom i izražavanjem svojih kreativnih sposobnosti, i uživaju u podsticajima da rade sa istomišljenicima. Nezadovoljstvo je možda najbolje opisao Handy Š3Č kad je izrazio bojazan da bi «svijet u kojem je pojedinac prepusten više svojim vlastitim pronalascima, dok se život i rad sve više usložnjava van institucija društva, mogao biti svijet određen na sebičnost». Handy-jeva hipoteza se ipak više bavi promjenom u sve složenijem društvu i mišlu da «jedino predviđanje koje će se ostvariti jeste to da se neće ostvariti niti jedno predviđanje». Nezadovoljstvo postojećom paradigmom stvara prazan prostor u procesu kontrole koji koncept organizacijskog učenja pokušava da popuni. Koncept učenja i širenja znanja se sve više prihvata jer ima za cilj da prevaziđe mnoge probleme koji su izazvali sumnje u tradicionalnu paradigmu. Kako se korak inovacije proizvoda i promjene na tržištu i dalje ubrzavaju, organizacije koje uče u dinamičnom okruženju moraju postati žustrije, fleksibilnije i moraju brže reagovati na potrebe kupaca.

While at the same time, labour and in particular intellectual labour has generated a very powerful influence across all media and even into the high technology sector. Graham [21] stated that for several decades the world's most prescient observers of societal change have predicted the emergence of a new economy in which intellectual prowess, not machine capability would be the critical resource. While Drucker [8] has been credited with foretelling the downfall of capitalism, Peters and Waterman [1] established the organisational significance of each employee within a company irrespective of size. They suggest that in excellent companies employees are identified as a key resource. Their research showed that excellent companies were, above all, brilliant on the basics. Tools didn't substitute for thinking. Intellect didn't overpower wisdom. Analysis didn't impede action. Rather, these organisations worked hard to keep things simple in a complex world. The intellectual capital of individuals must be liberated if an organisation is to have any chance of long-term survival, as it is the workforce that is the primary driving force of organisational success. In the same time, the knowledge workers, collectively, are the new capitalists because they collectively own the means of production. [11]

#### **2.1.4. Dissatisfaction with the Traditional Management Paradigm**

Drucker Š9,11Č contrasts the notion of need for control in modern organisations with the development of information technology and increasing numbers of 'knowledge employees' who are less likely to respond to autocratic management. Rather he sees employees seeking opportunities for challenge, as well as outlets for creative ability, while enjoying the stimulation of working with like-minded individuals. This dissatisfaction probably is best articulated by Handy Š3Č when he expresses the fear that in "a world where the individual is left even more to his own devices, as the complexities of life and work develop outside the institutions of society, could be a world designed for selfishness". Though Handy's hypothesis is concerned with change in an increasingly complex society and the idea that "the only prediction that will hold true is that no prediction will hold true". Dissatisfaction with the existing paradigm is creating an empty space in the control process, which the concept of organisational learning is endeavouring to fill. The concept of learning and knowledge transfer is attracting greater acceptance because it purports to overcome many of the concerns that have led to the discrediting of the traditional paradigm. As the pace of product innovation and market place changes continue to accelerate learning organisations within dynamic environments must become more nimble, flexible and responsive to customers needs.

### **2.1.5. Priroda globalnog poslovanja**

Globalizacija ne znači samo poslovanje van granica jedne države. Globalizacija također znači povećanje konkurentnosti za gotovo svaku vrstu organizacije. Generalni direktori današnjice moraju shvatiti da se suočavaju sa stranim konkurentima jednako kao i sa lokalnim. Takva globalizacija multinacionalnih organizacija predstavlja upravljanje čiji je izazov naučiti kako raditi u različitim kulturološkim okruženjima. Kupci sada imaju veći izbor i postaju sve sofisticiraniji u svom izboru proizvoda i usluga. Očekuju nove i unaprijedene proizvode, bolju uslugu i niže cijene. Dva glavna pokretača globalizacije su rast tržišta i inicijative na smanjenju troškova. Ako organizacija želi da stekne svoj dio tržišta, onda je proširivanje rada izvan granica zemlje jedna od strategija. U skorije vrijeme su se i trgovinske i političke prepreke smanjile ili potpuno uklonile stvaranjem trgovinskih blokova više zemalja.

### **2.2. Inovativno okruženje**

Pitanja o tome kako i zašto jedna firma treba biti inovativna u vezi su s općenitijim pitanjima o tome kako i zašto se firme razlikuju u praksi. Međutim, teoretičiranje koje se zasniva na resursima se ne zanima za praktični dio upravljanja efektivnim, inovativnim firmama. Njihovi recepti se u različitim omjerima slažu sa teorijom i empirijskim posmatranjima, mada im se stilovi značajno razlikuju. Drugi autori [27,28] naglašavaju stratešku vrijednost upravljanja sticanjem i primjenom znanja, te time i organizacijskom učenju. Jedina održiva konkurentna prednost je sposobnost organizacije da oči brže nego njeni konkurenti. Inicijative na širenju znanja postaju od životne važnosti za organizacijsko učenje i efektivnost. Lako je prepoznati i prenijeti dobrobiti od znanja, međutim, teškoće se gomilaju kad god organizacije započnu namjerno provođenje u cijeloj organizaciji. Dok mlade, dinamične organizacije naglašavaju kreativnost i inovativnost kao ključni faktor organizacijske kulture, starije, zrelijе kompanije mogu smatrati primjenu inicijativa na učenju prilično izazovnom aktivnošću. Izvršno rukovodstvo je posebno zaduženo da pazi na stvaranje i prenošenje dinamičke vizije načina na koji se znanje može efektivno proširiti u organizaciji. «Društvo koje ima znanje,» kaže Drucker [11] «je društvo pretpostavljenih i radnika, a ne društvo šefova i podređenih.»

### **2.1.5. Nature of Global Business**

Globalisation doesn't just mean conducting business across national borders. It also means expanding competition for almost every type of organisation. Today's executives must understand that they face foreign competitors as well as local and national ones. Such globalisation of multinational organisations presents management with the challenge of learning to operate in diverse cultural settings. Consumers now have wider choices and are becoming more sophisticated in their selection of products and services. They expect new and improved products, superior service and lower prices. The two major forces driving globalisation have been market growth and cost reduction initiatives. If an organisation wishes to gain market share, expanding operations outside its national borders is one such strategy. In recent years both trade and political barriers have been lowered or eliminated altogether by the creation of multi-country trading blocks.

### **2.2. Environment of Innovation**

Questions on how and why firms need to be innovative are related to the more general questions of how and why firms differ in practice. However, resource based theorising has typically not been concerned with the practicalities of managing effective, innovative firms. Their prescriptions draw in varying degrees on theory and empirical observation, though their styles differ markedly. Other writers [27,28] emphasise the strategic value of managing the acquisition and application of knowledge and thus organisational learning. The only sustainable competitive advantage is an organisation's ability to learn faster than its competitors. Thus knowledge diffusion initiatives become a vital consideration for organisational learning and effectiveness. Recognising and communicating the merits of knowledge is easy; however, difficulties abound whenever organisations begin deliberate organisation wide implementation. While young, dynamic organisations emphasise creativity and innovation as key factors of organisational culture, older, more mature companies may find the implementation of learning initiatives a particularly challenging activity. Executive management in particular has a duty of care to create and communicate the dynamic vision of how knowledge can be effectively diffused throughout the organisation. "The knowledge society", say Drucker [11], "is a society of seniors and juniors rather than of bosses and subordinates".

### **2.3. Uočena potreba i mehanizmi organizacijskog učenja**

Organizacije koje uče su stalno uključene u razvijanje razumijevanja, pomaganje drugima u učenju i razmjenu svojih iskustava. Zato se na pitanje do kojeg je stepena neka organizacija organizacija koja uči može odgovoriti ispitivanjem opsega mehanizama organizacijskog učenja koje redovno koristi, kao što su poređenje (benchmarking), inovacija tehnologija, te pristup mogućim problemima između ostalih. Dodgson [14] je definirao organizacije koje uče kao firme koje s namjerom usvajaju strukture i strategije koje podstiču učenje. Ta nas ideja vodi do sljedeće faze modela učenja, koja ispituje strategije i mehanizme učenja. Učenje se javlja kad organizacije sintetiziraju i institucionaliziraju intelektualni kapital i učenje ljudi, njihovo pamćenje, kulturu, sisteme znanja, uobičajene načine postupanja i suštinske sposobnosti. Uposlenici mogu doći i otići, i vođstvo se može promijeniti, ali pamćenje organizacije čuva ponašanje, pravila, vrijednosti i «mentalnu mapu» dugo vremena. Bavljenjem i rješavanjem problema koji se odnose na preživljavanje, organizacija gradi organizacijsku strukturu koja postaje spremište naučenih lekcija.

### **2.4. Izazov i procesi učenja za rukovodstvo**

Učenje se ne može javiti u vakuumu, potrebni su predanost i fukcionalna podrška izvršnog rukovodstva, kako bi se iz neprimjetno učenje razvilo u aktivnost u cijeloj organizaciji. To znači da bi svi aspekti kompanije trebalo da aktivno podržavaju učenje. U organizacijama koje uče odluke rukovodstva se vide kao nešto što zavisi od dešavanja u budućnosti, a ne kao nešto definitivno, i one su uvijek važan dio procesa strateškog odlučivanja. To nam omogućava da se utvrdi koja je sljedeća faza modela, koja se bavi izazovima s kojima se izvršno rukovodstvo suočava, kao i procese učenja koji su razvijeni kako bi olakšali kontinuirano učenje. Marsick and Watkins Š24Ć tvrde da spoj emotivnih i kognitivnih aspekata učenja predstavlja najveći izazov za one koji se bave razvojem ljudskih resursa, koji nastoje da omoguće efektivno, kontinuirano učenje na radnom mjestu. Argyris Š6Ć ističe da su ti emotivno nabijeni zadaci često najteži onima koji su prvi koji to rade. Organizacijski razvoj i imperativi razvoja organizacijskog učenja, međutim, ne zavise samo od sposobnosti izvršnog rukovodstva, mora se uzeti u obzir i kulturološka perspektiva.

### **2.3. Perceived Need and Organisational Learning Mechanisms (OLMS)**

Learning organisations are continuously engaged in developing understanding, helping others to learn and sharing their experiences. Thus, the question to what degree a particular organisation is a learning organisation can be answered by examining the range of OLMs it regularly utilises, such as benchmarking, technology innovation and contingency approach among others. Dodgson [14] defined learning organisations as firms that purposefully adopt structures and strategies that encourage learning. This idea leads us on to the next phase of the learning model, which examines learning strategies and mechanisms. Learning occurs when organisations synthesise and then institutionalise people's intellectual capital and learning, their memories, culture, knowledge systems, routines and core competencies. Employees may come and go and leadership may change but an organisation's memories preserve behaviour, norms, values and "mental maps" over time. As an organisation addresses and solves problems of survival, it builds an organisational structure that becomes the repository for lessons learned.

### **2.4. Executive Challenge and Learning Processes**

Learning cannot occur in a vacuum, it requires executive management commitment and functional support in order to develop from discrete to organisational wide activity. This means that all aspects of the company should be actively embracing learning. In learning organisations management decisions are seen as contingent rather than as definitive but always remain an important part of the strategic decision making process. This allows us to locate the next phase of the model dealing with the challenges facing executive management and the learning processes developed to facilitate continuous learning. Marsick and Watkins Š24Ć contend that the juncture between emotional and cognitive aspects of learning poses the biggest challenge to human resource developers seeking to enable effective, continuous learning in the workplace. Argyris Š6Ć points out that these emotionally charged tasks often are hardest for those that must lead the way. However, organisational development and the imperatives of developing organisational learning is not solely dependent on the competence of executive management, there is a cultural perspective that must be considered as well.

## **2.5. Kulturološki imperativi pribavljanja resursa za učenje**

Efektivno učenje zavisi od uspostavljanja kulture koja promovira ispitivanje, otvorenosti i povjerenja Š23C. Zato organizacijsko učenje ima dva vida, opipljivi «hardware», koji se sastoji od mehanizama učenja i neopipljivi «software», koji se sastoji od razmijenjenih vrijednosti i uvjerenja koji osiguravaju da ti mehanizmi zapravo dovedu do učenja (odnosno, novih shvatanja i ponašanja), a ne do pukih rituala učenja. Prema Schein-u [4], organizacijska kultura je normativni sistem razmijenjenih vrijednosti i uvjerenja, koji oblikuju način na koji se članovi organizacije osjećaju, razmišljaju i ponašaju. Vrijednosti nisu lako uočljivi entiteti. O njihovom se postojanju zaključuje iz retorike koju članovi organizacije koriste za opisivanje onoga što je prikladno, važno i vrijedno žrtvovanja (prihvaćene vrijednosti) i iz postupaka članova koji iziskuju žrtvovanje ili neka manja ulaganja resursa i napora (vrijednosti u upotrebi). Upravo tu se zvanično prihvácaju korporativne vrijednosti učenja, kao što je poštivanje izražavanja pojedinca i radnih načela u jednom kontekstu koji podstiče na bolji zajednički rad, a istovremeno smanjuje autokratski autoritet [21], međutim Hamel i Prahalad [13] tvrde da bilo koja organizacija koja ne može zamisliti budućnost neće biti tu da u njoj uživa.

## **2.6. Učenje u cijeloj organizaciji**

Proces učenja zahtijeva neučenje jednakog učenje. Neučenje uključuje proces restrukturiranja prošlih uspjeha kako bi se uklopili u uslove okruženja i situacije koja se mijenja. Greške, loš rad ili nesigurnost u okruženju su često ti koji ga pokreću. Neučenje je teško pod bilo kojim okolnostima. Neučenje stvara inovacije, improvizacije i eksperimentiranje novih načina na koje se stvari rade. Vodi ka kreativnom procesu učenja, promjeni i strategiji razvoja. Organizacijsko učenje se razlikuje od učenja pojedinca u nekoliko važnih stvari. Prije svega, to je zajednički događaj. Kao rezultat toga, organizacije uče samo onoliko brzo koliko uči najsporija karika. Usvajanje novih modela ili revizija starog žanra je zakočeno, osim ako se svi glavni donosioci odluka ne posvete zajedničkom skupu aktivnosti. Učenje nije jednostavno zbir učenja svih članova. Organizacijsko učenje mora spojiti modele u glavama pojedinačnih izvršnih direktora i modele koji su zajednički za timove i grupe. Središnja stvar za uspjeh bilo kakvog programa učenja je koncept neuspjeha. Sve učenje se dešava u kontekstu neuspjeha, ako učite da radite nešto i to ne uključuje neuspjeh, niste ništa naučili.

## **2.5. Cultural Imperatives in Resourcing Learning**

Effective learning is contingent on establishing a culture that promotes inquiry, openness and trust Š23C. Thus, organisational learning has two facets, a tangible "hardware" that consists of learning mechanisms and an intangible "software" facet that consists of shared values and beliefs that ensure that the mechanisms produce actual learning (i.e., new insights and behaviour) and not mere rituals of learning. According to Schein [4] organisational culture is a normative system of shared values and beliefs that shape how organisation members feel, think and behave. Values are not observable entities. Rather, their existence is inferred from the rhetoric that organisational members use to describe what is appropriate, important and worthy of sacrifice (espoused values) and from members' actions that require sacrifice or some lesser investment of resources and effort (values in use). It is here that learning corporate values such as respect for individual expression and operating principles are formally espoused within a context that inspires superior collective performance while simultaneously reducing autocratic authority [21]. While Hamel and Prahalad [13] argued that any organisation that cannot imagine the future won't be around to enjoy it.

## **2.6. Organisational Wide Learning**

The learning process demands unlearning as much as learning. Unlearning involves the process of restructuring past successes to fit the changing environmental and situational conditions. Mistakes, poor performance or environmental uncertainty frequently trigger it. Under any circumstances, unlearning is difficult. Unlearning generates innovation, improvisation and experimentation in new ways of doing things. It leads to the creative processes of learning, change and strategy development. Organisational learning differs from individual learning in several important respects. First, it is a collective event. As a result, organisations learn only as fast as the slowest link. Adoption of new models or revision of old genre is inhibited, unless all of the major decision-makers commit to a common set of actions. Learning is not simply the sum of each member's learning. Organisational learning must blend the mental models of individual executives with those that are shared among teams and groups. Central to the success of any learning programme is the concept of failure. All learning takes place in the context of failure, if you are learning to do something and it does not involve failure, you haven't learned anything.

