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Vzdrževanje glede na stanje - uporaba endoskopske metode

Condition Maintenance - Applying an Endoscopic Method

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Vzdrževanje glede na stanja, ki temelji na merjenju in nadzoru parametrov stanja predmetov z uporabo tehničnega razpoznavanja, je osnova vseh sodobnih zasnov vzdrževanja, predvsem dejavnega vzdrževanja. V prispevku sta na splošno prikazana vloga in pomen tehničnega razpoznavanja ter vrste metod in tehnik razpoznavanja. Posebej sta poudarjena pomen in uporaba endoskopa pri razpoznavanju notranjih površin delov motorjev, na primeru ladijskih motorjev. Podani so delni rezultati obsežnega raziskovalnega projekta. Prikazane so uporabljene metode razpoznavanja, značilke inštrumentov in kratek opis njihove uporabe. Posebej so prikazani rezultati merjenj, ki so ponazorjeni s fotografijami opaženih pojavov. Podani sta preglednična in besedna analiza rezultatov. Namen prispevka je opozoriti na veliko potrebo in učinkovitost uporabe prikazanih metod razpoznavanja v postopkih vzdrževanja, ne samo velikih (ladijskih) motorjev temveč tudi drugih strojev, pri katerih razpoznavanje notranjosti predstavlja osnovni podatek za načrtovanje ustreznih dejavnosti vzdrževanja.
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(Ključne besede: vzdrževanje, tehnična diagnostika, endoskopija, parametri stanja)

Maintenance according to a condition based on measuring and controlling the parameters of the object's condition using technical diagnostics represents the basis of all modern concepts of maintenance, and primarily of proactive maintenance. This paper shows the role and significance of technical diagnostics as well as of the various types of diagnostic methods and techniques. The importance and the application of endoscopes, in particular, have been shown in the domain of the diagnostics of the internal surfaces of engine elements in ships' engines. This paper presents research that was performed in the context of a larger research project. It shows applied methods of diagnostics and instrument characteristics and gives a brief description of their use. Furthermore, the results of measurements, illustrated with photographs of the observed phenomena, are shown, followed by an analysis of these results. The aim of this paper is to emphasise the effectiveness of using the described methods of diagnostics in the maintenance processes not only of large ship engines, but also of other engines for which the diagnostics of internal surfaces offers essential information for planning the appropriate maintenance activities.
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(Keywords: condition-based maintenance, technical diagnostics, endoscopes, condition parameters)

0 UVOD

Stanje določenega predmeta, stroja opišemo z določeno množico parametrov (pretok tekočine, debelina stene, hrup, temperatura in druge značilnosti), ki naj bi zadovoljili načrtovano funkcijo cilja v določenih razmerah in v določenem časovnem obdobju [1]. Spremembe parametrov vodijo k spremembi funkcije predmeta, najpogosteje se ta poslabša.

Kakovostna analiza razpoznavnega signala temelji na sedanjem znanju o določenih značilnostih

0 INTRODUCTION

The condition of an object or a machine is described by a specific group of parameters, for example, the thickness of a wall, the noise, the temperature, and other characteristics [1]. All of these parameters should achieve the designed function of a goal under particular conditions in a fixed amount of time. However, changing the parameters leads to a change in the object’s function, which then usually weakens the object’s function.

The qualitative analysis of a diagnostic signal is based on already generated knowledge about in pojavih različnih primerov in stanj. Vzdrževanje glede na stanje temelji na razpoznavanju stanja z uporabo ([2] in [3]):

- časovne slike stanja oz. analize dejavnikov učinkovitosti sistema v odvisnosti od časa,
- nadzora parametrov stanja z uporabo tehničnega razpoznavanja.

Vzdrževanje glede na stanje z nadzorom parametrov pomeni množico pravil za določanje režima diagnostike sestavnih delov sistema v dejanskem postopku uporabe kakor tudi za odločanje o nujnosti zamenjave ali nujnih dejavnosti vzdrževanja na podlagi informacij o dejanskem tehničnem stanju sistema ter njegovih sestavnih delov.

Merjenje parametrov stanja se izvaja z razstavljanjem ali brez njega, oziroma z zaustavitvijo sistema ali brez nje, z uporabo opreme in sredstev za tehnično diagnostiko. Diagnostika stanja naj bi bila zveznega značaja, brez zaustavitve ali razstavljanja sistema.

Napetosti in deformacije, ki se pojavljajo v mehanskih delih sistema, običajno povzročajo neposredne spremembe kinematike, obstojnosti, vibracij, hrupa, temperature in drugih odločilnih pojavov. Poleg tega posredno povzročajo spremembe mazalnih značilnosti, npr. pojav obrabnih delcev kot znamenje povečanega trenja.

Da bi parameter izhodnega postopka lahko postal parameter razpoznavanja, mora zadovoljiti pogoje homogenosti, široko področje uporabe in dostopnost merjenja. Za zahteven sistem se ne da teoretično podati vseh možnih stanj, zato preizkušamo in ugotavljamo verjetnost pojavljanja posameznih stanj, s čimer se omogoča izbira parametrov razpoznavanja v odvisnosti od stanja celotnega sistema ali dela sistema.

Parametri stanja so definirani z ustreznimi signali. Razvrstitev razpoznavnih signalov sloni na: predmetu razpoznavanja, stanju signala, vlogi razpoznavnih signalov in fizikalnih lastnostih. Postopki in pojavi, ki povzročajo odpovedi, so naključne narave, kar ima za posledico: en simptom – eno razpoznavanje, dva simptoma ali več – eno razpoznavanje, en simptom – dve razpoznavanji ali več.

Merjenje parametrov stanja je mogoče z razstavljanjem ali brez njega oz. z zaustavitvijo celotnega sistema ali brez nje, z uporabo posebnih inštrumentov in opreme za tehnično diagnostiko ([4] do [7]).

the specific characteristics and phenomena of various cases and conditions. The condition maintenance is based on the diagnostics of this condition, using the following elements ([2] and [3]):

- Time pictures, either of a condition or analyses of the effectiveness of a system as a function of time,
- Control of condition parameters, using technical diagnostic methods.

Maintenance according to a condition, by controlling the parameters, represents a group of rules for determining a diagnostic regime in a real exploitation process. In addition, it serves the purpose of making decisions about the necessity for a replacement or maintenance activity, based on information about the real technical condition of the system and its parts.

It is important that the measuring of condition parameters happens with or without disassembling the system, which means with or without detaining the system by using the equipment and the facilities for technical diagnostics. Therefore, a tendency exists for the condition diagnostics to always be continuous, without halting or disassembling the system.

Tensions and deformities appearing in the mechanical segments of the system usually cause a direct change in cinematic forms, resistance, vibrations, noise, temperature and in other crucial phenomena. Furthermore, they indirectly cause changes in lubricant characteristics, such as the appearance of particles as a sign of friction.

In order for the parameter of an output process to become a diagnostic parameter, it must fulfil the conditions of homogeneousness, broad use and measurement attainability. It is not possible to number all the conditions of a complex system; it is therefore useful to examine, investigate and determine the probability of some of them appearing. This makes the selection of diagnostic parameters possible in the function of the whole or a part of the system condition.

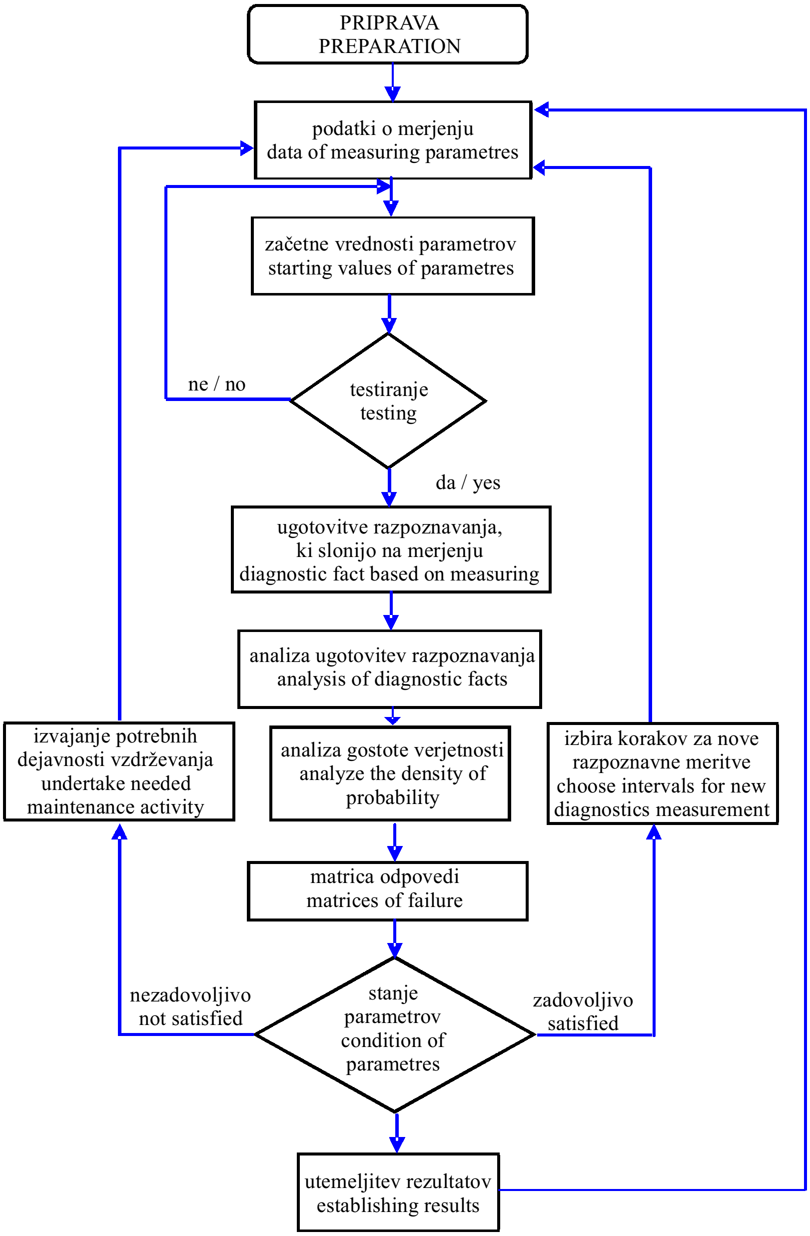
The condition parameters are defined by appropriate signals. The categorisation of diagnostic signals is conducted according to the following: the subject of the diagnosis, the signal status, the role of diagnostic signals and the physical characteristics. The processes and occurrences that cause failures have a stochastic character. This means, therefore: one symptom – one diagnosis, two or more symptoms – one diagnosis, one symptom – two or more diagnoses.

The measuring of condition parameters could be done with or without stopping the whole system, using special instruments and equipment for technical diagnostics ([4] to [7]).

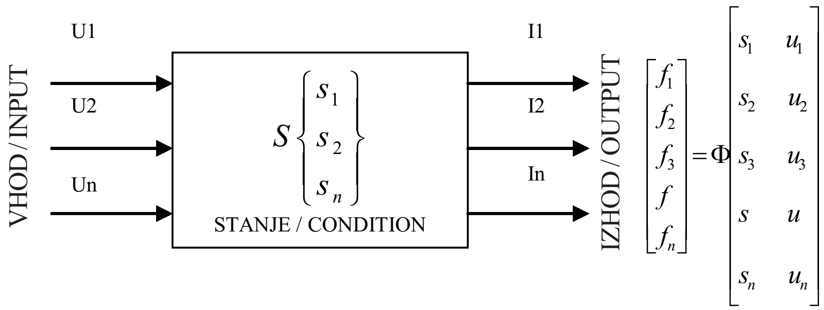
Osrednja naloga razpoznavanja je odkriti številne povezave med strukturnimi elementi U_1, U_2, ... U_n in ustreznimi razpoznavnimi parametri S_1, S_2, ... S_n, z uporabo diagnostične matrike [3]:

The main task of a given diagnosis is to discover many relations between the entities U_1, U_2, ... U_n and the diagnostic parameters S_1, S_2, ... S_n, using a diagnostics matrix [3]:

	U_1	U_2	U_3	U_4	U_5
S_1	0	0	1	0	0
S_2	1	1	0	1	1
S_3	0	0	0	0	0
S_4	0	1	1	0	1
S_5	0	1	0	0	0



Sl.1. *Algoritem za razpoznavanje parametrov stanja*
Fig.1. *Algorithm of diagnostic parameters' condition*



Sl. 2. *Razpoznavna povezovalna shema*
Fig. 2. *Diagnostic block scheme*

Presečišče vrstice in stolpca označuje možnost pojava odpovedi.

Odvisnost med strukturnimi in razpoznavnimi parametri se določa z algoritmom na sliki 1 [3].

V splošnem se postopek razpoznavanja lahko prikaže tudi v obliki povezovalnega diagrama (sl. 2), pri čemer so: $\vec{U}$ - vektor pogojev diagnostike, $\vec{S}$ - vektor stanja predmeta, $\vec{I}$ - vektor diagnostičnih signalov.

The cross point of the horizontal and vertical column means the possibility of failure exists.

The dependence between the structural and the diagnostic parameters is based on an algorithm (Fig. 1) [3].

The process of diagnostics can be shown using scheme (Fig. 2). Where are: $\vec{U}$ - vector of diagnostic condition, $\vec{S}$ - vector of object condition, $\vec{I}$ - vector of diagnostic signals.

0.1 Meje diagnostičnih parametrov stanja

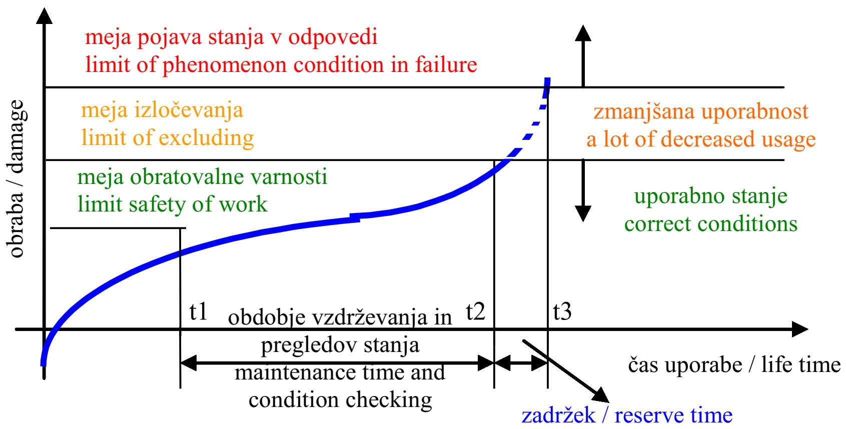
Določiti je treba meje parametrov za razpoznavanje, da bi s tem dosegli boljše rezultate pri oceni stanja. Podana sta dva načina za oceno stanja:

- ocena zmožnosti sistema za načrtovano funkcijo – izmenjujoča ocena ter
- predvidevanje obnašanja sistema pri nadaljnji uporabi. V tem primeru so parametri stanja opazovani v določenem časovnem obdobju uporabe pred pričakovano odpovedjo sistema.

0.1 Limits of diagnostic parameters' conditions

It is necessary to define the limits of the parameters for diagnostics for better results and an evaluation of the condition. There are two principles in the condition evaluation:

- The evaluation of the system's capability for the goals' function – alternative evaluation,
- The prediction of system behaviour during further use. In this case the condition parameters are observed in a specific period of usage until the expected problem or failure.



Sl. 3. *Krivulja obrabe*
Fig. 3. *Worn-out curve*

V obeh primerih je treba določiti mejne vrednosti parametrov stanja. V razpoznavanju v strojništvu so posebej zanimive mejne vrednosti, ki so povezane z obrabo, utrujanjem materiala, jamičenjem, spremembami temperature, hrupom, vibracijami itn. V vsakem primeru se pojavi določena obraba, zato se tudi krivulja, ki kaže stanje sistema imenuje krivulja obrabe (sl. 3) [3].