*U stvarnom svijetu, naravno, neuspjeh često uključuje sramotu i nedostatak samopouzdanja. U drugom dijelu ovog prenošenja organizacije prolaze značajne strukturalne promjene, i razvijaju horizontalne mreže timova koji su fokusirani na zadatku koji vode ravnoj strukturi organizacije. Ti novi horizontalni sistemi će biti organizirani oko procesa a ne zadatka, koje će voditi potrebe i doprinos kupaca i koji će zavisiti o radu grupe.*

## **2.7. Organizacije koje uče**

*Kompanija koja uči je organizacija koja olakšava učenje svim svojim članovima na način koji transformira, a ne na uobičajeni način prenošenja. Prema Garvinu [15] je to organizacija koja je vješta u stvaranju, sticanju i širenju znanja i u transformiranju same sebe kako bi odražavala novo znanje i shvatanja. To nas dovodi do središnje zagonetke organizacije koja uči, a to je: ako rukovodstvo može učiti, može li se učenjem upravljati. Prihvaćeno je da organizacije imaju taj kapacitet da zajednički uče i da se takvo učenje javlja različitim brzinama i na različitim nivoima unutar kompanija, međutim, uposlenici su ti koji u organizaciji uče, a ne sama organizacija, pojedinci stvaraju učenje koje dovodi do transformiranja u firmi. Organizacije nemaju mozak, ali imaju kognitivne sisteme i pamćenje. Pojedinci dođu i odu, vođstvo se mijenja, ali u pamćenju organizacije ostanu određena pravila i vrijednosti. Međutim, sve dok se učenje organizacije odnosi isključivo na ukupan zbir organizacije koja radi skladno bez reference na proširivanje i dogradnju, zbog čega onda nešto ostaje nerazvijeno, nije shvaćena suština koncepta organizacije koja uči [18].*

*Učenje načina kako postati efektivan treba da se podudara s procesom sazrijevanja, samoispunjjenja, perspektive i odlučnosti pojedinca koji uči, treba da se odnosi i gradi na onome što pojedinci unesu u svoje učenje [19]. Zbog svoje neuhvatljivosti, učenje je više od metafore, ono se može dostići i ostavlja prepoznatljiv i poseban osjećaj. Dale [16] je obuhvatilo to shvaćanje kad je rekao da organizacije koja uči nastoji da stvari vrijednosti, politike i procedure u kojima »učenje« i »rad« imaju isto značenje u cijeloj organizaciji. Da bi organizacija dostigla to da bude ona organizacija koja uči, potrebne su aktivnosti na mnogo frontova. Prema Mabey-u i Salaman-u [22], potrebna je ozbiljna, dalekosežna i vjerovatno neudobna predanost i promjena od strane najvišeg rukovodstva, koja prodire u srž organizacije.*

*In the real world, of course, failure often involves embarrassment and lack of self-esteem. Another part of this transition will see organisations undergoing significant structural change, developing horizontal networks of task-focused teams leading to flatter organisations. These new horizontal systems will be organised around processes rather than tasks, driven by customer needs and inputs and dependent on group performance.*

## **2.7. Learning Organisations**

*A learning company is an organisation that facilitates the learning of all its members in a transformational rather than in the more normal transactional manner. According to Garvin [15] it is an organisation skilled at creating, acquiring and transferring knowledge and at transforming itself to reflect new knowledge and insights. This brings us to the central conundrum of the learning organisation, if management can be learned, can learning be managed. It is accepted that organisations have the capacity to learn collectively and that such learning occurs at different speeds and levels within companies. However, it is employees within organisations rather than organisations themselves that learn, individuals create transformation learning within firms. Organisations do not have brains but they have cognitive systems and memories. Individuals come and go and leadership change, but organisations' memories preserve certain norms and values. However, so long as organisational learning refers exclusively to the sum total of the organisation working in unison without reference to expanding and building on that, which remains undeveloped, then the point of the learning organisation concept is being missed [18].*

*Learning to be effective needs to coincide with the processes of maturation, self-fulfilment, perspective and self-determination of the individual learner, it needs to relate to and build on what individuals bring to their learning [19]. For all its elusiveness, organisational learning is more than a metaphor it is attainable, it has a recognisable and distinctive feel. Dale [16] captured this understanding when she stated that a learning organisation strives to create values, policies and procedures in which 'learning' and 'working' are synonymous throughout the organisation. Achieving a learning organisation, then, requires activity on a wide range of fronts. According to Mabey and Salaman [22] it demands serious, far-reaching and probably uncomfortable commitments and change from senior management, penetrating to the core of the organisation.*

### **3. ZAKLJUČAK**

Konkurentna priroda poslovnog okruženja, s pritiskom na kompanije koje trebaju da reagiraju na potrebe kupaca koji progresivno raste, postavlja neprikladne zahtjeve pred organizacije. Odnos poslovnog okruženja i potreba kupaca nije odmah uočljiv, ali je posljedica veće raznovrsnosti proizvoda koji se mogu izabrati. Nastajanje globalnog tržišta daje kupcima priliku da izaberu proizvode ili usluge kompanija iz svih dijelova svijeta, što zauzvrat daje kupcu mogućnost da traži bolji rad svojih snabdjevača, posebno kad su na raspolaganju alternativni kvalitetni proizvođači. Razvijanje kulture reagiranja na potrebe kupaca i intelektualni imperativi su dvije strane medalje. Odnos ova dva pokretača nije odmah uočljiv, ali kad se govori o kapacitetu organizacije da uči, mi kao rezultat toga odražavamo pristup firme razvoju svojih ljudskih resursa, što je posljedica povećanja kulture u jednoj organizaciji. Sve više i više kompanija počinje da smatra proces učenja organizacije odgovarajućim odgovorom na neke ili sve ovakve razvoje. Korak ka tome da se postane organizacija koja uči počinje integriranjem prethodnica zajedno s međusobnim približavanjem okolnosti koje su i unutrašnje i vanjske toj organizaciji.

Paralelno sa sve većom stopom tehnoloških promjena, postsocijalističke zemlje centralne i istočne Evrope još uvijek pokušavaju da izđu nakraj s velikim političkim preokretima koji su se desili pred početak drugog milenijuma. Da bi se mogla desiti neophodna transformacija koja će omogućiti ovima zemljama da budu konkurentne, one se moraju pozabaviti nizom paralelnih inicijativa procesa promjena, kao što su poduzetništvo, vođstvo, edukacija i programi razvoja, te etička pitanja. Trenutno informirane osobe unutar organizacija prepoznaju da su procesi tranzicije, reorganizacije i reforme u ovim zemljama komplikirani nego što se to u početku činilo onima onima koji su na to gledali iz pozicije van organizacija [25,26]. Kolaps "socijalističkog" sistema je prirodna posljedica ignoriranja intelektualnog kapitala (znanja), kao jednog od ključnih faktora uspješnog ekonomskog razvoja [27]. Možda je proces organizacije koja uči odgovarajući odgovor na neke od tih problema.

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### **3. CONCLUSION**

The competitive nature of the business environment with its progressively increasing pressure on companies to respond to customers changing needs is placing undue demands on organisations. The relationship between the business environment and customer needs is not immediately apparent but it is a consequence of a greater variety of products to choose from. The advent of the global market gives customers the opportunity to select products or services from companies from all parts of the globe, which in turn gives customers the opportunity to demand improved performance from their suppliers particularly when alternative quality producers are available. Developing a customer responsive culture and intellectual capital imperatives are opposite sides of the same coin. The relationship between these two drivers is not immediately apparent but when one speaks of an organisation's capacity to learn, we are in effect reflecting the firm's approach to the development of its human resources, which is a consequence of an organisation's cultural prerogative. More and more companies perceive the learning organisation process as an appropriate response to some or all of these developments. The move towards a learning organisation begins with the integration of the antecedents together with a convergence of circumstances both internal and external to the organisation.

In parallel with the increasing rate of technology change, the post-socialist countries in Central and Eastern Europe are still trying to come to terms with the great political upheavals that have occurred towards the close of the second millennium. A series of parallel change processes such as entrepreneurship, leadership, training and development programmes and ethical issues must be addressed in order that the necessary transformation that will enable these countries to compete on the open market might occur. Currently, the informed insider view recognises that the processes of transition, reorganisation and reforming in said countries is more complicated than it initially appears to those looking in from the outside [25,26]. The collapse of the "socialist" system is a natural consequence of ignoring intellectual capital (knowledge) as one of the key factors for successful economic development [27]. Maybe the learning organisation process is an appropriate response to some of these problems.

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## **RJEŠAVANJE NELINEARNOG PROBLEMA PRENOŠENJA TOPLOTE POSEBNOM ANALITIČKOM METODOM**

*Lect. Eng. Sorin Rațiu, Lect. Eng. Imre KISS, Univerzitet u Timișvari, Mašinski fakultet – Hunedoara*

### **REZIME**

*Ovaj rad se bavi distribucijom temperature u ingotu zagrijanom u dubinskoj peći. Da bismo odredili nestacionarno toplotno polje, koristili smo linearnu diskretizaciju termo-fizičkih parametara u vremenskim intervalima. Za svaki interval vršena su polinomska tumačenja temperature i provjera Galerkinovog integrala.*

*Dobiveni analitički rezultati su upoređeni s eksperimentalnim mjeranjima datim u referentnoj literaturi, što je pokazalo zadovoljavajuću približnost.*

**Ključne riječi:** *ingot, nestacionarno toplotno polje, dubinska peć*

## **PARTICULAR METHOD FOR THE ANALYTICAL SOLUTION OF A NON-LINEAR TEMPERATURE TRANSFER PROBLEM**

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### **SUMMARY**

*This paper deals with the distribution of temperature in an ingot heated inside a pit furnace. In order to determine the non-stationary thermal field we resorted to a linear discretizing of the thermo-physical parameters along time intervals. For each interval we considered a polynomial interpretation of temperature, imposing besides the connection conditions we also considered the checking of the Galerkin integral.*

*The analytical results we obtained were compared to the experimental measurements given in the reference literature, which lead to satisfactory approximations.*

**Keywords:** *ingot, non-stationary thermal field, pit furnace*

### **1. UVOD**

Pucanje ingota od legiranog čelika uzrokuje termički šok, čija vrijednost dostiže temperaturnu granicu prije nego što temperatura u središtu premaši granicu elastičnosti ( $500 - 550^{\circ}\text{C}$ ). Izbor odgovarajuće tehnologije obrade topotom za ove vrste čelik prije svega zavisi od uslova zagrijavanja, o čemu se odlučuje na osnovu njihovih tehnoloških karakteristik. Izbor optimalnog načina zagrijavanja najčešće se vrši na osnovu praktičnog iskustva.

Ovaj rad predstavlja analitički metod koji omogućava najprecizniju procjenu temperaturnog polja za zagrijavanje ingota, omogućavajući tako posmatraje veličine i distribucije termičkog šoka kao rezultat procesa zagrijavanja.

### **1. INTRODUCTION**

*It is well known that the cracking of the alloyed steel ingots during heating is induced by the heat stress. Its value can reach the ultimate stress before the temperature in the center of the ingots exceeds the limit of elasticit ( $500-550^{\circ}\text{C}$ ). The establishment of the hot-metal working technology for these grades of steel depends in the first place of the heating conditions, function of their technological characteristics. The choice of the optimum heating regime is mainly based on practical routine.*

*In this paper, we will show an analytical method for proper evaluation of the temperature fields during the heating of these ingots and, so, to be able to estimate the values and the distribution of the heat stress which appears during the heating process.*

Metod koji mi predlažemo je direktn i predstavlja moćan instrument za izučavanje linearnih i nelinearnih problema u mehanici i fizici. Kao rezultat ovog direktnog metoda, dobiveno je približno analitičko rješenje jednačine koja je razmatrana. U mnogim slučajevima praktično mašinstvo smatra takvo rješenje, čak i pored toga što je približno, vrednjim od "preciznog" numeričkog rješenja. Rješavanje jednačine topotne provodljivosti se obično veže s velikim poteškoćama, posebno zbog nelinearnosti (osobine materijala koje zavise od temperature), kao i zbog graničnih stanja koja su u vezi s pojmom radijacije. Ova studija je usmjerena na nelinearne probleme koje uzrokuju promjene temperaturu osobina materijala.

Metod koji je predstavljen u radu sastoji se od sekvensijalnog pretvaranja temperaturnih koeficijenata u linearne, kako bi se pojednostavila glavna jednačina. Kao rezultat tog pristupa, umjesto jedne nelinearne diferencijalne jednačine s parcijalnim izvodima, imamo ekvivalentan skup linearnih diferencijalnih jednačina. U posmatranom slučaju, ovaj metod daje zadovoljavajuće rezultate za široki raspon temperatura.

Autori smatraju da i dalje postoje problemi koji se odnose na radijaciju (što će biti jako zanimljiva tema za mnoge istraživače), ali kod ovog pristupa su rezultati prihvativi barem za neke temperature. Vrijednosti temperature dobivene predstavljenom metodom uporedit će se s veličinama koje je prof.dr. Ilca Ioan dobio eksperimentalnim putem u Rumuniji [1].

## 2. MATEMATIČKI MODEL

Da bi se izveo matematički metod koji bi odgovarao fenomenu zagrijavanja ingota, moramo uzeti u obzir nekoliko hipoteza. Sa fizičkog stanovišta, riječ je o krutom, izotropnom tijelu (ingotu), u kojem dolazi do nestacionarne pojave provođenja topote. Sa geometrijskog stanovišta, ingot se može asimilirati u paralelopiped sa kvadratnom osnovom i beskonačnom visinom. Usljed simetrije po poprečnom presjeku i usljed relativnog položaja ingota unutar dubinske peći (slika 1), ponašanje posmatranog sistema se može opisati uz pomoć parabolske diferencijalne jednačine, koja simulira problem provodljivosti u jednom pravcu, te također uz pomoć početnog graničnog stanja predstavljenog u jednačini [2]:

$$\rho(T) \cdot c_p(T) \cdot \frac{\partial T}{\partial t}(y, t) = \frac{\partial}{\partial y} \left[ \lambda(T) \cdot \frac{\partial T}{\partial y}(y, t) \right] \quad (1)$$

$$T(y, 0) = T_0 \quad (2)$$

The proposed method is a direct one and represents a strong tool for the study of linear and non-linear problems proceeded from mechanics and physics. Following the direct method, we obtain an analytical approaching solution for the respective equation. In many practical cases, the analytical solution, even the approaching one, is more successfully than the numerical calculations for the same problem. The finding of the heat conductivity equation is very difficult, especially due to the non-linearity (which depends on the temperature) and the outline conditions regarding the radiation phenomenon. In this paper, we focuses on the non-linearity problems caused by the temperature variation of the material condition.

We will use a method that consists of the linearity of the temperature coefficient on zones, to simplify the main equation. Consequently, in this way, instead of a non-linear differential equation with partial derivatives, we will have an equivalent set of linear differential equations. This method gives us satisfying results for a large temperature range. The authors consider that the problems in connection with the radiation conditions still exist (and these problems have interest for many researchers), but with such approach, the results are at least acceptable for many temperature ranges.

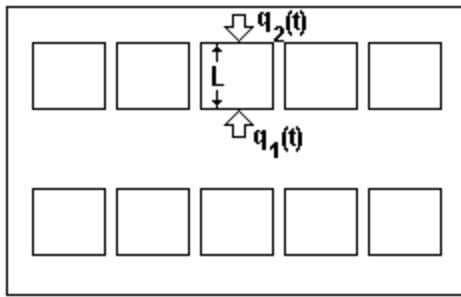
The temperature values obtained using this method will be compared with the experimental values [1].

## 2. THE MATHEMATICAL MODEL

For the mathematical simulation of the ingot heating phenomenon, it must be taken into account some hypothesis. Physically, we have a rigid isotropic body (the ingot) and inside it takes place a non-steady heat conductivity phenomenon. Geometrically, the ingot is considered a parallelepiped with square base and infinite height. Due to the symmetry of the cross-section and the lay-out of the ingots into the furnace (see figure 1), the behavior of the system can be described by the help of a parabolic differential equation which simulates a unidirectional conduction phenomenon, using some primary and boundary conditions, as we see below [2]:

$$\lambda(T) \cdot \frac{\partial T}{\partial y}(0,t) = \varepsilon \cdot \sigma_0 \cdot [T_f^4(t) - T^4(0,t)] + \alpha \cdot [T_f(t) - T(0,t)] = q_1(t) \quad (3)$$

$$\lambda(T) \cdot \frac{\partial T}{\partial y}(L,t) = \varepsilon \cdot \sigma_0 \cdot [T_f^4(t) - T^4(L,t)] + \alpha \cdot [T_f(t) - T(L,t)] = q_2(t) \quad (4)$$



Slika 1. Polaganje ingota u peć  
Figure 1. Ingots lay-out into the furnace

gdje je:  $T = T(y,t)$  distribucija temperature na poprečnom presjeku ingota, u zavisnosti od širine i vremena  $t$ . Lateralni ingot je označen sa  $L$ ;  $\rho$  je specifična masa,  $c_p$  je specifična toplota, dok  $\lambda$  predstavlja toplotnu provodljivost posmatranog čelika. Pored toga,  $\varepsilon$  je faktor emisije površine ingota i  $\sigma_0 = 5,67 \cdot 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$  je konstanta radijacije apsolutno crnog tijela, ili Stefan – Boltzmann-ova konstanta. Početna temperatura ingota je  $T_0 = 293 \text{ K}$ , a temperatura u dubinskoj peći je označena sa  $T_f(t)$ . Na kraju,  $\alpha [\text{W}/(\text{m}^2 \cdot \text{K})]$  predstavlja srednji koeficijent konvektnog prijenosa toplote na površini ingota.