Merila za določanje mej so:

- tehnični in tehnološki,
- ekonomski (stroški ukrepov, finančno tveganje ipd.),
- varnostni (možne posledice napak),
- ergonomski (vpliv hrupa in vibracij ipd.).

Po navadi upoštevamo več meril za oceno mej, ki se določijo na temelju izkustvenih ali eksperimentalnih raziskav.

In any case it is very important to define the limits of the condition parameters. The limits connected to wearing out, pitting and changes of temperature, vibration etc., are very interesting for mechanical diagnostics. It is a question of wearing out, so the curve that shows the system condition is called the wearing-out curve (Fig. 3) [3].

The criteria for defining the limits are:

- Technical and technological
- Economic (costs of interventions, financial risk, etc.)
- Safety (possible consequences of failure)
- Ergonomic (influence of loudness and vibration, etc.)

Usually, it is necessary to take more criteria for the evaluation, which are determined on the basis of experience and an experimental investigation.

0.2 Napoved preostalega časa uporabe

Na podlagi poznavanja povprečne obratovalne dobe strojev in naprav, kakor tudi doseženih vrednosti parametrov stanja, je mogoče z uporabo napovedati obnašanje parametrov pri nadaljnji uporabi. Ena od metod za napovedovanje sloni na povprečni statistični vrednosti poškodb. Ta metoda se uporablja, ko ni znano, ali je premalo poznan posamezni potek poškodbe izbranega elementa ali sistema. Napoved temelji na trenutni izmerjeni vrednosti stanja (sl. 4).

Točko tk določimo po obrazcu:

0.2 Prognoses for the period of usage

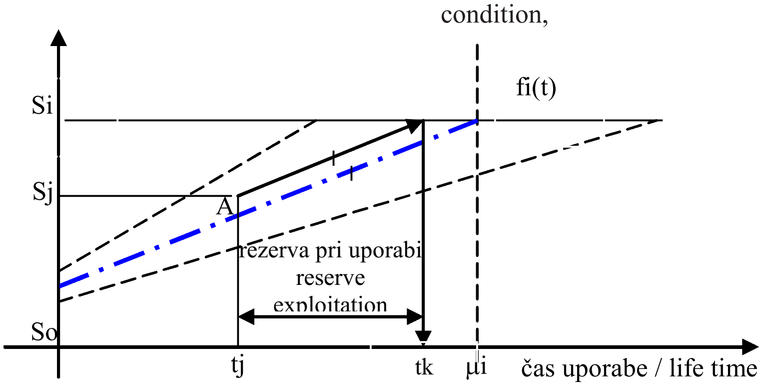
Knowing the average lifetimes of machines and equipment usage, as well as the values of condition parameters, it is possible to predict the behaviour of the parameters' usage. One of the prediction methods is based on the middle statistics values of damages. This method is in use when it is not known, or not sufficiently well known, whether there is a single development of damage on a concrete element or on the system. The prediction is based on the measured condition value at that moment (Fig. 4).

The point is defined by the formula:

$$t_k = \frac{S_1 - S_j}{S_i - S_o} \cdot \mu_i \quad (1),$$

So – začetna vrednost opazovanega parametra,
Si – mejna vrednost opazovanega parametra,
Sj – izmerjena vrednost opazovanega parametra stanja,

So – the starting value of the observed parameter,
Si – the limited value of the observed parameter,
Sj - the measured value of the observed parameter condition,



Sl. 4. *Napoved z metodo povprečne statistične vrednosti*
Fig. 4. *Prediction using the method of the middle statistical value*

μ – mejna vrednost obstojnosti elementa,
(*tk-tj*) možen prihranek pri uporabi opazovanega elementa.

1 RAZLIČNE VRSTE IN TEHNIKE TEHNIČNEGA RAZPOZNAVANJA

Tehnično razpoznavanje lahko opazujemo z različnih vidikov, odvisno od namena, rezultatov, načina izvedbe, značilnosti, uporabe in obsega (sl. 5).

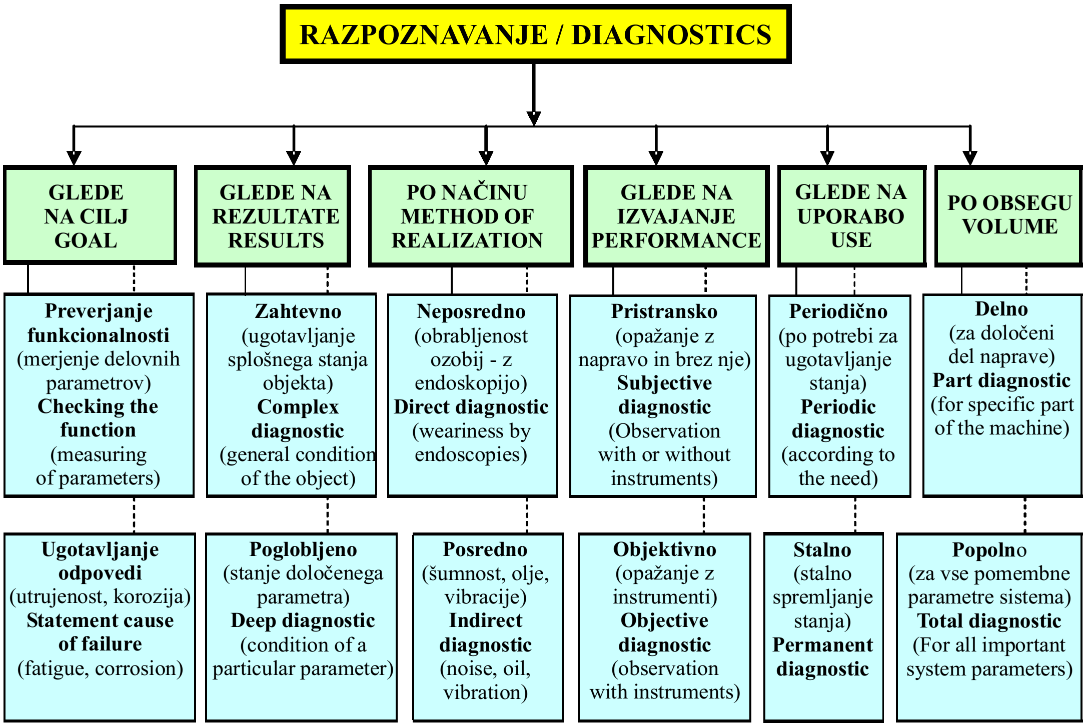
- **Preverjanje funkcije** predstavlja razpoznavanje z namenom ugotavljanja funkcionalnosti opreme. Izvaja se z merjenjem delovnih parametrov (npr. tlaka, napetosti, števila vrtljajev) med delovnim postopkom.
- **Določanje odpovedi** predstavlja razpoznavanje, katerega osnovni namen je oceniti stanje pri odpovedi oziroma vzroke tega stanja (merjenje obrabljenosti, korozije, poškodb materiala ipd.) ([3] in [5] do [7]).
- **Zahtevno razpoznavanje** uporabljamo za ugotavljanje splošnega stanja naprave. Obsega spremljanje parametrov stanja, to so kakovost delovanja motorja, moč motorja, pa tudi tlak kompresorja.
- **Poglobljeno razpoznavanje** je, v nasprotju z zahtevno, namenjena za določanje stanja celotnega motorja ali njegovih delov, izvaja pa se z podrobnim raziskovanjem določenih parametrov.
- **Neposredno razpoznavanje** se izvaja z neposrednim merjenjem in analizo določenega parametra stanja. Posredno razpoznavanje pomeni merjenje posrednih veličin za določanje stanja naprave (npr. merjenje hrupa ali vibracij za oceno stanja prenosnikov, ležajev).
- **Pristransko razpoznavanje** se izvaja skozi oceno na podlagi opazovanj stanja. Opazovanja temeljijo na človeških čutilih: vidu, sluhu, vonju ali dotiku. Pri tem se lahko dodatno uporablja specifična oprema (tehnični stetoskop ali endoskop).
- **Nepristransko razpoznavanje** se izvaja z uporabo opreme in merilnih instrumentov, ki kažejo vrednost parametrov. S tem se izključuje pristranskost operaterja (npr. število vrtljajev, tlak, vibracije, hrup ali temperature).
- **Periodično in stalno razpoznavanje** se uporabljata odvisno od potrebe po določitvi

μ – the value limit of the life time,
(*tk-tj*) the possible reserve of the observed element usage

1 DIFFERENT TYPES AND TECHNIQUES OF TECHNICAL DIAGNOSTICS

Technical diagnostics can be seen from several aspects, depending on the goal, the results, the manner of realisation, the performance, the use and the dimensions (Fig. 5).