Potražili smo rješenje jednačine (1) u obliku:

$$T(y,t) = a_1(t) + b(t) \cdot y + c(t) \cdot y^2 \quad (5)$$

Koeficijenti  $b(t)$  i  $c(t)$  trebaju biti određeni postavljanjem takvih uslova da rješenje iz (5) zadovolje uslove jednačine (3) i (4):

$$b(t) = \frac{q_1(t)}{\lambda(T)} \quad (6)$$

$$c(t) = \frac{q_2(t) - q_1(t)}{2 \cdot L \cdot \lambda(T)} \quad (7)$$

Iz (5), (6) i (7) slijedi rezultat

$$T(y,t) = a_1(t) + \frac{q_1(t)}{\lambda(T)} \cdot y + \frac{q_2(t) - q_1(t)}{2 \cdot L \cdot \lambda(T)} \cdot y^2 \quad (8)$$

where  $T=T(y,t)$  is the heating pattern in the ingot section, depending of the width  $y$  and time  $t$ . The ingot edge is noted  $L$ ;  $\rho$  is the density,  $c_p$  is the specific heat capacity,  $\lambda$  represents the heat conductivity of the steel grade and all of them are depending of temperature. Moreover,  $\varepsilon$  is the emission factor of the ingot surface and  $\sigma_0 = 5,67 \times 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$  is the radiation constant of the absolute black body or the Stefan-Boltzmann constant. The initial temperature of the ingot is  $T_0 = 293 \text{ K}$  and the temperature inside the furnace is noted with  $T_f(t)$ . Finally,  $\alpha [\text{W}/(\text{m}^2 \cdot \text{K})]$  represents the medium coefficient of heat transfer by convection for the ingot surface.

We are looking for the equation (1) this type of solution

$$T(y,t) = a_1(t) + b(t) \cdot y + c(t) \cdot y^2 \quad (5)$$

The coefficients  $b(t)$  and  $c(t)$  are found out imposing the solution (5) to obey the conditions (3) and (4), so

$$b(t) = \frac{q_1(t)}{\lambda(T)} \quad (6)$$

$$c(t) = \frac{q_2(t) - q_1(t)}{2 \cdot L \cdot \lambda(T)} \quad (7)$$

From (5), (6) and (7) it results

$$T(y,t) = a_1(t) + \frac{q_1(t)}{\lambda(T)} \cdot y + \frac{q_2(t) - q_1(t)}{2 \cdot L \cdot \lambda(T)} \cdot y^2 \quad (8)$$

Da bismo olakšali rješavanje problema, pribjegli smo pojednostavljinju hipoteze, što se sastoji od posmatranja termo-fizičkih parametara kao konstanti u određenim vremenskim intervalima, čiji će raspon i broj biti na odgovarajući način izabrani kasnije. Ako, dakle, pretpostavimo da je  $\lambda = \text{ct.}$ ,  $c_p = \text{ct.}$  i  $\rho = \text{ct.}$  u intervalima, dobijemo:

$$T(y,t) = \frac{1}{\lambda} \cdot \left[ \lambda \cdot a_1(t) + q_1(t) \cdot y + \frac{q_2(t) - q_1(t)}{2 \cdot L} \cdot y^2 \right] \quad (9)$$

Zapisat ćemo da je:  $\lambda \cdot a_1(t) = a(t)$  i izvođenjem izraza (9) u odnosu na vrijeme dobijemo:

$$\frac{\partial T}{\partial t}(y,t) = \frac{1}{\lambda} \cdot \left[ a'(t) + q'_1(t) \cdot y + \frac{q'_2(t) - q'_1(t)}{2 \cdot L} \cdot y^2 \right] \quad (10)$$

Zatim izvodimo isti izraz (9) u odnosu na  $y$  i dobijamo:

$$\lambda \cdot \frac{\partial T}{\partial y}(y,t) = q_1(t) + \frac{q_2(t) - q_1(t)}{L} \cdot y \quad (11)$$

$$\frac{\partial}{\partial y} \left[ \lambda \cdot \frac{\partial T}{\partial y}(y,t) \right] = \frac{q_2(t) - q_1(t)}{L} \quad (12)$$

Da bismo pronašli izraz  $a(t)$  uvodimo provjeru stanja Galerkinovog integrala:

To define the expression for  $a(t)$ , we impose the Galerkin integral condition

$$\int_0^L \left\{ \rho(T) \cdot c_p(T) \cdot \frac{\partial T}{\partial t}(y,t) - \frac{\partial}{\partial y} \left[ \lambda(T) \cdot \frac{\partial T}{\partial y}(y,t) \right] \right\} \delta T dy = 0 \quad (13)$$

Budući da su  $\lambda$ ,  $c_p$  i  $\rho$  konstante u vremenskim intervalima, uzimajući u obzir (10) i (12), s obzirom na to da je  $\delta T = \frac{\partial a}{\lambda}$  Galerkinov integral postaje:

which, for  $\lambda$ ,  $c_p$  and  $\rho$  invariable on ranges and taking into account (10) and (12), it becomes

$$\delta T \cdot \int_0^L \left\{ \frac{\rho \cdot c_p}{\lambda} \cdot \left[ a'(t) + q'_1(t) \cdot y + \frac{q'_2(t) - q'_1(t)}{2 \cdot L} \cdot y^2 \right] - \frac{q_2(t) - q_1(t)}{L} \right\} dy = 0 \quad (14)$$

Da bi izraz (14) bio tačan bez obzira na vrijednosti koje ima da Galerkin-ov integral mora biti nula, što znači:

For the expression (14) being true for all the  $\delta T$  values, the Galerkin integral must nullify, so

$$\frac{\rho \cdot c_p}{\lambda} \cdot \left[ a'(t) \cdot L + q'_1(t) \cdot \frac{L^2}{2} + \frac{q'_2(t) - q'_1(t)}{2 \cdot L} \cdot \frac{L^3}{3} \right] - \frac{q_2(t) - q_1(t)}{L} \cdot L = 0 \quad (15)$$

i

and

$$a'(t) = \frac{\lambda \cdot [q_2(t) - q_1(t)]}{\rho \cdot c_p \cdot L} - q'_1(t) \cdot \frac{L}{2} - \frac{q'_2(t) - q'_1(t)}{6} \cdot L \quad (16)$$

Integral iz izraza (16) u odnosu na vrijeme je:

$$a(t) = \frac{\lambda}{\rho \cdot c_p \cdot L} \cdot \int [q_2(t) - q_1(t)] dt - \frac{L}{2} \cdot q_1(t) - \frac{L}{6} \cdot [q_2(t) - q_1(t)] + C \quad (17)$$

Da bi se odredili tokovi topline  $q_1(t)$  i  $q_2(t)$ , posmatrali smo varijacije temperature u glavnoj dubinskoj peći u odnosu na vrijeme  $T_f(t)$ , kao što je predstavljeno na slici 2 i varijacije  $T(0,t)$ , odnosno  $T(L,t)$  su uzete kao linearne varijacije. Ako je:

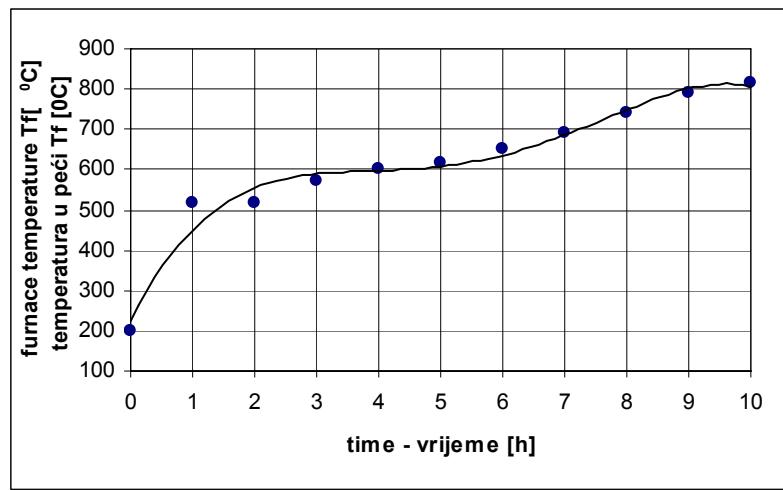
$$\int q_1(t) dt = g_1(t); \quad \int q_2(t) dt = g_2(t) \quad (18)$$

i uvedemo (17) u (9), dobit ćemo konačni izraz za približnu distribuciju topline u poprečnom presjeku ingota (u određenom vremenskom intervalu):

$$T(y,t) = \frac{q_2(t) - q_1(t)}{\lambda} \cdot \left( \frac{y^2}{2 \cdot L} - \frac{L}{6} \right) + \frac{g_2(t) - g_1(t)}{\rho \cdot c_p \cdot L} + \frac{q_1(t)}{\lambda} \cdot \left( y - \frac{L}{2} \right) + \frac{C}{\lambda} \quad (19)$$

To define the heat flows  $q_1(t)$  and  $q_2(t)$ , we considered a variation of the furnace temperature dependent on time,  $T_f(t)$ , as we see in figure 2, and the variations  $T(0,t)$  and, respectively  $T(L,t)$ , where considered linear variations. Noting

and introducing (17) in (9), we obtain the final expression for the approximate heating pattern in the ingot section (into a defined time range)



Slika 2. Promjena temperature u odnosu na vrijeme  
Figure 2. Furnace temperature variation in time

Kao što smo već spomenuli, da bi hipoteze:  $\lambda = ct.$ ,  $c_p = ct.$  i  $\rho = ct.$  (u intervalima) bile što je moguće vjerodostojnije, moramo uzeti u obzir vremenski interval podijeljen u nekoliko kraćih intervala. Ovi intervali si izabrani kao da su modifikacije termo-fizičkih vrijednosti osobina beznačajne. Kao rezultat takvih hipoteza, konstanta integracije iz (19) bit će izmijenjena za svaki interval. Bez obzira na to, očigledno je da je temperatura (tačke na poprečnom presjeku ingota) na kraju jednog vremenskog intervala jednaka temperaturi na početku narednog intervala:

$$T_{n+1}(y, n\Delta t) = T_n(y, n\Delta t) \quad (20)$$

As we had mentioned before, to make the hypotheses:  $\lambda=ct.$ ,  $c_p=ct.$  and  $\rho=ct.$  (on ranges) to be more plausible, we must consider the time range divided into smaller ranges. These little ranges were chosen so that the modifications of the thermo-physical characteristics values to be insignificant inside them. Therefore these hypotheses, the integration constant from (19) will alter for each range partially. Anyway, it is evidently that the temperature (of a point on the ingot section) at the end of a range is the same with the temperature at the beginning of the next range

$$T_{n+1}(y, n\Delta t) = T_n(y, n\Delta t) \quad (20)$$

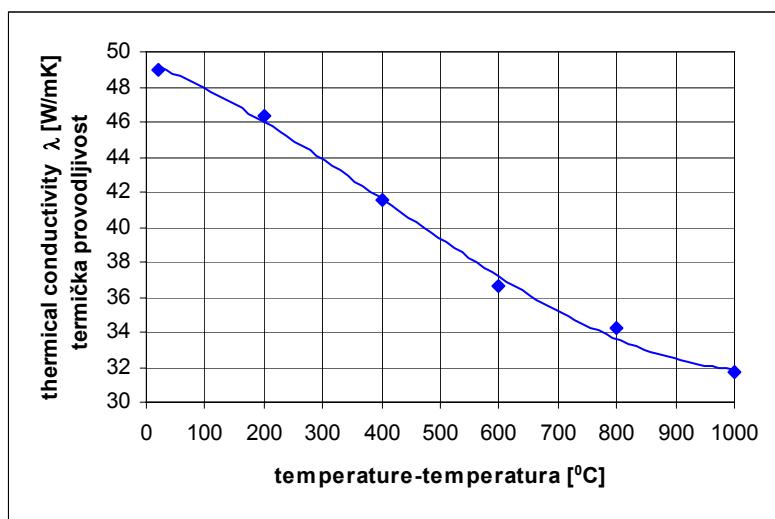
gdje  $n = 0, 1, 2, \dots$  predstavlja broj vremenskog intervala, a  $\Delta t$  je vremenski interval. Kombinirajući (19) i (20), dobijamo formulu za određivanje funkcije temperature u toku posmatranog intervala  $(n+1)$ :

$$T_{n+1}(y, t) = T_n(y, n\Delta t) + \frac{1}{\lambda_{n+1}} [q_2(t) - q_2(n\Delta t) + q_1(n\Delta t) - q_1(t)] \left( \frac{y^2}{2L} - \frac{L}{6} \right) + \\ + \frac{1}{\rho_{n+1} \cdot c_{p_{n+1}} \cdot L} [g_2(t) - g_2(n\Delta t) + g_1(n\Delta t) - g_1(t)] + \frac{1}{\lambda_{n+1}} [q_1(t) - q_1(n\Delta t)] \left( y - \frac{L}{2} \right) \quad (21)$$

Ukupno vrijeme zagrijavanja je 10 sati. Interval je podijeljen na 10 jednakih dijelova, tako da je  $\Delta t = 1$  sat. Stvarne varijacije topotne provodljivosti  $\lambda$  i specifične topote  $c_p$  su predstavljene na slikama 3, odnosno 4, a njihove varijacije u toku posmatranih intervala su prikazane na slikama 5, odnosno 6. Smatra se da je vrijednost specifične mase konstantna u toku cijelog zagrijavanja i iznosi  $\rho = 7800 \text{ Kg/m}^3$ .

where  $n = 0, 1, 2, \dots, N$  represents the time range number and  $\Delta t$  is the width of this range. Combining (19) with (20), it results the formula for the temperature function, on the respectively range  $(n+1)$

The total heating time is 10 hours. This range was divided into 10 equal parts, resulting  $\Delta t = 1$  hour. The variations of the heat conduction  $\lambda$  and the specific heat capacity  $c_p$  are shown in figure 3 and, respectively, 4. Function of these variations, we adopt, on the selected time ranges, certain constant values for  $\lambda$  and  $c_p$ , values which differ from one range to another. The density value is considered to be constant on the whole heating range and to be equal with  $\rho = 7800 \text{ kg/m}^3$ .



Slika 3. Promjene termičke provodljivosti u odnosu na temperaturu  
Figure 3. Thermal conductivity variation with the temperature

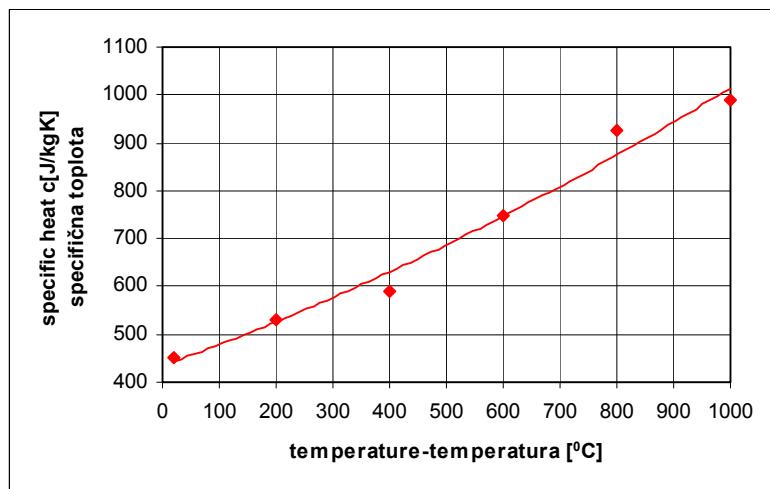
### 3. REZULTATI

Slijede vrijednosti koje smo dobili uz pomoć metode za temperature tačaka na površini ingota ( $y = 0$ ) i unutar ingota ( $y = L/2$ ). Ove vrijednosti su upoređene s temperaturama dobivenim eksperimentalnim mjeranjima u industrijskim uslovima.

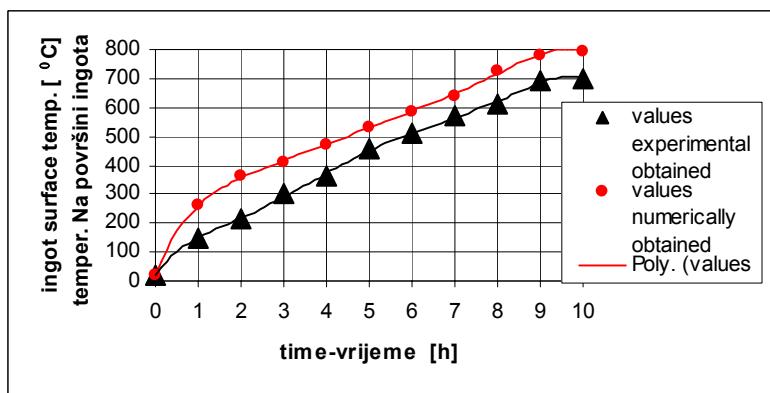
### 3. RESULTS

Further on, we will present the values obtained using this method, for the temperature of the points located on the ingot surface ( $y=0$ , see figure 5) and in its center ( $y = L/2$ , see figure 6). These values are compared with the temperature values obtained after many measurements made on industrial conditions.