- An **examination of the function** represents a diagnosis for the purpose of determining the functionality of the equipment. The examination can be done by measuring the functional parameters, for example, the pressure, the tension and the number of turns during the working process.
- A **determination of failure** represents a diagnosis with the goal to examine the condition during failure or the cause of such a condition (measuring the wear, the corrosion, the damages to a material, etc.) ([3] and [5] to [7]).
- **Complex diagnostics** is used to establish the general condition of the equipment. It includes observing the condition parameters, such as the quality of an engine's work, the power of the engine as well as the pressure of the compressor.
- **Deeper diagnostics**, as opposed to complex diagnostics, serves to determine the condition of the whole machine or a part of the machine. This can be done with a detailed investigation of certain parameters.
- A **direct diagnosis** is performed by direct measurements and an analysis of a certain parameter of a condition. Indirect diagnostics means determining the indirect measures for establishing the equipment's condition (for example, measuring the noise or vibration to determine the condition of the transmission).
- **Subjective diagnostics** could be completed by an evaluation on the basis of the observations of a condition. The observations are performed with the human senses: eyesight, hearing, smell or touch. In addition, certain specific equipment can also be used (a technical stethoscope or an endoscope).
- **Objective diagnostics** is performed by using equipment as well as measuring instruments, which show the conditions of the parameters. In this way the subjectivity of the personnel that use the instruments is excluded (for example, the number of turns, the pressure, the vibrations, the noise or the temperature).
- **Periodic and permanent diagnostics** can be completed, depending on the need for determining



Sl. 5. *Delitev tehničnega razpoznavanja*
Fig. 5. *Division of the technical diagnostic*

stanja naprave (potrebna raven zanesljivosti opreme v funkciji njene uporabe). Delna diagnoza se nanaša na določitev stanja posameznega dela ali enega parametra.

- **Popolno razpoznavanje** se uporablja za celovito oceno vseh pomembnih parametrov stanja naprave. Nepristranski postopki v tehničnem razpoznavanju se izvajajo z inštrumenti za merjenje in prebiranje vrednosti parametrov in s tem izključimo pristranskost sklepov operaterja. Nepristranski tehnični postopki obsegajo tri skupine parametrov:
  - delovni parametri,
  - parametri poškodb elementov naprave,
  - parametri stanja stranskih produktov.

1.1 Endoskopska metoda tehničnega razpoznavanja naprav

V tehniki se vse bolj in bolj uporabljajo optična vlakna za opazovanje težko dostopnih delov (običajno so to različne votle oblike in odprtine) ali v primerih ko druge tehnike vidnega nadzora terjajo zelo drago razgradnjo. Poleg področja razpoznavanja in nadzora je uporaba optičnih vlaken dandanes pomembna tudi pri

the equipment's condition (the required level of reliability of the equipment during its use). Partial diagnostics refers to a determination of the condition of a particular element or a single parameter.

- **Total diagnostics** is performed for a total evaluation of the conditions of all the important parameters of the equipment conditions at hand. The objective acts in technical diagnostics are performed with instruments that measure and read out the parameter conditions, which in turn excludes subjective conclusions. Objective diagnostic acts embody three groups of condition parameters:
  - The working parameters,
  - The parameters of equipment-element damages,
  - The parameters of by-product condition.

1.1 The endoscope method for the technical diagnostics of equipment

The use of optical fibres is becoming commonplace in technical fields, for example, in the process of observing parts that are difficult to access (usually different kinds of cavities and holes) and in those cases where other techniques of visual control necessitate a very expensive disassembly process. The use of optical fibres is not only important in postopku vzdrževanja oz. pri popravilu strojev brez nepotrebnih razstavljanj, kar naredi sam postopek bistveno bolj gospodaren.

Prvi endoskopi (s tem razumemo vse naprave za opazovanje v zaprtem prostoru) so bili oblikovani za medicinske namene. Beseda “endoskop” je grškega izvora in dobesedno pomeni “pogled od znotraj”. Izrazita uporaba endoskopa se je začela z iznajdbo cistoskopa, na katerem je bil zasnovan nadaljnji razvoj moderne urologije. Zatem so bile razvite naprave imenovane “boroskopi”, ki predstavljajo povezani sistem leč, opremljen s svetilko. Pri modernih videoendoskopih je omogočeno neposredno usmerjanje in snemanje opazovanega predmeta z uporabo računalniškega sistema. Dejavna uporaba elektronike je bistveno razširila področje uporabe vidnega nadzora in videosnemanja.

V večini primerov se postopki tehničnega razpoznavanja in nadzora izvajajo pri slabi osvetlitvi ali pri dnevni svetlobi. Takšne razmere še posebej niso primerne za izvajanje resnega vidnega nadzora, ker človeško oko, zaradi preslabe osvetlitve, ne more optimalno sodelovati v tem postopku, tudi če uporabimo najboljše optične inštrumente.

Človeško oko ima sposobnost učinkovitega prilagajanja različni stopnji osvetlitve. Osrednjo vlogo pri tem ima zenica, ki se lahko zoža ali razširi, odvisno od jakosti svetlobe. To omogoča, da gledamo v zelo močne izvore svetlobe pa tudi, da vidimo pri zelo šibki svetlobi ali v temi. Potreben je samo kratek čas, da se oko prilagodi na trenutno stanje ali spremembo svetlobe. Očesu je potrebno 10 do 15 minut za popolno prilagoditev pri zmerni spremembi svetlobe ter okoli 30 minut za prilagoditev na popolno temo. To je razlog, zakaj je pri delu z endoskopom treba biti pozoren na to človeško lastnost.

Drugi pomemben dejavnik, ki vpliva na delo z optičnimi sredstvi, je dnevna svetloba. Ta postavlja različne omejitve pri delu, odvisno od sredstev, ki se uporabljajo.

Prožne endoskope z optičnimi vlakni (fiberscope) uporabljamo v primerih, ko razdalja do predmeta ne presega 0,5 m.

1.2 Moderni boroskopi

Togi boroskopi (sl. 6a in b) imajo v primerjavi s fiberskopom zelo preprost optični sistem leč. Pri

the fields of diagnostics and control, but their application is currently of great significance in the process of maintenance, for example, for the repair of machines that can be completed without disassembling them, which in turn makes this process far more economical.

The first endoscopes - the meaning of this term being all equipment used for the purpose of observation in a closed space - were designed for medical purposes. The word “endoscope” has a Greek root and it can be translated as “examination from the inside”. The intensive exploitation of endoscopes began with the invention of a cistoscope that set the path for the development of modern urology. Following this, the so-called boroscope was made, i.e., a system of lenses equipped with a lamp. Modern endoscopes make the direct steering and recording of an observed object possible with the use of a computer system. The widespread use of electronics has significantly broadened the fields of application of visual control and video recording.

In most cases the processes of technical diagnostics and control are performed under poor lighting conditions or during daylight. However, these conditions are not suitable for performing serious visual control, due to the fact that the human eye cannot optimally assist us in this process under poor lighting conditions, even if it possesses the best optical instrument.