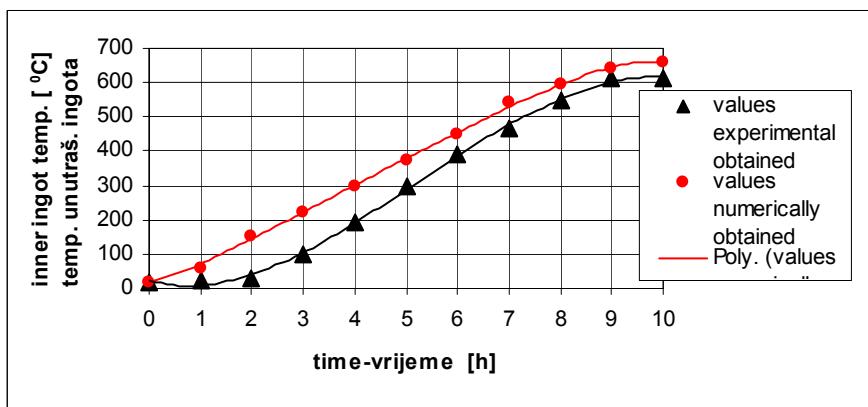
Having got only the experimental curves for the temperature variation at the surface and, respectively, the center of the ingot, during the heating period, we compared only the results corresponding to these areas.



Slika 4. Promjene specifične toploće u odnosu na temperaturu  
Figure 4. Specific heat variation with the temperature



Slika 5. Temperatura tačaka koje pripadaju presjeku ingota, gdje je  $y=0$  (vanjska površina)  
Figure 5. Temperature of the points belonging to the ingot section, where  $y=0$  (outer surface)



Slika 6. Temperatura tačaka koje pripadaju presjeku ingota, gdje je  $y=L/2$  (središte ingota)  
Figure 6. Temperature of the points belonging to the ingot section, where  $y=L/2$  (ingot center)

#### 4. ZAKLJUČCI

Vrijednosti temperature na površini ingota utvrđene analitičkim putem poklapaju se s eksperimentalnim vrijednostima, s greškom koja se razlikuje prema vremenskom intervalu zagrijavanja. To se može primijetiti na slici 5.

#### 4. CONCLUSIONS

The temperature values for the ingot surface analytically obtained coincide with the experimentally metered values, having a deviation which differs function on the time range in which the heating takes place. This can be seen in the figure 5.

Razlog zbog kojih se ove razlike javljaju na način na koji su određena stanja prijenosa topote, odnosno konvekcije i radijacije, između sagorenih gasova i površine igota. Ingot globalnog koeficijenta razmjene topote  $\alpha$ , s konstantnom prosječnom vrijednošću sve vrijeme zagrijavanja površine ingota, čini posmatrani model bližim stvarnosti kad je u pitanju raspon temperatura koji odgovara srednjoj vrijednosti  $\alpha$ , odnosno srednjoj zoni ukupnog intervala zagrijavanja ( $400 - 600$  °C), kao što se vidi na slici 5.

Vrijednosti temperature u središtu ingota dobivene analitičkim putem relativno se razlikuju od eksperimentalnih, posebno u toku prvog dijela zagrijavanja, što je predstavljano na slici 6.

Objašnjenje ovih grešaka leži u činjenici da po uspostavljanju termo-fizičkih osobina materijala temperatura varira (toplotna provodljivost  $\lambda$  i specifična topota  $c$ ), mogli bismo koristiti samo neke od tih vrijednosti koje odgovaraju posljednjim vremenskim intervalima zagrijavanja. Da bi se pokrio vremenski interval koji odgovara cijelom vremenu zagrijavanja, ekstrapolirali smo postojeće vrijednosti i napravili smo približne krivulje varijacija za te veličine (vidi slike 3 i 4). Očigledno je da je preciznost ovih krivulja manja od prihvatljive, posebno u dijelu niskih temperatura, te su zbog toga vrijednosti izračunate za temperature u središtu ingota podložne greškama.

Spomenuto objašnjenje se zasniva na činjenici da se prijenos topote u ingotu iz toplih u hladnije dijelove vrši isključivo termičkom provodljivošću, pojavom na koju direktno utječe termo-fizičke osobine materijala unutar kojeg se ona dešava.

Na kraju, za greške se naravno može kriviti i način na koji je konstruiran matematički model koji opisuje ovu pojavu, kao i način njihovog rješavanja.

Možemo, dakle, zaključiti da razmatrani analitički model može svom korisniku dati relativno tačne rezultate koji se odnose na razvoj temperaturnog polja u analiziranoj oblasti, pod uslovom da su početni podaci najbliži onim praktičnim i da su granična stanja, početna ili prostorna, što više pojednostavljena, tako da numerički model oponaša stvarni problem, što je moguće bolje.

The reason for which these deviations appear is the different ways used to establish the heat transfer conditions, convection or radiation, between the burnt gases and the ingot surface. The choice of an overall heat exchange coefficient  $\alpha$  at the ingot surface, having a medium value, constant during the whole heating period, makes the considered model to be almost true on the temperature range corresponding the medium value for  $\alpha$ , this means in the medium area of the entire heat range ( $400 - 600$  °C), as it can be seen in the figure 5.

The temperature values in the ingot center, obtained analytically, differ relative much from the experimental ones, especially in the starting heating period. We can see this in the figure 6.

The explanation for these deviations is: when we establish the thermo-physical properties of the material, which vary with the temperature (the heat conduction  $\lambda$  and the specific heat capacity  $c_p$ ), we had got some of their values 1 , corresponding to the last temperature ranges. To cover the temperature range corresponding to the whole heating period, we did the extrapolation of the existing values and the curve-tracing for the approximate variation of these parameters (see the figures 3 and 4). It is obviously that this curves exactness is not very good, especially in the low temperatures area and, for this reason, the calculated values for the temperatures in the points from the ingot center are affected by errors.

The above explanation is based on the fact that, inside the ingot, the heat transfer from the hot areas to the less hot ones is made exclusively through heat conductivity phenomenon, which is directly influenced by the thermo-physical properties of the material.

Finally, the arisen errors may occur due to the mathematical model design, which describes the phenomenon and its solving method.

At the end, we are concluding that the proposed analytical model can offer to the user approximately precise results regarding the evolution of the temperatures field inside a selected range for analyzing, if the initial data are closer the ones existing in practice and if the limit conditions (initial and three-dimensional ones) are as less simplified as it is possible, so that the numerical model to simulate more accurately the real phenomenon.

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## **SAVREMENE METODE ANALIZE ULJA U MAŠINSKIM KONSTRUKCIJAMA**

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**REZIME:**

Maziva su fluidi koji moraju odgovoriti brojnim zahtjevima. Razvojem novih tehnika analize podmazivanja, povećava se mogućnost utvrđivanja stanja mašine, maziva i nečistoća u ulju. Analiza ulja je široko korišten i veoma efikasan alat programa za monitoring stanja uređaja. Mnogobrojni uredaji i testovi za analizu ulja su razvijeni i nastavljaju se razvijati, kako bi omogućili što kvalitetniji monitoring i dijagnosticiranje problema nastalih u procesu podmazivanja.

Razvoj maziva u budućnosti predstavljati će veliki izazov za naučnike. Okolina sve više predstavlja jedan od osnovnih razloga razvoja maziva. Od modernih vozila se zahtjeva da emituju znatno manje štetnih gasova u poređenju sa starijim automobilima i kamionima. U praksi se susrećemo sa velikim brojem tipova mašina i ležišta, što povlači za sobom i znatan broj vrsta maziva, specijalno dizajniranih za pojedina mjesta primjene. Zbog toga, da bi postigli maksimalan radni vijek mašine i maziva od velike je važnosti odabir odgovarajućeg maziva.

**Ključne riječi:** Monitoring stanja, Analiza ulja

## **MODERN METHODS OF OIL ANALYSIS IN MECHANICAL CONSTRUCTIONS**

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**SUMMARY:**

Lubricants are fluids, which have to respond to numerous demands. Developing new techniques of lubrication analysis increases the ability of determining machine, lubricant and contaminant condition from the oil. Oil analysis is a widely used and very effective tool in a machinery condition-monitoring program. Numerous tests and instruments have been developed to help monitor and diagnose machinery lubrication problems.

Scientists will face great challenges in developing lubricants in future. Environment becomes one of the main reasons for the development lubricants. Modern vehicles are required to emit fewer pollutants than older cars and lorries. There are many different types of machines and many different types of bearings, and there are so many types of lubricants too, specifically designed for their individual application. In any machine application, the most important aspect for insuring maximum machine and lubricant life is the selection of the correct oil.

**Keywords:** Condition Monitoring, Oil Analysis

## **1. UVOD**

Maziva su od velikog značaja u životu modernog čovjeka. Analiza ulja je široko zastupljen i efikasan alat u programu za monitoring stanja neke mašinske konstrukcije. Mnogobrojni uređaji i testovi za analizu ulja su razvijeni i nastavljaju se razvijati, kako bi omogućili što kvalitetniji monitoring i dijagnosticiranje problema nastalih u procesu podmazivanja.

Razvojem računara i opreme, moderni program analize ulja postaje jednostavan za provođenje. Mnoge kompanije koriste softvere za analizu ulja. U zadnje vrijeme se mnogo govorilo o razvoju novih tehnika za analizu podmazivanja i povećanju sposobnosti određivanja stanja mašine, maziva i nečistoća u ulju.

## **2. MONITORING STANJA KROZ TESTOVE ANALIZE ULJA**

Postoji veliki broj različitih testova unutar analize ulja koji se koriste u procjeni njegovog stanja. Testovi moraju pokriti tri oblasti od interesa: stanje mašine, stanje nečistoća u mazivu i stanje maziva. Termin "analiza ulja" prihvaćen u industriji može se shvatiti na način da je primarna oblast od interesa analiza stanja maziva, dok je u stvarnosti, to u stvari monitoring stanja mašine.

Sa aspekta stanja mašine posebnu pažnju treba obratiti na pojavu i trend promjene broja metalnih čestica u ulju. Drugi fokus bi bilo stanje maziva, gdje je pažnju potrebno obratiti na znakove koji upućuju na promjenu viskoznosti, povećane oksidacije i trošenja aditiva. Treći fokus bi bilo stanje nečistoća u ulju, gdje je potrebno pažnju obratiti na brojnost čestica, sadržaj vode i metalnih nečistoća. Teoretski, analize ulja podijeljene su u tri klase. U stvarnosti sve tri klase monitoringa stanja su međusobno povezane i moraju se posmatrati kao cjelina. Tako na primjer, povećanje viskoznosti može biti naznaka procesa oksidacije maziva. Međutim, to može biti pogrešan zaključak, ako nema pokazatelja trenda povećanja oksidacije dobivenih preko analize vrijednosti kiselinskog broja (Acid Number-AN) i infracrvene analize na principu Furijerove transformacije (FT-IR).

I pod najboljim uvjetima rada, mazivo će vjerojatno degradirati. Vršeći monitoring stanja maziva, u mogućnosti smo izvršiti osvježenje ili zamjenu maziva prije nego što nastupe ozbiljnija oštećenja mašine. Ako je oštećenje primjećeno tokom rada, zbog nečistoća u ulju ili problema vezanih za mazivo, stanje mašine se može nadzirati i odmah izvršiti prekid njenog rada u cilju smanjenja oštećenja.

## **1. INTRODUCTION**

Lubricants are important in modern life. Car lubricants perform four major functions: control of engine friction and wear, protection of engine from rusting, cooling of the pistons, and protection of the engine oil stored in the sump from combustion gases. Oil analysis is widely used and a very effective tool in a machinery condition-monitoring program. Numerous tests and instruments have been developed to help monitor and diagnose machinery lubrication problems. With increased computer and instrumentation capacity, a modern oil analysis program is both easy to manage and provides a high return of maintenance investments. Many companies are using oil analysis software to track their equipment data. A great deal has been written about the development of new techniques for lubrication analysis and enhancing the ability to determine machine, lubricant, and contaminant condition from oil.

## **2. CONDITION MONITORING THROUGH OIL ANALYSIS TESTS**

There are many different types of oil analysis tests that are used to evaluate lubricants. The tests must cover three areas: machine condition, contamination condition, and lubricant condition. The industry-accepted term oil analysis can imply that the primary area of interest is the condition of the lubricant. But in reality, monitoring the machine condition is primary.

From the machine condition aspect, the specific focus would be to look for the presence and trending of any wear metals. The second focus would be the lubricant condition. From that aspect, the focus would be to look at the evidence of viscosity change, increase in oxidation, and signs of additive depletion. The third focus would be the contaminant condition. Emphasis should be placed on particle counts, water content, and contaminant metals.

Theoretically, oil analyses are divided into three classes. In reality, all three condition-monitoring classes are interrelated and must be considered as a whole. For example, an increase in viscosity could be an indication that a lubricant is oxidizing. But oxidation could be an incorrect conclusion, if there is no indication of an increasing oxidation trend either by acid number (AN) values or Fourier Transform-Infrared (FT-IR) analysis.

Even under the best of conditions, a lubricant will probably degrade. By monitoring its condition, actions can be implemented to refresh or replace the lubricant before serious machine damage begins.

If damage is noticed in the course of operation, due to contaminant, or lubricant problems, the machine condition can be monitored and the machine may be shut down immediately to minimize damage.

Druga mogućnost je da se, u zavisnosti od situacije, produži rad mašine do prve pogodne prilike za njeno isključenje.

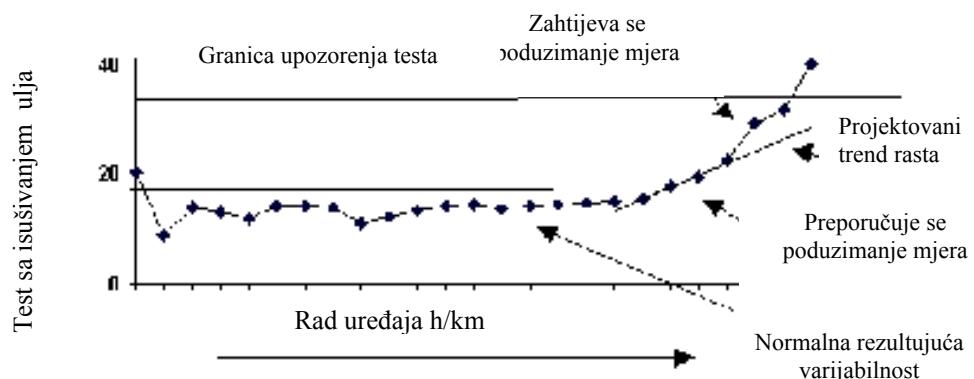
Postoje dva tipa alarma tj. upozorenja korištenih u analizi ulja: absolutni i statistički alarm. Efikasna analiza ulja počiva na kombinaciji oba tipa.

Slika 1. predstavlja jedan primjer kombinacije alarma [1]. Granica upozorenja predstavlja absolutni alarm. Statistički trend, uzima u obzir promjenljivost, koja je posljedica uzorkovanja ulja, zaprljanja ulja i sl., predstavlja standardnu devijaciju (odstupanje). Odstupanje od ove normalne promjenljivosti signalizira pojavu ozbiljnijih problema. Ovo odstupanje predstavlja prvi znak za poduzimanje mjera u cilju rješavanja nastalog problema. Kako se trend odstupanja približava granici upozorenja potrebno je poduzeti mjere kao što je zamjena ili prečiščavanje ulja ili pregled mašine.

Another possibility would be to extend the machine runtime to a suitable shutdown opportunity, depending on the situation.

There are the two types of alarming methodologies that are employed in oil analysis: absolute and statistical alarms. Effective oil analysis relies on the combination of both types of alarms. The following illustration (Figure 1.) is an example of the alarm combination [1]. The warning limit is the absolute alarm. Statistical trending, taking into account the variability based on the sampling, contamination, etc. will develop the standard deviations.

Departure from this normal variability signals that genuine problems are occurring. This is the earliest possible time to take action and resolve problems. Failing this, as the trend approaches its warning limit, action such as changing or cleaning the oil, or inspection of the unit is required.



Slika 1. Kombinacija apsolutnog i statističkog alarma

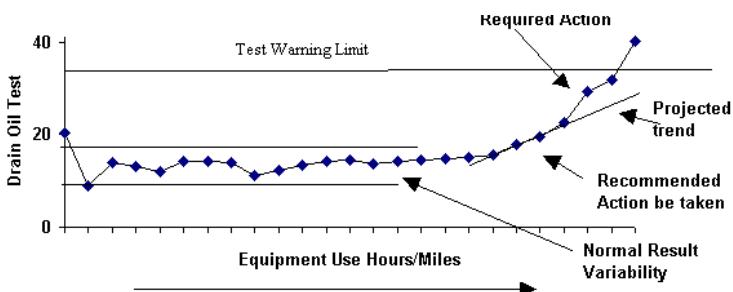


Figure 1. Combination of Absolute and Statistical Alarms

Test može obuhvatiti kontrolu sadržaja metalnih čestica, kontrolu viskoznosti ili neke druge parametre. Oblast normalne promjenljivosti uzima u obzir male varijacije nastale uslijed analitičke tačnosti, homogenosti uzorka, itd. Uspostavljanje statističkih alarma, koji obezbjeđuju najranije moguće upozorenje, bez lažnih alarma, je teško ostvariti. Faktori kao što su dodavanje ili zamjena ulja, zamjena filtera i tehnika uzorkovanja utiču na tačnost rezultata.

The test used could be iron content, viscosity or other parameters. The normal result variability range takes into account minor variations caused by analytical accuracy, sample homogeneity, etc. As the trend approaches the warning limit, some action must be taken, either cleaning the oil or inspecting the equipment. Establishing statistical alarms, which provide the earliest possible warning without false alarms, is a difficult task. Factors such as adding or changing oil, filter changes, sampling technique can distort the results.

Korištenjem programa za analizu ulja u slučaju motornih ulja, osigurava se nekoliko prednosti: smanjenje neplaniranog vremena otkaza vozila, poboljšanje pouzdanosti vozila što je od koristi prilikom organizovanja efikasnog plana održavanja, produženje radnog vijeka motora, optimiziranje intervala zamjene ulja i smanjenje troškova održavanja vozila.

Sljedeći testovi su najčešće korišteni testovi prilikom monitoringa stanja mašine od kojih se kod nekih prepliću tri interesne oblasti.

## 2.1 Spektrometrijska analiza

Spektrometrijska analiza je tehnika za utvrđivanje i kvantificiranje metalnih čestica nastalih habanjem, zaprljanjem i sl. Uzorak ulja se pobuđuje tako da svaki element emituje ili apsorbuje određenu količinu energije što ukazuje na koncentraciju elemenata u ulju.

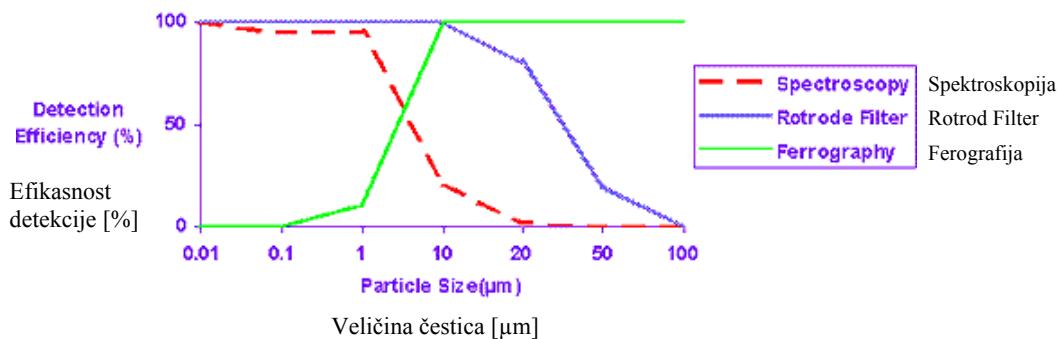
Rezultati predstavljaju koncentraciju svih rastvorenih metala i čestica. Oprema za spektrometrijsku analizu danas predstavlja standardnu opremu laboratorija za analizu ulja, koja obezbeđuje informaciju o stanju mašine, zaprljanju i habanju relativno brzo i tačno.

Using Oil Analysis programs for engine oils has several benefits: reduction of unscheduled vehicle downtime, improvement of vehicle reliability, help in organizing effectiveness of maintenance schedules, extension of engine life, optimization of oil change intervals and reduction of cost of vehicle maintenance.

The following tests are the most used in condition monitoring. With some of them, the three areas of interest may overlap.

## 2.1 Spectrometric Analysis

Spectrometric analysis is a technique for detecting and quantifying metallic particulates in used oil arising from wear, contamination and additive packages. The oil sample is energized to make each element emit or absorb a quantifiable amount of energy, which indicates the element's concentration in the oil. The results represent the concentration of all dissolved metals and particles. The equipment for spectrometric analysis is the standard equipment for oil analysis laboratories today. It provides information on machine, contamination and wear condition relatively quickly and accurately.



Slika 2. Efikasnost detekcije  
Figure 2. Detection efficiency

Spektroskopija je manje-više "slijepa" za veće čestice u uzorku ulja, tačnije za čestice veće od 10  $\mu\text{m}$  u prečniku, a koje su pokazatelj pojave izrazito povećanog habanja. (sl. 2) [2]. Nekoliko vrsta habanja (kao što su: habanje kao posljedica raspadanja materijala pod uticajem topote, nekoliko kliznih habanja i rezno habanje) generira velike čestice koje se ne mogu otkriti spektroskopijom. Veličina čestice pri kojoj spektrometri počinju da gube sposobnost detekcije zavisi od brojnih faktora kao što su vrsta i tip spektrometra, ali gledajući generalno spektrometri gube sposobnost detekcije čestica prečnika između 1 i 10  $\mu\text{m}$ . Ovo je glavni nedostatak spektrometrijske analize.

Spectroscopy is more-or-less blind to the larger particles in an oil sample, more precisely, to particles greater than 10  $\mu\text{m}$  in diameter, which are more indicative of an abnormal wear mode (Figure 2.) [2]. Most severe wear modes (such as spalling, severe sliding wear, and cutting wear) generate large particles, which go undetected by spectroscopy. Large contaminant particles are also missed by spectroscopy. The particle size at which spectrometers begin to lose their detection ability depends on a number of factors including spectrometer and type, but it is generally agreed that spectrometers lose their ability to detect particles in the 1 to 10 micrometer range. That is a major limitation of the spectrometric analysis. Particle detection efficiency is poor for particles 5 microns in size or greater. The technique is accurate to 10%, although with new equipment it is within 3% [2].

Analiza ulja spektrografijom je našla dobru primjenu kod motora sa unutrašnjim sagorijevanjem i hidrauličnih sistema, jer su pohabane čestice najčešće sitne. Ove male čestice se ravnomjerno rasporede u uzorku ulja i lako sagore u spektrometru, tako da operator ima jasno očitanje.

## 2.2 Analitička ferografija

Analitička ferografija je tehnika koja odvaja pohabane magnetne čestice iz ulja. Ove čestice se slijedu na staklenu površinu poznatu kao ferogram. Mikroskopsko ispitivanje omogućava da odredimo tip habanja, a vjerovatno i izvor habanja u mašini. Analitička ferografija je jedan izuzetan indikator izrazito povećanog habanja dijelova od neobojenih metala, ali je neprikladna u slučaju habanja dijelova od obojenih metala.

Test je od izuzetne koristi kod već uspostavljenog procesa habanja. Rezultati uključuju izvještaj o veličini, morfologiji i količini čestica od neobojenih metala i nečistoća.

Ferografija je dosta rasprostranjena tehnologija analize pohabanih čestica. Predstavlja dijagnostičko-prognozirajuću tehniku koja nudi jedan pogodan način tačnog procjenjivanja on-line stanja podmazivanih dijelova u kontaktu bez isključivanja mašine. Jedna automatizovana verzija ove tehnike je DR (Direct Read) Ferografija koja mjeri odnos krupnih i sitnih čestica u ostacima uljnog uzorka. Mala količina uzorka se razrjeđuje rastvaračem i pušta da teče kroz malu kapilarnu cijev koja se kreće kroz magnetno polje. Dva optička senzora su neovisno jedan od drugog postavljeni na ulaz i neznatno usmjereni niz kapilarnu cijev mijereći gustoću čestica neobojenih metala sabranih na oba mjesta. Ovi podaci se mogu koristiti pri određivanju koncentracije pohabanih čestica i indeksa ozbiljnosti situacije.

Kada se je DR ferogram pojavio sedamdesetih godina, doživio je veliki uspjeh, zahvaljujući sposobnošću otkrivanja kako velikih tako i malih čestica neobojenih metala u ulju, kao i sposobnošću određivanja njihovog odnosa koji karakteriše pojavu povećanog habanja kod mašina sa rotacionim dijelovima. DR ferografija je i dalje bazirana na magnetnom odvajaju, tako da se ovaj princip ne može koristiti u slučaju čestica od obojenih metala bilo koje veličine, kao i u slučaju anorganskih nemetalnih čestica (pijesak, nečistoće, i sl.). Ovaj nedostatak dolazi do izražaja posebno kod monitoringa opreme sa kritičnim dijelovima od obojenih metala. Zbog toga, tradicionalna spektroskopija, ostaje sastavni dio analize ulja upravo zbog sposobnosti da otkrije sitne čestice obojenih metala.

Spectrographic oil analysis works well for internal combustion engines and hydraulic systems because the wear particles are usually small. These small particles disperse evenly in the oil sample. They also burn readily in the spectrometer; therefore, the operator gets a good reading.

## 2.2 Analytical Ferrography

Analytical ferrography is a technique which separates magnetic wear particles from oil. Those particles settle on a glass slide known as a ferrogram. Microscopic examination enables to determine the wear mode and probable sources of wear in the machine. Analytical ferrography is an exceptional indicator of abnormal ferrous wear and it is inadequate for nonferrous wear. The test is most useful for an established wear trend. Results include report of size, morphology, and quantity of ferrous wear, and contaminant particle.

Ferrography is a rapidly expanding technology of wear particle analysis. It is a diagnostic and predictive technique which offers a convenient means of accurately evaluating the online condition of interacting lubricated components without having to shut down the machine. An automated version of this technique is DR (direct read) ferrography. It measures the ratios of large and small debris particles in the sample. A small amount of sample is diluted with solvent and flowed through a small capillary tube, which runs through the magnetic field. Iron-based particles are systematically (largest to smallest) separated by the magnetic field as the sample flows through the capillary tube. Two optical sensors are respectively set at the entrance and slightly downstream of the capillary tube to measure the density of the iron particles collected at each of the two points. This data may be used to calculate the wear particle concentration and the severity index.

When the DR Ferograph was introduced in the 70's, it met with immediate success because of its sensitivity to both large and small ferrous particles in lubricating oil, and its capability of determining the ratio whereby abnormal wear could be characterized in rotating machinery. DR Ferrography is still based on magnetic separation, and this is a principle weakness when nonferrous metal particles of any size are present in an oil sample, not to mention large nonmetallic inorganic particles such as sand/dirt. This drawback is evident when monitoring equipment with critical nonferrous components. Consequently, traditional spectroscopy continues to remain an integral part of oil analysis because of the ability to detect fine nonferrous debris.

Kombinacija DR ferografije i spektrometra je do pojave Rotrode Filter Spektroskopije (RFS) bila popularna metoda ekranizacije uljnih uzoraka radi detekcije povećanog habanja. Međutim, čak i u kombinaciji, ove metode ne mogu otkriti krupnije čestice obojenih metala.

### 2.3 Rotrode Filter Spektroskopija (RFS)

Rotrod filter spektroskopija je prvi put predstavljena 1992. godine. Ova spektrometrijska tehnika detektuje krupne metalne čestice i nečistoće u uljnom uzorku. Prečnik ovih čestica je do 25 µm. Ove krupne čestice su od posebnog značaja, jer predstavljaju prve indikatore povećanog intenziteta habanja.

RFS predstavlja jednu poboljšanu spektroskopsku metodu analize korištenog ulja za monitoring stanja odnosno predviđanja potrebnog održavanja, bez ograničenja po veličini ili tipu čestice kao u slučaju kombinovane spektrohemiske metode i DR ferografije. Superiornija je u odnosu na DR ferografiju, jer ima mogućnost detekcije čestica kako neobojenih metala tako i obojenih, kao i nečistoća. Efikasnost detekcije opada sa porastom prečnika čestica iznad 25 µm.

Metoda koristi spektrometar sa elektrodom u obliku rotacionog diska, poznat kao RDE (Rotating Disk Emission) spektrometar, koji obezbeđuje spektrografičku analizu ulja (SOA).

RDE spektrometar sastoji se od karbonskog diska koji je pritisnut na kraj rotirajućeg vratila. Osjetljivost metode je odlična. Koristi se višestepeni uređaj tako da se više uzoraka može filtrirati istovremeno. Metoda je brza i ekonomična i zahvaljujući prednostima koje posjeduje predstavlja jedan moćan predskazivač kvara opreme.

Povišen stepen habanja prouzrokuje značajno povećanje u koncentraciji i veličini pohabanih čestica. Koristeći poroznu grafičku "rotrodu" kao filtrirajući medij krupne čestice se apsorbuju i podvrgavaju RDE spektroskopiji dobijajući više-elementnu analizu uljnog uzorka. Prvenstveno se mjeri koncentracija i veličina ovih apsorbovanih krupnih čestica nezavisno od sitnih i rastvorenih čestica nečistoća u uzorku. Kombinujući rezultate analize krupnih čestica sa konvencionalnom RDE analizom rastvorenih i sitnih čestica u ulnjom uzorku može se dobiti kompletan slika analize pohabanih čestica određene mašine.

Rotrod filter spektroskopija je brza i efikasna metoda analize ulja. Dobiveni podaci se mogu iskoristiti i za analizu nečistoća kojom se dobiva sastav po elementima krupnih čestica nečistoća (silikon). Prednost ove tehnike je i ta da se može odrediti da li je neki element porijeklom od pakovanja aditiva (silikonski polimer protiv pjenušanja ulja) ili je u pitanju čestice nečistoća (pijesak, i sl.).

Until now, the combination of the DR and spectrometer has been a popular method of screening oil samples to detect abnormal wear. However, even in combination, they remain insensitive to large nonferrous particles.

### 2.3 Rotrode Filter Spectroscopy (RFS)

RFS was first introduced in 1992. This spectrometric technique detects coarse wear metals and contaminants in a used oil sample. Diameter of those particles is up to 25 µm, but it excludes all additives. The coarse particles are especially important. They are the first indicators of abnormal wear situations. RFS was developed to provide an improved spectroscopic method for analysis of used oils for condition monitoring/predictive maintenance without the particle size or metal-type limitations of the combined spectrochemical and DR ferrographic techniques. It is superior to DR ferrography because it detects ferrous, nonferrous and contaminant elements. The detection efficiency of large material gets poorer as particle size increases above 25 µm diameter. Its accuracy range is within 15% [2].

This method uses a rotating disc electrode spectrometer, known as an RDE spectrometer, which performs spectrographic oil analysis (SOA). In the RDE spectrometer, a carbon disc is pressed onto the end of a shaft, which rotates causing the disc to rotate. The sensitivity of the method is excellent. A multi-station fixture is used so that a number of samples can be filtered at once. The procedure is fast and economical to perform. It is an ideal screening test for analytical ferrography. The technique has several advantages, which make it a powerful predictor of equipment failure.

Most abnormal wear modes cause a significant increase in concentration and size of wear particles. Using porous graphite rotrodes as a filtering media, large particles are captured and subjected to RDE (Rotating Disk Emission) Spectroscopy to obtain a multi-elemental analysis. These captured coarse particles are measured essentially independently of fine and dissolved particle contaminants in the sample. Removal of the used oil from the spectroscopic analysis reduces the energy required to vaporize the sample. By combining such large particle results with conventional RDE analysis of the dissolved and fine particles in the oil sample, a complete wear analysis picture for a machine of interest can be obtained.

Rotrode Filter Spectroscopy is fast and efficient. The data is also excellent for contamination analysis. It gives elemental composition of large contaminant particles (silicon). The advantage of this is that it can determine whether the element is sourced from an additive package (silicone polymer for defoaming) or a contaminant (sand/dirt particles)

## 2.4 Infracrvena analiza (FT-IR)

Infracrvena spektroskopija furijerovom transformacijom (FT-IR) je spektrometrijska tehnika za detekciju organskih nečistoća, vode i produkata degradacije ulja u uljnom uzorku. Vrši se kontrola degradacije maziva (oksidacija, nitracija, sulfatacija, trošenje aditiva) i tečnih nečistoća (voda, glikol, razblaživanje maziva gorivom).

Tokom radnog vijeka maziva, akumuliraju se proizvodi oksidacije, prouzrokujući degradiranje ulja i u većini slučajeva lagani porast njegove kiselosti. Ako se oksidacija pojavi u većoj mjeri, mazivo će prouzrokovati koroziju kritičnih površina uređaja. Povećanje oksidacije dovodi do većeg "oksidacionog broja". Slično tome, "nitracioni broj" ukazuje na nivo jedinjenja nitrogena u ulju prouzrokovanih vezivanjem atoma azota (česta pojava kod motora na prirodnim gasima). Pojave kao što su bijeljenje ulja, taloženje mulja, ljepljivi klipni prsteni i začepljenje filtera javljaju se u sistemima sa problemom oksidacije i/ili nitracije.