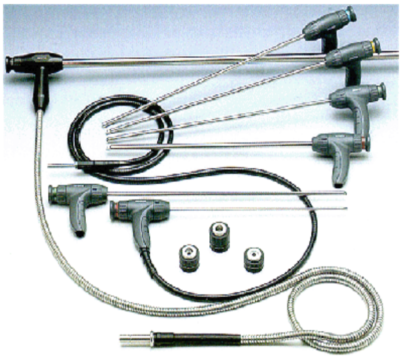
The human eye has the ability to adapt to various light intensities using the pupil, which can either dilate or contract, depending on the intensity of the light. This enables us to look at very bright light sources, but also to see under very poor lighting conditions, and even in the dark. Only a certain amount of time is needed for an eye to be able to adjust to present or changing lighting conditions. The human eye needs 10–15 minutes for a total adaptation during a modest change in lighting, and around 30 minutes for an adaptation to total darkness. This is the reason why when using an endoscope one has to take the possibilities of human sight into consideration.

The second important factor that influences work with optical equipment is daylight. This sets various limitations during the work, depending on the facilities being used.

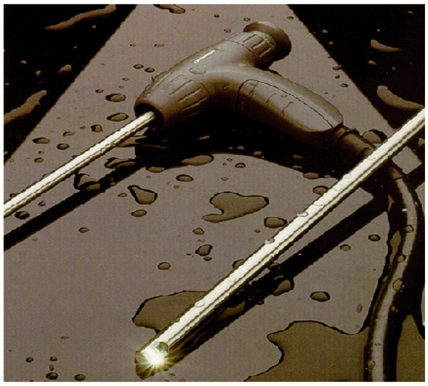
Flexible endoscopes with optical fibres (fiberscope) are used in cases when the distance to the object does not exceed 0.5 m.

1.2 Modern boroscope

Inflexible (stiff) boroscopes (Fig. 6 a, b) have a very simple optical system of lenses compared to that of



a)



b)

Sl. 6. *Boroskop (a), uporaba boroskopa v nasilnem okolju (b)*
Fig. 6. *Boroscope (a), the use of a boroscope in an aggressive environment (b)*

boroskopu je slika zelo jasna. Ker se pri boroskopih ne uporablja koherentni snop optičnih vlaken, so ti nekajkrat cenejši od fiberskopa. Trdna konstrukcija in možnost krmiljenja dolžine, premera, kota in vidnega polja, kakor tudi preprostost uporabe, so naredili boroskop za zelo razširjeno sredstvo vidnega nadzora.

Zaradi trdne konstrukcije je tudi vzdrževanje boroskopov preprosto, kljub temu da so pri uporabi izpostavljeni različnim oblikam nečistoč. Pomembno je, da se po uporabi temeljito obrišejo. Boroskope lahko uporabljamo do temperatur 150 °C ([1] in [8]).

1.3 Fiberskop

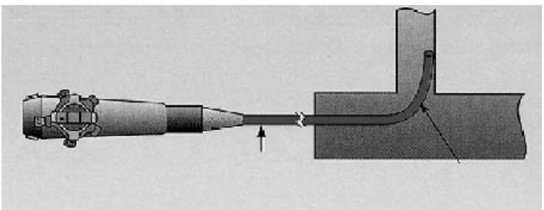
Najbolj pomembna značilka fiberskopa je njegova prožnost (sl. 7 in 8), kar omogoča upogibanje brez škodljivega vpliva na sliko, ki jo prenaša. Fiberskop ima dva vira svetlobe, dve optični vlakni, prevodnika za objektiv in okular. Prevodniki svetlobe

the fiberscope. In the case of boroscopes the picture is very clear. Since the boroscopes do not use coherent sheaths of optical fibres, they are several times cheaper then fiberscopes. The firmness of its construction and the possibility of regulating its length, diameter, angle and visual field as well as its simple usage, make the boroscope a widespread tool for visual control.

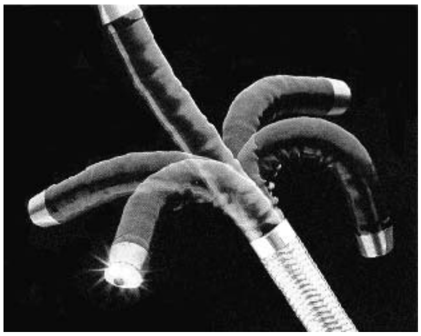
Boroscopes are easy to maintain due to their firm construction, even after exposing them to dirty conditions. It is important to clean a boroscope very carefully after its use. In addition, a boroscope can be used in high temperatures up to 150ºC ([1] and [8]).

1.3 Fiberscope

The main characteristic of a fiberscope is its flexibility (Figs. 7 and 8); however, it is noteworthy that its ability to bend does not have consequences for the quality of the picture that it processes. The fiberscope has two sources of light, i.e., two fibre light conductors – a lens



Sl. 7. *Ponazoritev prožnosti fiberskopa*
Fig. 7. *Illustration of a fiberscope's flexibility*



Sl. 8. *Možnosti pregleda (ocenjevanja) z vrhom (konico) fiberskopa*
Fig. 8. *Steering possibilities with the tip of the fiberscope*

za prenos slike sestoje iz približno 120.000 vlaken, premera 0,009 do 0,017 mm. Slika nastaja na visoko poliranih čelih obeh koncev svetlobnih prevodnikov za prenos slike ([1] in [8]).

Konci fiberskopa se lahko upogibajo, kar omogoča ne samo neposredni temveč tudi bočni pogled (sl. 7 in 8). Minimalni premer fiberskopa je 2 mm. Lahko ga priklopimo na TV zaslon ali monitor računalnika.

2 ENDOSKOPSKO RAZPOZNAVANJE VALJA MOTORJA

Pomen tehničnega razpoznavanja kot osnove strategije vzdrževanja glede na stanje je ponazorjen na primeru uporabe endoskopije pri vzdrževanju motorja – ugotavljanje stanja čela bata, ventila ali valja brez razstavljanja motorja. Razpoznavanje je izvedeno na ladijskih motorjih za posebne namene, pri čemer so za ta postopek pomembni številni elementi: izbrana metodologija, priprava, izbira inštrumentov, izbira mesta za izvajanje razpoznavanja, načrtovanje, prikaz rezultatov razpoznavanja, ponazorjen z endoskopskimi fotografijami ali preglednicami z opisom. Ladijski motorji, ki so predmet raziskovanja, so vgrajeni v ladje za posebne namene, zato njihove značilke v tem prispevku niso podane. Poglavitni namen prispevka je splošni prikaz primera endoskopskega razpoznavanja.

2.1 Metodologija razpoznavanja ladijskega motorja

Zanesljivo zaznavanje vzroka za prisotnost hladilne emulzije v valjih motorja ni bila mogoča brez uporabe endoskopa. Namen je bil izogniti se razstavitvi motorja z nosil, kar bi bistveno znižalo stroške popravila motorja. Pred pričetkom celotnega postopka je potrebno segreti hladilno emulzijo na 60 °C z vključitvijo obtočne črpalke za hladilno emulzijo motorja. Po 4 urah segrevanja motorja je opravljen endoskopski pregled z namenom odkriti mesto, kjer hladilna emulzija vdira v valje motorja. Da bi uspešno izvedli endoskopsko razpoznavanje je treba razdelati metodologijo za izvajanje endoskopskega nadzora. Metodologija diagnostike ladijskega motorja, kot tehnična procedura, sestoji iz naslednjih operacij ([4] in [8]):

- definiranje mesta pregleda motorja (sklopi, podsklopi, elementi, oprema motorja) na podlagi dostopne dokumentacije in pregleda motorja;

and an ocular conductor. These light conductors, whose function is the transmission of the picture, are composed of nearly 120,000 fibres, with a diameter of 0.009–0.017 mm. The picture is formed on the highly polished heads of both light conductors that transmit the picture ([1] and [8]).

The fiberscope tips are flexible, which makes a lateral view also possible (Figs. 6 and 7). The minimum diameter of a fiberscope is 2 mm. Furthermore, a fiberscope can be connected to a TV screen or a computer monitor.