FT-IR spektroskopija takođe, utvrđuje zaprljanje ulja uslijed vode, glikola antifriza, naslaga čadi, razblaživanja ulja gorivom. Postoje preporuke proizvođača vezano za oksidacione brojeve i tečne nečistoće.

## 2.5 Viskoznost

Viskoznost je otpornost fluida tečenju i predstavlja najznačajniju fizičku osobinu maziva. Mazivo mora posjedovati odgovarajuće karakteristike, kako bi osiguralo adekvatno snabdijevanje podmazivanih površina u kontaktu pri različitim radnim temperaturama. Fluid se stavlja u viskozimetar (kalibrirana kapilarna cijev za precizno mjerjenje protoka između dvije obilježene tačke na cijevi) i predgrijava na zadalu temperaturu u "viskoznoj kadi" koja je najčešće napunjena uljem. Nakon što se ulje zagrije na određenu temperaturu, uslijed djelovanja gravitacije počinje teći kroz viskozimetar. Mjeri se vrijeme potrebno da ulje protekne između dvije kalibrirane tačke na cijevi.

Smicanje maziva se javlja u slučaju cijepanja njegovih molekula na manje molekule. Ovo se dešava iz dva osnovna razloga: toplota i pritisak iz sistema. Indeks viskoznosti (VI) je mjera otpora maziva usitnjavanju njegovih molekula sa porastom temperature. Predstavlja jednu važnu osobinu maziva na nižim temperaturama. Tako na primjer, zbog pumpabilnosti maziva zahtijeva se njegova manja viskoznost, dok s druge strane zbog obezbjeđenja potrebne moći nošenja mazivnog filma na radnoj temperaturi, zahtijeva se njegova dovoljna gustoća. U slučaju motornih ulja, ispunjenju ovih zahtjeva uspješno potpomažu poboljšivači indeksa viskoznosti bazirani na polimerima.

## 2.4 Infrared Analysis (FT-IR)

Fourier-Transform Infra-Red Spectroscopy is a spectrometric technique for detecting organic contaminants, water and oil degradation products in a used oil sample. It monitors lubricant degradation (oxidation, nitration, sulfation, additive depletion) and liquid contaminants (water, glycol, fuel dilution).

During a lubricant's service life, oxidation products accumulate, causing the oil to become degraded, and in most instances, slightly acidic. If oxidation becomes severe, the lubricant will corrode the equipment's critical surfaces. The greater the "oxidation number", the more oxidation is present. Similarly, the "nitration number" reflects the level of nitrogen compounds in the oil resulting from nitrogen fixation (common in natural gas fueled engines). Conditions such as varnishing, sludge deposits, sticky rings, lacquering and filter plugging occur in systems with oxidation and/or nitration problems.

FT-IR spectroscopy also indicates contamination due to free water, glycol antifreeze, soot deposits and fuel dilution. There are guidelines issued for oxidation numbers and liquid contaminants by manufacturers, but this is essentially a trending tool.

## 2.5 Viscosity

Viscosity is the resistance of a fluid to flow and the most important lubricant physical property. Lubricants must have suitable flow characteristics to insure that an adequate supply reaches lubricated parts at different operating temperatures. The fluid is placed in a "viscometer" (a calibrated capillary tube for precise flow measurement between two pre-marked points on the tube) and pre-heated to a given temperature in a "viscosity bath" (which is usually oil-filled). After the oil reaches the desired viscosity temperature, gravity-influenced flow of the oil is initiated in the viscometer and timed between two calibrated points. This time becomes the determinant for the result.

Shearing of a lubricant occurs when its molecules are split into yet smaller molecules. This can happen from two basic processes: heat and pressure from the system. This can affect even the lubricant's base stock, although it more aptly applies to any viscosity-index improvers which may have been present during mechanical shearing, such as a ring scraping against a cylinder wall, trapping of lubricant molecules and cutting of lubricant molecules. Viscosity Index (VI) is a measure of a lubricant's resistance to thinning as temperature increases.

Viskoznost maziva znatno zavisi od njegove klasifikacije ili gradacije kao i od stepena oksidacije i zaprljanja tokom rada.

Razlozi za povećanje viskoznosti maziva leže u sljedećem: oksidacija maziva, kavitacija uslijed pjenušanja maziva, rastvaranje maziva s vodom, punjenje sistema mazivom veće viskoznosti od preporučene i zaprljanje maziva čvrstim česticama. S druge strane, razlozi za smanjenje viskoznosti maziva su: zaprljanje maziva gorivom, usitnjavanje molekula, zaprljanje maziva bez njegovog rastvaranja s vodom, punjenje sistema mazivom manje viskoznosti od preporučene i uticaj sredstva za hlađenje (erkodišn sistem).

Ako se viskoznost maziva razlikuje više od 10% od nominalne gradacije, proizvođači maziva preporučuju njegovu zamjenu. Tokom rada i vremena, očekuje se porast viskoznosti maziva. Smanjenje viskoznosti se smatra opasnijim od njenog povećanja. Stoga, je dozvoljena gornja granica +20% iznad nominalne vrijednosti, a donja -10% ispod nominalne vrijednosti.

*It is an important property in cold climates: one wants a low viscosity for pump-ability, but then wants the lubricant to remain thick enough to provide film strength at operating temperature. Polymer-based "VI improvers" help accomplish this in motor oils. VI is of little use in used motor lubricant analysis. The viscosities of lubricants vary depending on their classification or grade, as well as the degree of oxidation and contamination in service.*

*The reasons for increase in the viscosity are: lubricant oxidation, foaming/pump cavitation, emulsion with water, wrong fill or make-up lubricant (higher viscosity than recommended), and solids contamination. However, the reasons for the reduction in viscosity are: fuel or solvent contamination, molecular shearing, non-emulsified water contamination, wrong fill or make-up lubricant (lower viscosity than recommended), and refrigerant (air-conditioning systems). If viscosity of the lubricant differs by more than 10% from the nominal grade, the lubricant supplier recommends a change of oil. When the equipment is on a condition-monitoring program, more specific controls may be put in place. Oil viscosity is expected to rise over time and use, and loss of viscosity is considered to be more serious than its increase. Therefore, a working alarm range is +20%, -10%, i.e. not more than 20% over nominal, and not less than 10% under the nominal grade. The accuracy of this test is very good, 0.5% [3].*

## 2.6 Ukupni kiselinski broj (TAN)

Ukupni kiselinski broj je neutralizacioni broj namijenjen za mjerjenje svih kiselinskih i kiselinsko-aktivnih materijala u mazivu uključujući jake i blage kiseline. To je titraciona metoda koja pokazuje relativnu kiselost maziva.

Uzorak se razblažuje razrjeđivačem i alkalnom bazom, u obliku kalijum hidroksida (KOH) i dodaje u kontrolisanoj mjeri iz menzure dok se uzorak ne neutralizira. Kalijum hidroksid je titrant. Neutralizacija se mjeri jedinicom volt ili pH faktorom. Tačka početka neutralizacije se kreće oko vrijednosti faktora pH 11. TAN se određuje na osnovu utrošene količine KOH.

Jake kiseline imaju tendenciju da postanu korozivne i njihova količina u mazivu mora se obavezno kontrolisati. Kiselinski broj koristi se kao pokazatelj oksidacione degradacije ulja tokom rada. Kada vrijednost TAN-a dosegne određeni definisani nivo za dato mazivo i za njegovo mjesto primjene potrebno je izvršiti zamjenu ulja. Neočekivani porast vrijednosti TAN-a može upućivati na abnormalne radne uslove (npr. pregrijavanje) što zahtijeva istragu. Većina proizvođača maziva daje preporučene vrijednosti TAN-a u katalozima.

## 2.6 Total Acid Number (TAN)

TAN is a neutralization number intended for measuring all acidic and acid-acting materials in the lubricant, including strong and weak acids. It is a titration method designed to indicate the relative acidity in a lubricant.

The sample is diluted with solvent and base (alkaline), in the form of potassium hydroxide (KOH), and added in controlled increments from a burette (a calibrated tube with a stopcock valve at the bottom to allow gravity feed) until the sample is neutralized. The KOH is the tyrant. Neutralization is determined with a volt or pH meter. The neutralization point usually occurs around pH 11. The TAN is calculated from the amount of KOH consumed. Strong acids tend to be corrosive and are much more necessary to control.

The acid number is used as a guide to follow the oxidative degeneration of oil in service. Oil changes are often indicated when the TAN value reaches a predetermined level for a given lubricant and application. An unexpected increase in TAN would be indicative of abnormal operating conditions (e.g. overheating) that require investigation. Most lubricant suppliers give TAN condemnation limits in the catalogs. Accuracy of this test is within 15% [3].

## **2.7 Ukupni bazni broj (TBN)**

TBN je neutralizacioni broj namijenjen za mjerjenje svih bazičnih (alkalnih) materijala u mazivu. Suprotno od TAN, ovaj metoda titracije služi za određivanje rezerve alkalnosti maziva. Posmatrajući generalno, TBN predstavlja jedan pokazatelj sposobnosti ulja da neutralizira štetne kiselinske koprodukte sagorijevanja gasova u motoru.

Uzorak se razblažuje razrjeđivačem i kiselinom (hlorovodonična ili perhlorna) i dodaje u kontrolisanoj mjeri iz menzure dok se uzorak ne neutralizira. Kiselina je titrant. Neutralizacija se mjeri na isti način kao i kod TAN-a, s tom razlikom da tačka početka neutralizacije se najčešće javlja oko vrijednosti pH 4. TBN se određuje na osnovu utrošene količine kiseline.

Vrijednost TBN-a je najveća kod novog nekorištenog ulja, a smanjuje se sa vremenom provedenim u radu. Niska vrijednost TBN-a ukazuje na skor kraj radnog vijeka ulja.

TBN se najčešće koristi kod motornih maziva. Kiseline nastale sagorijevanjem (sumporna kiselina) smanjuju vrijednost TBN-a.

## **2.7 Total Base Number (TBN)**

TBN is a neutralization number intended for measuring all basic (alkaline) materials in the lube (acid-neutralizing components in the lubricant additive package). The converse of the TAN, this titration is used to determine the reserve alkalinity of a lubricant. The TBN is generally accepted as an indicator of the ability of the oil to neutralize harmful acidic byproducts of engine combustion.

The sample is diluted with solvent and acid (hydrochloric or perchloric) is added in controlled increments from a burette until the sample is neutralized. The acid is the tyrant. Neutralization is determined with a volt or pH meter, and the neutralization point usually occurs around pH 4. The amount of acid consumed is recorded, and the TBN calculated from that value.

The TBN is highest when oil is new and decreases with its use. Low TBN normally indicates that the oil has reached the end of its useful life. TBN is a measure of the lubricant's alkaline reserve, and mostly applies to motor lubricants. If a lube contains no alkaline additives, there is little use to determine a TBN, as there will likely be none. Combustion acids attack TBN, e.g., sulfuric acid, decreasing as it consumes.

## **2.8 Količina vode i čestica**

Veće zagađenje ulja vodom može se vizuelno registrovati. Prekomerna količina vode u sistemu slabih nosivih moći će maziva t.j. sposobnost formiranja uljnog filma između pokretnih dijelova što rezultira znatnim povećanjem habanja, a time, uslijed trenja, do stvaranja znatne količine toploće. Zagađenje ulja vodom ne treba da pređe 0,25% za većinu uređaja i ne više od 100 ppm (broja dijelova u milionu dijelova posmatranog uzorka) za turbinska maziva i maziva u kontrolnim sistemima.

Postoji više metoda koje se koriste za testiranje ulja od zagađenja vlagom (FT-IR metoda na vodu, centrifugalna metoda, Karl Fischer) svaka sa različitim nivoom detekcije (1000 ppm ili 0,1% kod prve dvije metode i 10 ppm ili 0,001% kod Karl Fischer metode). Utvrđivanje količine čestica u ulju je metoda koja se koristi za određivanje broja čestica u fluidu i njihovu klasifikaciju prema opsegu veličina definisanih po ISO 4406 i NAS 1638 [3]. Postoji više različitih tipova instrumentacije na tržištu, prema raznolikosti mjernih mehanizama, od optičko laserskih mjeraca do kontrolnih uređaja na principu mjerena zapušenja pora.

## **2.9 Primjenljivost testova**

Industrijska oprema zahtijeva kombinaciju gore navedenih testova za monitoring stanja. Sljedeća tabela predstavlja primjenljivost testova kod različitih industrijskih uređaja [4].

## **2.8 Water and Particle Count**

Water can be detected visually if gross contamination is present. Excessive water in a system destroys a lubricant's ability to separate opposing moving parts, allowing severe wear to occur with resulting high frictional heat. Water contamination should not exceed 0.25 % for most equipment, and not more than 100 ppm (parts per million) for turbine lube and control systems.

There are several methods used for testing the moisture contamination (crackle, FT-IR water, centrifuge, Karl Fischer) each with a different level of detection (1000 ppm or 0.1 % for first three methods and 10 ppm or 0.001 % for Karl Fischer method).

Particle Count is a method used to count and classify particulate in a fluid according to accepted size ranges, usually to ISO 4406 and NAS 1638 [3]. There are several different types of instrumentation on the market, utilizing a variety of measurement mechanisms, from optical laser counters to pore blockage monitors.

## **2.9 Equipment Applications**

Industrial equipment needs a combination of the above tests for condition monitoring. The following table is a summary of the test applicability [4].

Tabela 1. Testovi za monitoring stanja industrijskih uređaja

Table 1. Tests for Condition Monitoring of Industrial Equipment

Uredaj Equipment	Testovi za monitoring stanja – Tests for Condition Monitoring							
	Analiza Analysis	Test	FT-IR	Specifikacija čestica Count	Karl Fisher	TAN	TBN	RFS
Motori - Motors	Z (R)	Z (R)	Z (R)					Z (R)
Mašine – Engines	Z (R)	Z (R)	Z (R)				Z (R)	P (A)
Zupčasti prenosnici - Gearboxes	Z (R)	Z (R)	Z (R)					Z (R)
Ležišta – Bearing		Z (R)	Z (R)	P (A)				Z (R)
uređaji – Hidraukics	Z (R)	Z (R)	Z (R)	Z (R)	P (A)	P (A)		Z (R)
Turbine – Turbines	Z (R)	Z (R)	Z (R)	Z (R)	Z (R)	Z (R)		Z (R)
Kompressori - Compressors	Z (R)	Z (R)	Z (R)		P (A)	Z (R)		Z (R)

Z : Zahtijevani test P : Preporučljiv test (osigurava dodatne informacije, naročito tokom rješavanja problema)  
(R) Required test (A) Advisable test, provides extra details, particularly during problem solving

### 3. ZAKLJUČAK

Prilikom upotrebe maziva bitno je odabrati ispravno mazivo i održavati ga čistim, svježim i bez prisustva vlage. U praksi, to povlači za sobom brojne tehnologije i pravila koja osiguravaju ispunjenje prethodnih uvjeta, a što u znatnoj mjeri zavisi od vrste aplikacije i njene specifičnosti. To podrazumijeva odabir ispravnog baznog ulja, ispravne viskoznosti i ispravnih aditiva za odgovarajuću namjenu. Također, nužno je voditi računa o zaprijanju ulja sa aspekta udjela vode i čestica što može imati izrazito štetne efekte na radni vijek mašine i maziva.

Ispravno održavanje maziva povećava radnu sposobnost mašine, produžava njen radni vijek kao i vijek maziva. Otkazi mašine su smanjeni kao i troškovi opravke. Također, umanjeni su troškovi nabavke maziva i njegovog odlaganja.

### 3. CONCLUSION

Lubrication best practices simply mean selecting the correct lubricant, and then keeping it clean, dry, and cool. In reality, it involves numerous technologies and practices to ensure those ideals are met and will vary depending on the application and the specific issues involved.

Lubrication best practices will maximize machine availability, machine life, and lubricant life. Machine downtime is minimized, as well as unit repair costs and lubricant purchase and disposal costs. Implementing such an approach enhances the value of the oil analysis by improving the signal-to-noise ratio of the information captured in the oil.

In any machine application, the most important aspect for insuring maximum machine and lubricant life is the selection of the correct oil. This process includes choosing the correct base oil, the correct viscosity, and the correct additives for the application. Next in importance is keeping the oil clean and dry. Particle and water contamination can have devastating effects on machine and lubricant life.

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## ***PRIPREMA PROIZVODNJE USKLAĐENA TEHNOLOGIJI PROIZVODA***

**v. prof dr Anton Miloš, dipl ing, Mašinski fakultet Sarajevo, Vilsonovo šetalište 9**

### **REZIME**

Ovo je jedan odgovor na pitanje organiziranja Pripreme proizvodnje u industrijskim malim i srednjim preduzećima za masovnu robnu proizvodnju i za proizvodnju usluga. Polazeći od naučnog razlikovanja tehnoloških karakteristika tehničkih sistema, izvode se specifične karakteristike profila organizacije Pripreme proizvodnje, za svaki od ova dva industrijska sektora.