2 THE ENDOSCOPIC DIAGNOSTICS OF AN ENGINE CYLINDER

The significance of technical diagnostics as a basic strategy in condition maintenance is illustrated by the use of an endoscope for the maintenance of an engine – defining the condition of a piston, valve or a cylinder without disassembly. The diagnosis was made on a ship's engine with a special assignment. There are many elements that are important for this process: the type of methodology, the preparation, the defining of the instruments, the places chosen for the diagnostic process, the planning, and the results, which are illustrated by photos or tables with a description. The ship's engine is used in special boats and its characteristics are not presented in this paper. The goal of this paper is to show examples of endoscope diagnostics in general.

2.1 Methodology of the diagnostics of a ship's engine

A reliable breakdown of the cause of the presence of a cooling emulsion in cylinders was not possible without using an endoscope. The main goal is to avoid removing the engine from its carrier, which would significantly lower the costs of repairing the engine. Prior to starting the whole procedure, it is necessary to warm up the emulsion to 60°C using a circular pump for the cooling emulsion of the engine. After four hours of warming up the engine, the endoscope examination is performed with the aim of discovering the place where the emulsion is leaking into cylinders. In order to implement the endoscope diagnostics, it is important to elaborate on the methodology for endoscope control. The methodology of the diagnostics of a ship's engine, as a technological procedure, consists of the following operations ([4] and [8]):

- Defining the place for the engine's examination (compositions, sub-compositions, elements, engine equipment) on the basis of the available documentation and an overview of the engine.

- zagotovitev dostopa endoskopske opreme na mesto, ki bo nadzorovano (skozi sedanje odprtine ali skozi na novo izdelane odprtine, upoštevajoč, da na novo izdelane odprtine ne oslabijo konstrukcije in ne motijo delovanja motorja);
- izbira najbolj ustrezne opreme in osebja za izvedbo endoskopskega nadzora;
- določanje časovnih korakov za pregled motorja;
- definiranje potrebne dokumentacije za podporo;
- analiziranje sedanjega stanja in sklepanje o tehničnem stanju dieselskega ladijskega motorja.

Priprava ladijskega motorja za endoskopski pregled vključuje množico dejavnosti, ki naj bi zagotovile dobre pogoje za nemoteno in zanesljivo izvajanje nadzora. Med temi pripravami je treba:

- zagotoviti želene razmere okolja (temperatura, tlak, vlažnost);
- pregledati tiste dele, ki bodo nadzorovani (da ne bo tujih predmetov, nesnage, iztekanja olja, goriva, hladilne emulzije);
- zagotoviti želeno stanje motorja (motor ne sme delovati, temperatura olja in hladilne emulzije pa na ustrezni ravni);
- pripraviti potrebno orodje.

Po končanih pripravah za endoskopski pregled motorja je treba določiti nadzorna mesta in poiskati najbolj ugodne poti za dostop z endoskopom. Na podlagi sklepov, ki sledijo iz analize mogočih dostopov k nadzornim mestom, se odpirajo tiste odprtine na motorju, ki so najbolj primerne za izvajanje pregleda. Izbira orodij in opreme je odvisna od: izbranih mest za preglede, konstrukcijskih rešitev odprtin za preglede in pogojev, pri katerih se bo izvajal pregled. Nadzorniki, ki izvajajo preglede morajo biti dobro seznanjeni z endoskopsko opremo (z načelom delovanja in uporabe v danih razmerah), kakor tudi s konstrukcijo in značilkami ladijskih motorjev, ki jih pregledujejo.

Zadnji korak postopka, definiranega z metodologijo pregleda ladijskega motorja, je sklepanje oz. ocena tehničnega stanja ladijskega motorja kot celotnega sistema, kakor tudi ocene stanja posameznih delov (podsklopov). Iz dobljenih rezultatov sklepamo o nadaljnji uporabi motorja oz. o potrebnem vzdrževanju, ki ga je treba izvesti takoj ali v bližnji prihodnosti.

- Ensuring access for the endoscope equipment to the places that are controlled (through already-existing openings or through boring new openings, but taking into consideration that those new openings do not jeopardise the construction and disturb the work of the engine).
- Choosing the most convenient equipment and staff that will perform the endoscope control.
- Determining the time intervals for examining the engine.
- Defining the supporting documentation.
- Analysing the present condition and making conclusions about the technical condition of the ship's diesel engine

Preparing the ship's engine for endoscope examination includes a series of activities that should provide good conditions for an undisturbed and a reliable control process. During this preparation it is necessary to:

- Provide the required environmental conditions (temperature, pressure, humidity),
- Examine those parts that will be controlled (for example, for the presence of foreign objects, dirt, oil, petrol or cooling-emulsion leakage),
- Provide the needed conditions for the engine (the engine must not be turned on and the temperature of oil and that of the cooling emulsion should be at the required level),
- Prepare the required tools.

After the preparations for the endoscope examination of the engine, it is important to determine the control places and find the best possible way for the endoscope to access them. On the basis of the conclusions drawn in the process of analysing the possible routes for accessing the control place for the examination, those openings that are the most convenient for performing the examination are selected for opening. The selection of tools depends on the following: the chosen places for the examination, the constructed solutions about openings for the examination and the conditions for performing it. The staff that performs the examination must be familiar with the endoscope equipment (principles of work and usage), as well as the construction and characteristics of the ship's engine that is being examined.

The last step in the process, defined by the examination methodology of the ship's engine, is drawing the conclusion and evaluating the technical condition of this ship's engine as an entire system as well as evaluating the technical condition of its parts. Based on the results a conclusion can be made about further exploitation of the engine as well as the necessary maintenance that should be performed either immediately or in the near future.

Preglednica 1. *Oprema za endoskopsko diagnostiko*
Table 1. *Equipment for endoscope diagnostics*

Vrsta endoskopske opreme **Type of endoscope equipment**	**Oznaka endoskopske opreme** **The mark of endoscope equipment**	**Premer endoskopa** **Diameter of endoscope**	**Smer opazovanja** **Direction of oversee**
vlaknoskop fiberscope	IF6C5X1-13	6,0 mm	neposredno - v vseh smereh directly – in all directions
video-endoskop video-endoscope	IV6C5	6,0 mm	neposredno - v vseh smereh directly – in all directions
video stekla video glasses	LCD stekla LCD glasses	-	-
vir svetlobe the source of light	ILV-2	-	-
boroskop boroscope	R060-063-000-50	6,0 mm	neposredno directly
boroskop boroscope	R060-063-090-50	6,0 mm	s strani laterally
računalniški zaslon computer monitor	14"	-	-
sistemski analizator system analyzer	IW-2 z opremo IW-2 with equipment	-	-

2.2 Definiranje opreme za endoskopsko razpoznavanje

Oprema, opisana v preglednici 1 se uporablja za endoskopsko razpoznavanje.

2.3 Definiranje merilnega mesta za endoskopsko razpoznavanje

Na sliki 9 je prikazan prečni prerez ladijskega motorja – predmeta raziskovanja – z nakazanim mestom vstavitve endoskopske opreme (boroskopa in vlaknoskopa) v valj motorja. Na vsakem valju je opravljeno opazovanje na definiranih mernih mestih, in to:

- čelo bata,
- puša valja,
- stična ploskev med valjem in pokrovom,
- sesalni in izpušni ventili s sedeži,
- sedež ventila,
- vodilo ventila.

Načrt endoskopskega pregleda batov in valjev, kompresorja in hladilnih naprav z merilnimi mesti ter mogočimi poškodbami je podan v preglednici 2. Ta program endoskopskega razpoznavanja, s predhodno opisano metodologijo, se lahko uporabi za ladijske motorje, ki so običajno v uporabi. Preglednica 2 prikazuje načrt pregleda za en valj.