**Ključne riječi:** Pripremu proizvodnje, organizacija, masovna robna proizvodnja, proizvodnja usluga, tehnologija proizvoda

## ***PRODUCTION ENGINEERING IN ACCORDANCE WITH THE PRODUCT TECHNOLOGY***

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### **SUMMARY**

This is an answer to the question as to how to organize the function of Production Engineering at small and medium enterprises for mass and service industry. Based on scientific distinction of technology characteristic of technique systems, specific characteristics of the organization profile of Production Engineering have been derived for both of the industry sectors.

**Key words:** Production Engineering, organization, mass goods production, service production, product technology

### **1. UVOD**

Glavne odgovornosti za pripremu proizvodnje obuhvataju projektovanje tehnološkog postupka izrade. Struktura odjeljenja za prihvatanje te odgovornosti i način njegovog rada zavise od tipa industrije.

U ovoj studiji se polazi od dosta česte klasifikacije industrijskih proizvođača na slijedeće četiri skupine, po osnovi ciljnog autputa: pojedinačna proizvodnja (brod, dalekovod, rafinerija), masovna robna proizvodnja (žica, podloška), serijska proizvodnja (bicikl, ventilator) i proizvodnja usluga (galvaniziranje, održavanje). U proizvodnji u BH su dominantna mala i srednja preduzeća (MSP) u sektoru uslužne proizvodnje i u sektoru masovne robne proizvodnje. Konkurenčki ciljevi bh preduzeća iz ovih tipova industrije (koja će najčešće biti subsidijari unutar jačih holdinga), kao što su kvalitet autputa, produktivnost, ekonomičnost, rentabilnost i inovativni menadžment tek treba da se dostignu, po globalnom kriterijumu, a oko toga je važna spoznaja da je moguće formulisati neka pravila organiziranja njihove pripreme proizvodnje, koja se apriori moraju poštovati, ako su naučno fundirana.

### **1. INTRODUCTION**

The main accountabilities for Production Engineering (PE) encompass designing of technological procedures of manufacturing. The department structure charged with that responsibility and the way of its doing depend on the type of industry.

This study starts with very often classification of industrial manufacturers in following four groups, based on targeted output: individual production (ship, pipe-line, refinery), large-scale or mass production (wire, washer), line production (bicycle, fan), and production of services (galvanization, maintenance). Production in BH is dominated by small and medium enterprises (SME's) for mass goods and for service industry sectors. The competing objectives of BiH companies around these types of industries (which most often will be subsidiaries within larger holdings), such as quality of output, productivity, economy, profitability and innovative management should be only reached, in accordance with global criteria, and there is an important notion that it is possible to formulate around them certain rules of organizing their PE, which *a priori* must be respected, if they are scientifically founded.

Tako se neće gubiti nepotrebno energija menadžmenta na iznalaženje rješenja za vlastiti, pojedinačni slučaj posebno, a pogotovo će se izbjegći veoma skupe pogreške u tom smislu, koje se u budućnosti vrlo teško, ako ikako, mogu kompenzirati.

Tehnologija determinira organizaciju fabrike [1]. Spolja, konkurenčne organizacije i korisnici proizvoda očekuju da će preduzeće proizvoditi robe ili usluge na nivou savremenih mogućnosti i tako se ponašaju. To je za organizaciju nametnuta okolnost koju mora uračunati. Iznutra, najviše ekonomski, organizacija koristi ili trpi određeni sklop stvarnih sredstava, potrebnih za realizaciju svog ciljnog proizvoda, koristeći taj sklop stvari većim ili manjim umjećem. **Proizvod tehnoški determinira profil organizacije direktno ili kroz uticaj na tehnologiju proizvodnog sistema.**

Stepen tehnoške kompleksnosti i regulisanosti jednog sistema [2] su determinante na kojima počiva ova studija. Pri tome se polazi od činjenice da je kod masovne proizvodnje roba autput tehnoški jednostavan i neregulisan, a kod uslužne proizvodnje je proizvod tehnoški regulisan, ali je jednostavan. Na toj distinkciji sistema, razvijamo organizacionu podlogu Pripreme proizvodnje, za svaki od ova dva industrijska sektora.

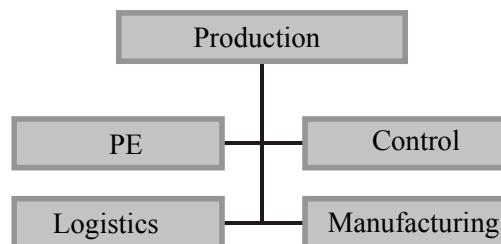
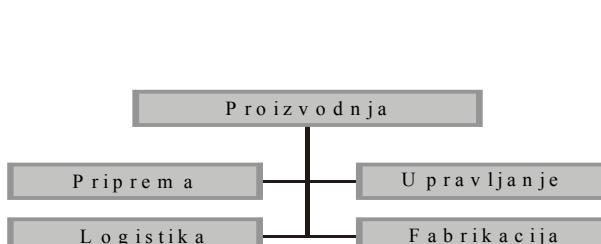
Da bi se popunila proizvodna šema odgovornosti koja obuhvata nabavku inputa, obradu materija i proizvodnju autputa, funkcija proizvodnje treba biti tako struktuirana da se može organizaciono odrediti odgovornost za svaki ključni zadatak [3]. Na slici 1. je pokazan samo najviši nivo razloženosti proizvodnog zadatka, kasnije bi možda trebalo da se ugleda odgovornost za nabavu alata, recimo, kao parcijalni zadatak Nabave ili montaža proizvoda, kao parcijalni zadatak Fabrikacije, itd.

*This is how unnecessary energy of management for finding solutions will not be wasted for own, individual case separately, and especially very costly mistakes will be avoided in this respect, which in future will be difficult, if at all possible, to compensate.*

The organization of the factory is determined by technology [1]. Externally, competing organizations and users of products expect that a company will produce goods and services at the level of contemporary capabilities and this is how they behave. This is for an organization an imposed circumstance which they have to take into account. Internally, for the most part economically, an organization uses or suffers from certain pattern of real means, necessary for realization of its targeted product, using this pattern with greater or lesser accomplishment. The profile of the organization is determined technologically by product, directly or through its influence on the technology of the production system.

The technological complexity and regulation degrees [2] of a system are determinants which this study is based on. Hereby we start from the fact that the output of the mass production of goods is technologically simple and unregulated, and at the service production it is technologically regulated but also is simple. On this distinction of the systems we are developing the organizational base for the production engineering function in both industrial sectors.

In order to fill a production scheme which includes purchase of input, processing of material and production of output, function of production should be structured so that it can organizationally define accountability for each major task [3]. In figure 1. is illustrated only the highest level of the production task breakdown structure; then, may be, it would be seen the responsibilities, for example, as for the purchasing of tools, as a part of the Logistics department job or the Assembly workshop of the product, as a part of the Manufacturing.



Slika 1. Dijelovi proizvodnog zadatka u poslovnom sistemu  
Figure 1. Parts of production task in a business system

Strateško programiranje struktura za proizvodnju traži saradnju organizatora proizvodnje sa konstruktorem, koji daje podatke o kvalitetima proizvoda, i specifičnim kvantitetima uz to, i sa preduzetnikom, koji daje podatke o količinama proizvoda i specifičnim rokovima uz to. Značajan doprinos se очekuje od autora specifičnih proizvodnih metoda; to su najčešće isporučiocici dotične proizvodne opreme (npr. za termičku obradu). U principu, to je idejni projekt fabrike (ili radionice ili radnog mesta), koji rješava slijedeće nivoje proizvodnog ambijenta: Fabrika – lokacija, konfiguracija, komunikacija Radionica – layout, infrastruktura, logistika Radno mjesto-mehanizacija, automatizacija, sigurnost Ovi projekti su podložni stalnim adaptacijama, ali u svakom trenutku moraju odgovarati na glavna pitanja oko:

#### Proizvodne tehnike

Mašina

Alat

Specijalna sredstva

#### Proizvodnog rada (proizvodnog znanja)

Vremenski standardi

Normativi

Analiziraćemo profil tzv elementarnog proizvodnog zadatka da bi lakše prodrli u suštini odgovornosti za pripremu njegovog izvršenja. Baš su standardni zadaci masovne proizvodnje roba i proizvodnje usluga – "elementarni". Problematika pripreme složenijih proizvodnih zadataka se da razložiti na dijelove, koji su istovjetni sa ovdje opisanom problematikom.

Koje su glavne karakteristike profila "elementarnog zadatka"?

Prva stvar jeste izrada jedinica proizvoda u okviru diferenciranih sorti, to je tzv. **sortna izrada**. Veliki broj proizvoda se danas izrađuje po sortama (npr. električni kućanski aparati, postrojenja za grijanje, elektromotori, transmisijske). Antipod takvoj proizvodnji je pojedinačna proizvodnja.

Proektne karakteristike sorte su:

- sličnost po jednostavnoj strukturi i po materijalu,
- različitost po obliku, boji i kvalitetu,

a produkcione:

- sličnost proizvodne tehnologije,
- relativno velike proizvedene količine.

Druga karakteristika profila "elementarnog zadatka" jeste tzv **jednostepena izrada**, koja sadrži kopletno izvršenje dotičnog proizvodnog zadatka. "Stepen izrade" je pojam, koji treba shvatiti što obuhvatnije, obzirom na uključeni pojam nižeg reda - "radni hod". Naime, u planiranju procesa produkcije veliki značaj ima prekid tog produktionog toka, nastao meduskladištenjem stvari, koje su predmet proizvodnje.

Strategic programming of structure requires cooperation of a production organizer with a designer, who is supplying details about quality of products, and specific quantities along with this, and with an entrepreneur, who is supplying details about quantities of products and specific terms along with that. Significant contribution is expected from the authors of specific production methods; mostly those are the providers of production equipment concerned (the heat treatment, for instance). In principle, that is a base design of a plant (or workshop or work-place) solving production ambiance levels, as follows:

Factory – location, configuration, communication

Workshop – lay-out, infrastructure, logistics

Work-place – mechanization, automation, security.

Production projects are submitted to perpetuated adaptation but steadily they are to answer the main questions about:

Production technique

Machines

Tools

Special features

Production work (production skill)

Time standards

Norms of doing

Let us analize so called elementary production task in order to easier penetrate the essence of accountability for preparation of its execution. The standard tasks of mass goods and service production are just – "elementary" ones. Problems of prepartion of complex production tasks can be separated into parts which are identical to the problems described here.

Which ones are the main profile characteristics of an "elementary task"?

The first thing is production of units of product within differentiated sorts, called **sort production**. A great number of products is being produced nowadays by sorts (for example, electrical household appliances, heating equipment, electrical motors, transmissions). An antypode to such production is individual production.

Product characteristics of a sort are:

- similarity by simple structure and by material
- difference in shape, color and quality,

and production ones are:

- similarity by production technology
- relatively high production volume.

The second characteristic profile of "the elementary production task" is so called **single stage production** containing complete execution of a production task in question. "Level of production" is a notion which must be understood more compresensively, taking into account the included notion of a lower order – "working flow". Namely, in planning a poduction process great significance is given to this interruption of production flow, generated by intermdiate storaging of items, which are the subject of production.

Na primjer, otkovke od kojih ćemo skidanjem strugotine, termičkom obradom itd dobiti zupčanik, odlažemo poslije kovanja vrlo često u skladište, to čak provodimo i knjigovodstveno. Ukupni proces izrade zupčanika je dakle višestepen. Taj princip stepenovanja je dobra konvencionalna osnova za razlikovanje pojedinih dijelova izrade. Po tome, jednoseptena izrada jeste ona, kod koje nema međuskladištenja, od prvog do posljednjeg radnog hoda izrade određenog autputa, recimo otkovka. Na primjer, pogon visoke peći i čeličana mogu da se shvate kao (jedinstveni) "metalurški stepen izrade (stepen topljenja, na primjer)", po principu prisilnog toka proizvodnje.

Ovo razlikovanje može biti vezano i za korišteni proizvodni tehnički resurs, npr. mašinu radilicu, ali tada:

- manuelni radni hodovi (npr. u Montaži) se nikako ili samo okolišno uzimaju u obzir,
- kod višekratne upotrebe iste mašine tokom izrade, ovaj princip nema smisla.

Napokon, treća karakteristika jeste tzv **parallelna izrada**. "Paralelna" izrada usvojćemo obuhvata mogućnost alternativnog izvršenja radnih hodova na više mašina. Ta se definicija orijentira prema rasporedu mašina duž toka izrade. Po tome, paralelu, jednoseptenu izradu imamo u slučaju kad input ulazi u sistem izrade na tehničkom proizvodnom resursu A, a odatle izlazi određeni autput, ali i kad se to isto (paralelno) može dešavati i na sistemima, recimo, B i C. Pri tome tehničke strukture A, B i C ne moraju da budu iste, pa ni troškovi izrade ne moraju, zato, da budu isti, ali autput mora da bude isti.

Planiranje procesa proizvodnje se raščlanjuje na:

Tok (proizvodnog) rada

- raščlanjivanje proizvodnog procesa
- program za operaciju
- program za metod

Specifične potrebe

- materijal
- tehnika
- rad

Na osnovu gornjih rješenja je moguće riješiti izvedbeni projekt dotičnog proizvodnog sistema: utvrditi konkretnе mašine, alate, prostore i komunikacije.

Organizovanje rada je sadržaj četvrtog zadatka Pripreme proizvodnje. Peti i šesti zadatak su eminentno ekonomski problemi buduće proizvodnje u dotičnom sistemu, prvi se odnosi na kapital vezan u materijalnoj perspektivi, a drugi na kapital uložen u vremenskoj perspektivi.

For instance, gorgings out of which we shall produce gears by removing shavings and heat treatment, are very often placed in a store after gorging and we do that even through accounting system. Therefore the entire production of gears is multi-level. With this in view, single level production is a production which does not include intermediate storing, from the first to the last working flow of production of a certain output, say forging. For instance, blast furnace and steel works can be understood as (single) "metalurgical level of production (level of melting, for instance)" by the principle of forced flow of production.

This differentiation may be referred to production technical resource used, for example machine tool, but then:

- manual work passes (for instance in Assembly) are not, or only indirectly are, taken into account,
- at the manyfold use of the same machine tool during the process of manufacturing that principle is not reasonable.

Finally, the third characteristic is so called **parallel production**. "Parallel" production includes possibility of alternative performing of working flows at a number of machines. This definition is oriented towards arrangement of machines along the production course. Therefore, we have parallel, single stage production in cases when an output enters a production system at technical production resource A, and a certain output leaves it, but this also can happen (parallel) at the systems, for instance B and C. By doing so, neither technical structures of A, B and C nor production costs must be the same, while the output must be the same.

The planning of the production process is broken down into:

Work flow

- breakdown of production process
- programm for operation
- programm for method

Specific needs

- material
- technique
- work

Based on the above mentioned solutions it is possible to resolve the production system in question: establish concrete machines, tools, space and communications.

The organizing of work is the subject of the fourth PE task.

## 2. ANALIZA

Determinante masovne proizvodnje su:

### a. automatizacija

Odjeljenje pripreme proizvodnje u ovom industrijskom tipu nosi bitnu odgovornost za **simultani inženjering**, organizovan i za rješavanje problematike tehnologije proizvoda i proizvodnje. Ovdje su proizvod i mašina za proizvodnju jedinstveni projekt. Pošto se proizvod izrađuje 24 sata dnevno, produktivnost mora biti maksimalna i projekt alatne maštine mora da bude maksimalno **specijaliziran** za taj proizvod, najviše za **familiju dijelova** koji čine kompleksni tip takvog proizvoda.

Pošto je proizvodnja ovdje tehnološki oslonjena na automaciju, **nije potrebno specijalističko znanje za pojedine vrste obrade materijala**. To specijalističko znanje je organizirano i raspoloživo kroz softver kojim se upravlja mašina radilica.

U smislu "normalne" organizacije Inženjeringu fabrike, u ovoj strukturi Pripreme se nalazi Konstrukcija u stilu **Lean Designa**. To znači da je u ovom odjeljenju principijelno jedan mali broj visoko specijaliziranih inženjera ili tehničara, vrhunskih poznavalaca tehnologije dotičnog proizvoda i sistema za njegovu izradu. Ti ekspertri pripreme su prije svega izvori za **know-how oko tog proizvoda** kako proizvođačima proizvodne opreme za njega tako i korisnicima dotičnog proizvoda.

### b. troškovi

Bitna "strukturalna" odgovornost Pripreme ya tehnologiju proizvoda tiče se **reprematerijala**. On mora biti definisan tako da, osiguravajući kvalitet, vodi minimalnim troškovima i to u smislu **minimiziranja specifične količine materijalnog inputa** po jedinici proizvoda. To je diktat konkurenkcije.

Šta strukturalno determinira organizaciju Pripreme u industriji servisa?