2.2 Defining the equipment for endoscope diagnostics

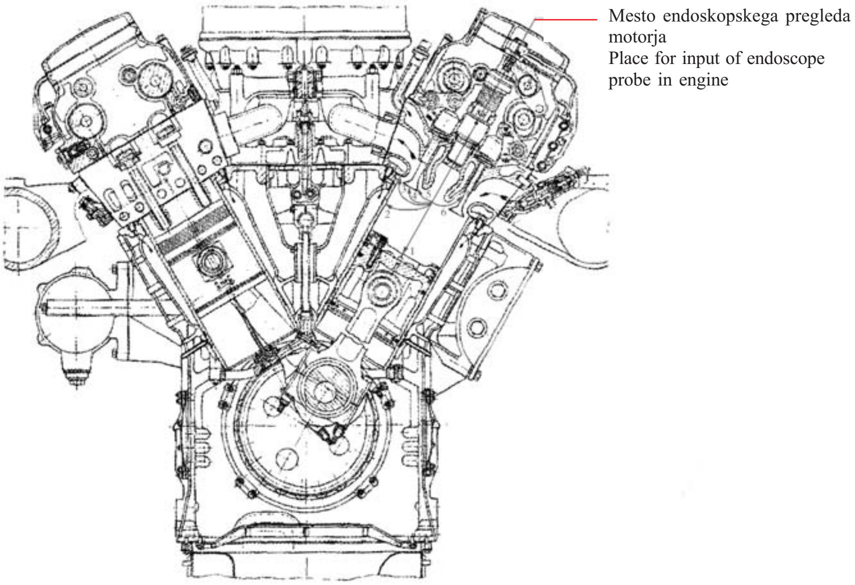
The equipment described in Table 1 is used for the endoscope diagnostics.

2.3 Determining the measurement locations for endoscope diagnostics

The cross-section shows the engine – the subject of the research – with the place for inputting the endoscope equipment (boroscope and fiberscope) into the cylinder (Fig. 9). Each cylinder was separately examined at defined measuring points:

- Head of piston
- Cover of cylinder
- Connection between cylinder and head
- Suction and exhaust valve with seats
- Valve seat
- Valve guides

A plan of the diagnosis is made for each of the engine cylinders. The plan defines the objects of the diagnosis and any possible damage. The examination of the endoscope diagnostics for the piston-cylinder group, compressor and air conditioners with control places and possible damage is given in Table 2. This programme of endoscope diagnostics with previously described methodology can be applied to an engine that is used in ships. Table 2 shows a plan of the diagnostics for one cylinder.



Sl. 9. *Prečni prerez motorja in mesto endoskopskega pregleda*
Fig. 9. *Cross-section of ship's engine and the place of endoscope examination*

Preglednica 2. *Endoskopsko razpoznavanje motorja – načrtovanje razpoznavanja*
Table 2. *Endoscope diagnostics of engine – planning the diagnosis*

SKUPINA BAT-VALJ IN VENTILNI MEHANIZEM PISTON-CYLINDER GROUP AND SEPARATING MECHANISM					
Objekt razpoznavanja Object of the diagnosis	**Mogoče poškodbe Possible damage**	**Objekt razpoznavanja Object of the diagnosis**	**Mogoče poškodbe Possible damage**	**Objekt razpoznavanja Object of the diagnosis**	**Mogoče poškodbe Possible damage**
čelo bata head of piston	obloge koksa deposit of coke	**puša valja surface of cylinder**	korozija corrosion	**glava valja head of the cylinder**	korozija corrosion
	razpoke fissure		vzdolžni risi longitude damages		razpoke fissure
	korozija corrosion		razpoke fissure		tesnost hermetically
	druge oblike poškodb other type of damage		žlebovi od obročkov channels of link		druge oblike poškodb other damage
			druge oblike poškodb other type of damage		
sesalni ventil intake valve	korozija corrosion	**izpušni ventil blow-out valve**	korozija corrosion	**KOMPRESOR COMPRESOR**	
	obloge koksa deposit of coke		obloge koksa deposit of coke	**kompresor compressor**	stanje difuzorja situate diffuser
	sedež ventila seat of valve		sedež ventila seat of valve		stanje lopatic rotorja situate rotor
	zračnost clearance		zračnost clearance		zračnost clearance
	gobica ventila head of valve		gobica ventila head of valve		druge oblike poškodb other damages

3 REZULTATI ENDOSKOPSKEGA RAZPOZNAVANJA

Med endoskopskim pregledom so bili pregledani vsi valji preiskovanega ladijskega motorja, da bi odkrili mogoče napake, to so: tesnost

3 RESULTS OF THE ENDOSCOPIC DIAGNOSIS

During endoscope diagnostics more cylinders of the ship's engine are checked for possible damage, including leakage of the cooling fluid, cor-

(puščanje) hladilnega sistema, korozija, mehanske poškodbe, poškodbe galvanske zaščite, deformacije, vsedline nečistoč, prisotnost tujkov itn.

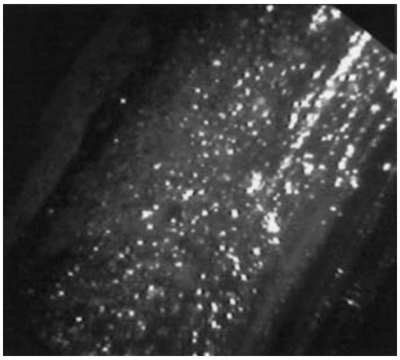
V prispevku so kot ponazoritev prikazani številni posnetki stanja valjev motorja, ki so bili razpoznani po načrtu razpoznavnih opravil. Opazimo suspenzijo vode in olja v valju, korozijo čela bata ali glave motorja ter podobno (sl. 10 do 17). Ob vsakem posnetku je podan kratek opis opaženega pojava in mesto pojavljanja. Ti pojavi kažejo na določene poškodbe posameznih elementov motorja in njihovo neustreznost delovanja, npr. zračni filtri, ki ne smejo prepuščati zraka zasičenega s kapljicami morske vode, kar je pogost pojav pri delovanju ladijskih motorjev.

Rezultati endoskopskega pregleda vseh valjev motorja so podani v preglednicah, ki vsebujejo

rosion, mechanical damage, damage to the galvanic protection, deformations, the deposit of dirt and coke, the presence of extraneous objects, etc.

There are many illustrations in this paper with pictures of the condition of the engine cylinder before diagnosis, which is done according to the plan of the diagnostics tasks. It is easy to see water or oil on the cylinder, corrosion on the head of the piston and cylinder, etc (Figs. 10 to 17). We describe the situation, the place and the damage for every illustration. Those pictures show some damage to the engine elements and show possible incorrectness of other elements, such as an air filter that must not pass air full of sea water, which is very often the situation in the exploitation of this sort of engine.

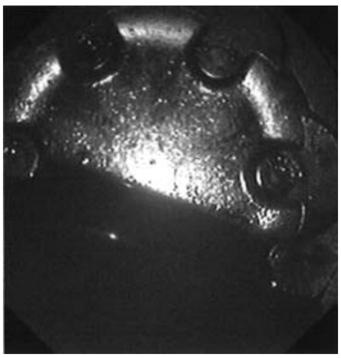
The results of endoscope observations for all the engine cylinders are shown in the tables that



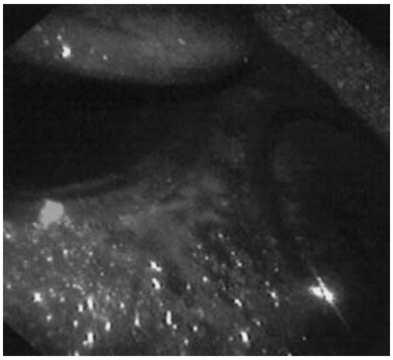
Sl. 10. *Pogled na glavo motorja (korozija zaradi vdora vode)*
Fig. 10. *View of a cylinder head at the location of the oil burner (the presence of corrosion due to water penetration)*

Sl. 11. *Površina glave motorja in odprti sesalni ventili (vidna korozija ventilov)*
Fig. 11. *The connection between the cylinder head and the surface of the cover with suction valves open (presence of corrosion on the valves)*