### a. materijalnost outputa

Servis je eminentno nematerijalni output. Odatile izlazi da Inženjering, u najširem smislu, u ovoj industriji **nema velikih odgovornosti za materijalni input**. Jednostavno, **Materijalna priprema**, kao bitan odsjek u standardnoj industrijskoj Pripremi rada, sa svim svojim sofisticiranim alatima za praćenje, analizu, razvoj, programiranje, planiranje i kontrolu materijalnog poslovanja, **ovde nema osobitog značaja**. Čak to vrijedi i za pogosko knjigovodstvo. Ova konstatacija naravno ne važi za doslovno sve servisne industrije, ali da za najveći broj.

Pošto je odgovornost ovog odjeljenja reducirana na tehnologiju proizvodnje i na rokove proizvodnje, a oslobođena materijalne problematike, normalnim se nameće organiziranje mesta u Pripremi kao autonomnih i specijaliziranih po sortama outputa. Dakle, maksimalna okrenutost ka autputima i to u stilu univerzalne kompetentnosti.

## 2. ANALYSIS

The determinants of the mass production structure are:

### a. automation

PE department of such industrial type bears essential accountability for **simultaneous engineering**, organized both for problems related to product technology and production. Here we consider a product and a machine for production as a unified project. Since a product is being manufactured 24 hours a day, productivity must be to its maximum and the project of machine tool must be **specialized** to its maximum for that particular product, mostly for the **family of components** that make complex type of such a product.

Because the production here is supported by automation, the specialized skill about individual kind of treatment of material is not necessary. This specialized skill is organized and disposable through the software by which the machine tools are controlled. In the sense of a "normal" Engineering organization of the factory, there is a Design department in that structure of the production Engineering, styled as a Lean Design. It means that in this department there is a rather small number of high specialized engineers and technicians, top connoisseurs of the technology of the product concerned and of the production system for its production. Those Production Engineering experts are in the first line resources of know-how about that product to the producers of the production equipment and users of the product as well.

### b. costs

Essential "structural" accountability of Preparation for product technology is related to **raw materials**. It must be defined so that, ensuring quality, it leads to minimum costs in sense of **minimizing specific quantities** of material input per product unit. This is a dictate of competition.

What determines the PE organization structurally in service industry?

### a. materiality of output

Service is evidently non-material output. Consequently, Engineering in the widest sense, in this industry **has not got much accountability for material input**. Simply, Material Preparation, as an essential department in standard industrial PE, with all its sophisticated tools for monitoring, analysis, development, programming and control of material business, **has not got here significant meaning**. This even applies to plant accounting. This statement does not literally apply to all service industries, but it does for the majority of them. Since accountability of this department is reduced to production technology and production terms, and it is exempted from material problems, organization of working posts in PE is normally imposed as autonomous and specialized by sorts of outputs. Therefore, maximum orientation towards outputs and this in style of universal competency.

### b. intenzitet odnosa s kupcem

Za mali produžnički biznis, ovaj intenzitet je uvek visok. Za srednju industriju servisa, kao što su infrastrukturni dobavljači (gas, toplina, elektrika, voda, čišćenje, komunikacije), važi obrnuto – intenzitet je mali, skoro nikakav. Mali proizvodni biznis nema formaliziranu Pripremu kao zasebnu, i srednje velike ne proizvode specijalno za poznatog kupca, tako da u oba slučaja struktura Pripreme jeste prilično jednostavna.

Kao zaključak, to znači da će ova mala grupa konstruktora raditi u okviru problematike određenog naloga, s punom svješću o detaljima iz ugovora sa dotičnim kupcem i tako će vršiti funkciju produkt inženjeringu.

Iz gore rečenog izlazi da je odgovornost za rješavanje problema specifičnih i posebnih zahtjeva kupca vezana za operativne inženjere produkcije u supsidijarnom preduzeću. Oni su obavezni da rješavaju sva pitanja vezana za varijante, nastojeći da ostvare te tražene varijante u koliko je moguće kasnijoj fazi produkcije, poželjno bi bilo da se to desi tek u Montaži, a optimalno u fazi isporuke proizvoda sa skladišta gotovih proizvoda i to u maloprodaji. To je naročito tipično kod provajdera tehnoloških usluga, na primjer galvanizacija, kaljenje ili površinska zaštita.

Odatle proizilazi jedan benefit i za holding: na osnovu iskustava oko lokalnih rješenja na licu mjesta, što znači kod SME, subsidijara, Razvoj kod holdinga prima informacije i ideje o pravacu daljeg osvježavanja baznog proizvoda.

Determinante procesa masovne proizvodnje su:

### a. razvijanje materijala

Odgovornost tehnologa u ovom odjeljenju glede materijala je tolika da se otvara jedan novi proces: **razvoj materijala**. Sad je komunikacija Odjeljenja okrenuta ka **Supply Chain Management** u potrazi za dobavljačem ili dobavljačima ili tehnološkim lancem dobavljača koji bi pomogli oko transformacije materijala a sve u smislu održanja kompetentnog **odnosa kvaliteta proizvoda i troškova** njegove proizvodnje. Strateški, odavde proizilazi i poslovna obaveza za **top menadžment** oko sve tješnjeg **povezivanja sa izabranim odličnim dobavljačima**, u smislu podjele poslovnih rizika, poslovnih investicija, razvoja proizvoda i **zajedničkog nastupa** prema trećim: konkurentima, kupcima i institucionalnim investitorima. Operativno, nameću se dva kapitalna procesa u novom stilu. Prvo, **logistika proizvodnje** u stilu Just-in-Time, zatim **inspekcija od strane Fabrike kod dobavljača u radionici na licu mjesta** gdje se dotični materijali proizvode. Vrhunski domet u ovakvoj kooperaciji po svoj prilici treba **da se razvije u fer poslovni odnos** u kome većina stvari ide dogovorom, obećanjem i konvergencijom interesa, a samo iznimno ugovorima, pregovaranjima i garantiranim transakcijama.

### b. Intensity of relationship with customer

For a small production business, that intensity is always high. For medium service industry, as the infrastructure supplier are (gas, energy, water, cleaning, communications), it is opposite – intensity is low, almost not at all. A small production business has not some Engineering department formalized as a separate one, and a medium large company does not produce specially for a certain customer, so both have a rather simple PE structure. As a conclusion, this means that a small group of designers will be working within the frame of problems of certain order, with full awareness about details from the contract with customer in question and by doing this it will be performing the function of product engineering. Consequently, accountability for resolving problems of specific and special request by a customer is linked to operational engineers in production in a subsidiary company. They are obliged to resolve all issues related to options, trying to realize these requested options in possibly later stages of production, and it would be desirable that this happened only at the assembly stage, and it would be optimum in the phase of delivery of product from the store of finished products and possibly in retail. This is especially typical for providers of technological services, for instance electroplating, hardening or surface protecting. This is where a benefit for holding companies derives: based on the experience linked to local solutions on the spot, which means with SME, subsidiaries, Development in holding companies receives information and ideas about the direction of further refreshing a basic product.

The determinants of the mass production process are:

### a. development of material

Accountability of a technologist in this department regarding material is such that a new process is being opened: **development of materials**. Now communication of the Department is directed towards **Supply Chain Management** in search for supplier or suppliers or technological chain of suppliers which could assist in transformation of material aiming at maintaining a competent **ratio of product quality and costs** of its production. From strategic point of view, business commitment for **top management** derives here related to very close **linking with selected exquisite suppliers** in sense of division of business risks, business investments, developing of products and joint appearance towards the third parties: competition, customers, institutional investors. Operationally, two capital processes in new style are being imposed at this point. Firstly, **production logistics** in style Just-in-Time, then **inspection by Factory of supplier in workshop on the spot** where materials in question are produced. The top achievement in such cooperation naturally should **expand into fair business relationship** in which majority of things are being done through agreement, promises and convergence of interests, and only exceptionally, by contracts, negotiations and guaranteed transactions.

### **b. razvijanje proizvodne opreme**

Odgovornost tehnologa za kvalitet projekta alatnih mašina i ostalih alata za proizvodnju vodi ka **razvijanju poslovnih i dobrih odnosa sa proizvođačima dotične opreme**. Tu se očekuje sinergija iz koje će rezultirati konkurentna i profitabilna rješenja. Ako se radi o fabričkim ugradnjama, moderna industrija sve češće bilježi da se proizvođaču opreme prepusti i proizvodnja dotičnog proizvoda, djelimično ili u potpunosti ali to nisu slučajevi iz sektora MSP koji ovdje nas u prvom redu interesira.

Polazeći od notorne činjenice da je kupac važan iznad svega, ovdje se mora naglasiti da postoji izvjesna ravnoteža i ekvivalencija između važnosti kupca i dobavljača za dotičnu fabriku. U ovom tipu industrije, mnogo češće se radi za nepoznatog nego za poznatog kupca. A dobavljač je uvek veoma poznat fabričkim, velikim naporima pronađen i "razvijen", nikad to nije bilo ko, pogotovo ne Trgovina koja isporučuje materijal, opremu i alate iz neimenovanih izvora. Ne mora to da znači da treba razvijati neki posebni Marketing za tržiste nabave ili neku posebo, visoko rangiranu centralnu funkciju Logistike, ali treba praktikovati mnoge tehnike, principi i znanja iz područja marketinga u radu tehnologa Pripreme. Utoliko je saradnja ovog odjeljenja sa odjeljenjem marketinga značajnija.

Komunikacija uspostavljena prometom znanja (know-how) o proizvodu služi fabričkim ugradnjama za izgradnju **dobrih poslovnih odnosa s kupcem**, ali i kao izvor i inspiracija za ideje o razvojnu proizvoda. Interni procesi komunikacije, saradnje i **timskog rada Odjeljenja sa Prodajom** su nezaobilazni. Know-how ne samo da donosi profit, već i doprinosi razvijanju najboljeg imidža fabrike, njenog imena, što u krajnjem vodi na kristaliziranje novog brenda.

Determinante procesa proizvodnje servisa su:

#### **a. ugovoreni rokovi**

U najvećem broju preuzeća iz ove klase **kupac nije spremjan da čeka uslugu** [4]. To je u prirodi stvari ovog autputa i njegove tražnje. To ne znači da Priprema mora da donosi odluke u ritmu prodaje servisa jer su oni najčešće kopije istog, ali ako se kvalitativno hoće dotični pogon diferencirati od konkurenčije, brzo rješavanje problema zadovoljavanja pojedinačnih zahtjeva kupaca postaje nezaobilazno. Kako se to postiže? Angažiranjem kreativnih izvršilaca naloga, sposobnih da dizajniraju uslugu, planiraju troškove i cijene, specifikiraju potrebne materijalne resurse i izvedu produkciju. To je vrlo blisko klasičnom stereotipu - (industrijski) "majstor" (njemački, der Meister).

#### **b. zalihe gotove robe**

Nema zaliha "gotove robe" kod provajdera servisa (npr. voda, telekom). Kao što vremenska determinanta vodi ka brzom odlučivanju inženjera iz Pripreme, tako ova, materijalna, determinanta vodi

ka (brzom) odlučivanju logističara iz Pripreme, u produkciji servisnog tipa.

#### **b. development of production equipment**

Accountability of a technologist for quality of design of machine tools and other production tools leads towards developing business and good relations with manufacturers of the equipment in question. One is expecting here synergy which will yield competitive and profitable solutions. If one is talking about a factory within a concern, modern industry very often registers that manufacturer of equipment is ceded with manufacture of the product in question, partially or fully, but these are not the cases in SME sector which is the subject of our interest in the first place. Starting from notorious fact that a customer is important above all, one has to underline here that there is a certain balance and equivalency between the importance of customer and supplier for the factory in question. In this type of industry, very often one is manufacturing for an unknown rather than a known customer. On the other hand, a supplier is always very well known to a factory, selected and "developed" with great efforts, and it is never just anyone, especially not a Trading business which is delivering material, equipment and tools from unknown sources. It does not necessarily mean that one should develop Marketing for the supply market or some special, highly ranked central function of Logistics, but one should practice many techniques, principles and knowledge in the domain of marketing in performance of technologist in PE. So much more cooperation of this department with marketing department is significant.

Communication established by transfer of know-how about a product is used by a factory for building good business relations with a customer, but also as a source and inspiration for ideas on development of products. The interests of communication processes, cooperation and team work of the Department with Sales Department are unavoidable. Know-how not only yields profits, but is also contributes against developing the best image of a factory, its name, which in the long run leads towards crystallization of a new brand. The determinants of the service production process are:

#### **a. contract terms**

In majority factories of this class a **customer is not ready to wait for the service** [4]. This is the nature of this output and its demand. It does not mean that PE has to make decisions in rhythm of sale of services since they are most often copies of the same, but one want to differentiate qualitatively the production line in question from competition, fast resolving of problems of meeting individual requests by customers becomes unavoidable. How does one achieve this? By engaging creative executors of orders, capable to design a service, plan costs and prices, specify necessary material resources and perform manufacture. This very close to a classical stereotype – (industrial) "master" (German, der Meister).

#### **b. stock of deliverabl goods**

There is no inventories of finished products by service providers (for example, water, telecom). As time determinant leads towards fast decision making by engineers in PE, so does this, material determinant leads to (fast) decision making by logisticians in PE, in manufacturing of service type.

Opet, imamo **naglašen značaj dobavljača**, više nego u ostalim tipovima industrijskih biznisa. Toliko naglašen da se nerjetko pokazuje problematičnijim od značaja kupaca. Uzmimo neku Toplanu; njeni odnosi sa dobavljačima goriva i sa održavaocima njenih tehničkih sistema (rezervni dijelovi i sklopovi) dominiraju svojom problematikom. Havarija zahtijeva brzu reakciju (njenih) tehničara. Nestanak plina zahtijeva brzu reakciju (njenih) logističara.

Zaključujemo da je osnovni procesni kvalitet, tražen od Pripreme i cijenjen od menadžmenta firme, u ovom tipu industrije – brzo operativno odlučivanje o svim fazama produkcije: programiranju, planiranju i izvršavanju.

### 3 ZAKLJUČAK

MSP masovne i uslužne proizvodnje u BH su većinom u nekom poslovnom lancu kao dobavljači, a vezani za svoje provajdere za know-how, alatne mašine i materijale. Tabela pokazuje glavne karakteristike ustrojstva i procesa Pripreme proizvodnje u tim preduzećima, obzirom na taj poslovni kontekst i na tehnologiju proizvoda. Vodeći računa o tehnološkim karakteristikama masovnih robnih autputa, njihova proizvodnja zahtijeva: Lean Design, centralnu podršku proizvodnje, sa naglaskom na problematiku razvoja znanja o materijalu.

<i>Industrija - Industry</i>	<i>Struktura - Structure</i>	<i>Proces – Process</i>
Masovna – Mass	Integrirana – Integrated	Razvijanje - Development
Uslužna - Service	Decentralizirana - Decentralized	Reagiranje - Reaction

Profil masovne proizvodnje karakterizira: Lean Design organizovano "na licu mesta", a ne centralizirano, i autonomne fleksibilne proizvodne grupe sa odgovornošću za pripremu proizvodnje, to jest efikasno i efektivno reagiranje na ugovorene naloge. Tekst je rezultat dugogodišnjeg testiranja prikazane metodologije u praksi Instituta za ekonomiku i organizaciju. Iznešena teza o raspoloživosti prototipa organizacije Pripreme proizvodnje *a priori*, aktualna je pred očekivanu ekspanziju industrijskog sektora MSP u BH, pogotovo onih za masovnu robnu proizvodnju i usluge. Ovaj prikaz može poslužiti i kreatorima nastavnih sadržaja na postdiplomskim studijama za industrijski menadžment. Priroda stvari oko organizovanja predmetne funkcije, kako je ovdje objašnjeno, uveliko bi trebala da bude poznata standardnom industrijskom menadžeru.

### 4. LITERATURA - REFERENCES

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Again, we have an **emphasized importance** of supplier, much more than with other types of industrial businesses. It is so much emphasized that it often proves to be more problematic than the importance of a customer. Let us take a Heating plant; its relations with suppliers of fuel and maintenance personnel of its technical systems (spare parts and assemblies) dominate with their problems. A damage requires fast reaction by (their) technicians. Lack of gas requires fast reaction by its logisticians. We can conclude that the basic process quality, requested from PE and appreciated by the management of the company in this type of industry is – fast operational taking a decision in all phases of production: programming, planning, and executing.

### 3. CONCLUSION

SME's of mass goods and of service production are mostly tied to some business chains, as suppliers who depend on their providers of know-how, machine tools and materials. The table illustrates the main characteristics of the PE structure and process at those enterprises, concerning that business context and product technology. PE profile at mass production is characterized by: Lean Design, central support of production with a stressed development of know-how about material.

To this end, service industry favors: efficient designing of a product, which means organized "on the spot" and centrally, and autonomous flexible production groups with accountability for PE, in other words, efficient and effective reaction to contracted orders.

The text is a result of longtime testing of methodology in practice of the Institute for Economics and Organization. The presented thesis on availability of prototype of an organization for Preparation of production *a priori* is actual in front of the expected expansion of industrial sector. This survey can serve authors of teaching contents at post-graduate studies for industrial management. The nature or organizing of the subject function, as explained here, should be known to a great extent to standard industrial manager.