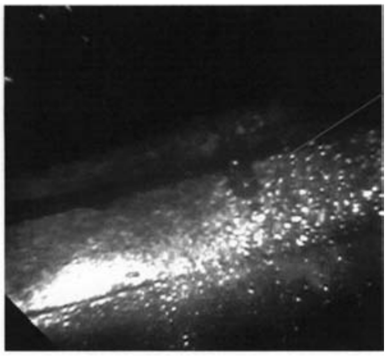
Sl. 12. *Odprt sesalni ventil in zaprt izpušni ventil (korozija glave motorja in ventila)*
Fig. 12. *Open suction valve and closed exhaust valve (presence of corrosion on the cylinder head and the valve)*



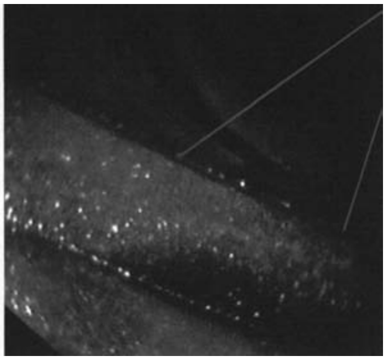
Sl. 13. *Nečistoče na čelu bata – detajl (korozija)*
Fig. 13. *Dirty piston head – detail (presence of corrosion)*



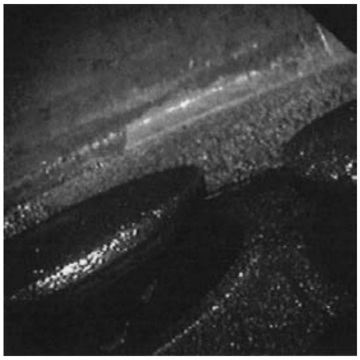
Sl. 14. *Nečistoče na čelu bata (petrolej)*
Fig. 14. *Dirty piston head with the presence of petroleum*



Sl. 15. *Oblikovanje kapljic vode na sestavu med glavo motorja in valjem*
Fig. 15. *Formation of water droplets on the connection between head and the cover of the cylinder*



Sl. 16. *Mesto vdora vode med glavo motorja in valjem*
Fig.16. *The place of water penetration between the head and the cover of the cylinder*



Sl. 17. *Prikaz sesalnega ventila z vidno korozijo*
Fig.17. *The appearance of suction valves with the presence of corrosion*

podatke o številu valjev, mestih merjenja, ugotovljenega stanja in sklepov operaterja. V preglednici 3 so za ponazoritev podani rezultati endoskopskega pregleda treh valjev.

Krivulja obrabe na sliki 18 prikazuje rezultat endoskopskega pregleda določenih merilnih parametrov stanja za izbrano število valjev motorja.

Grafični prikaz endoskopskega razpoznavanja kaže, da je v času zadnjega pregleda prišlo do kopičenja nezadovoljivih rezultatov. To pomeni, da je motor v stanju zmanjšane možnosti uporabe. Takšen sklep opozarja na potrebo po dejavnostih za zaustavitev motorja in popravilo ter zamenjavo delov motorja, tako tistih, ki so bili predmet pregledovanja (valji, bati itn.) kakor tudi delov, ki bi bili lahko vzrok za poškodbe valja: filtri, prečiščevalnik olja, hladilni sistem itn.

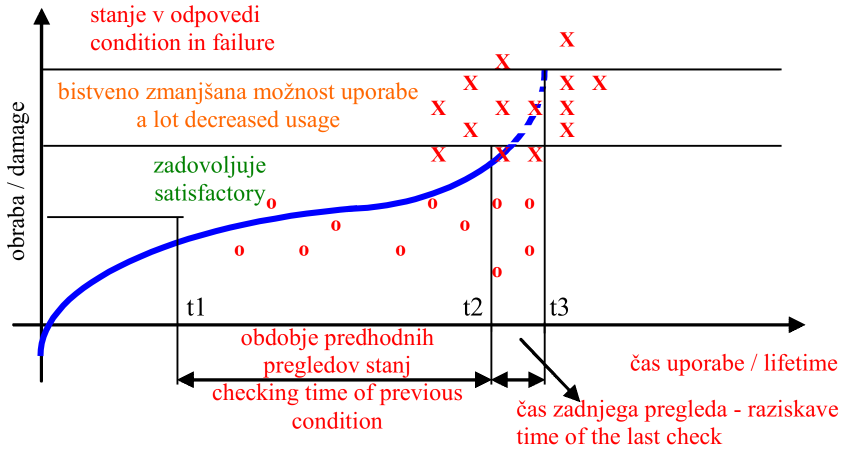
contain the number of the cylinder, the measuring location, the condition and the conclusion. Table 3 presents the results of the endoscope examination of three cylinders as an illustration in this paper.

The wearing-out curve shows the result of the endoscope diagnosis for defining the measuring condition parameters on a number of cylinders of the engine (Fig. 18).

The endoscope diagnostic graphic shows that there are many bad results about the conditions of some cylinder elements during the last examination. This means that the engine is in a condition of decreasing usage. The conclusion is that it is necessary to prepare the engine to stop working for a repair or to change some engine parts. It could be the objects of the examination (cylinder, piston, etc) or some parts that could have an influence on damage to the cylinder – filters, oil cleaners, air conditioners, etc.

Preglednica 3. *Tehnično stanje treh valjev motorja*
Table 3. *Technical condition in a number of cylinders of the engine*

Zap. število No. Cylinders	Predmet razpoznavanja Object of diagnostics	Predmet diagnostike Observed condition	Ugotovljeno stanje Conclusion
1	čelo bata head of piston	sledovi oblog traces of deposits	zadovoljivo satisfactory
	valj in glava cylinder and head	brez poškodb no damage	zadovoljivo satisfactory
	sesalni ventili suction valves	brez poškodb no damage	zadovoljivo satisfactory
	izpušni ventili exhaust valves	sledovi korozije traces of corrosion	nezadovoljivo not satisfactory
2	čelo bata head of piston	sledovi korozije traces of corrosion	nezadovoljivo not satisfactory
	valj in glava piston and head	korozija zaradi vdora vode corrosion due to water	nezadovoljivo not satisfactory
	sesalni ventili suction valves	korozija zaradi vdora vode corrosion due to penetration	nezadovoljivo not satisfactory
	izpušni ventili exhaust valves	korozija zaradi vdora vode corrosion due to water penetration	nezadovoljivo not satisfactory
3	čelo bata head of piston	brez poškodb no damage	zadovoljivo satisfactory
	valj in glava cylinder and head	brez poškodb no damage	zadovoljivo satisfactory
	sesalni ventili suction valves	sledovi korozije na gobicah traces of corrosion on "mushroom"	nezadovoljivo not satisfactory
	izpušni ventili exhaust valves	sledovi korozije na gobicah traces of corrosion on "mushroom"	nezadovoljivo not satisfactory



Sl. 18. *Rezultati endoskopske diagnostike*
Fig.18. *Results of endoscope diagnostics*

4 OCENJEVANJE KRITERIJEV SPREJEMLJIVOSTI NAPAK NA LADIJSKEM MOTORJU

Časovni korak pregledov se lahko določa na podlagi poznavanja konstrukcije ladijskega motorja M845 oz. delov, ki bodo razpoznavani, njihovih tehnično-tehnoloških značilk ter razmer pri delovanju. Prihodnji pregledi naj bi omogočili spremljanje poškodb posameznih delov motorja, na podlagi katerih bi lahko sprejeli kriterije

4 EVALUATION OF THE ACCEPTABILITY CRITERIA FOR DAMAGE TO THE SHIP'S ENGINE

The time intervals for the examinations can be proposed since one is familiar with the construction of the ship's engine, i.e., with those parts that need to be diagnosed, the technical and technological characteristics, and the conditions in which they work. The following examinations would enable observing the damage on the parts of the engine on the basis of which one could adopt the sprejemljivih poškodb. Ti kriteriji so lahko v pomoč pri izdelavi etalonov za kalibracijo, ki naj bi jih uporabljali pri analizi in postopku prilagajanja kriterijev sprejemljivosti poškodb delov motorja.

Za spremljanje in prilagajanje teh kriterijev je treba vse podatke in rezultate, dobljene med endoskopskim pregledom, zapisovati v določene obrazce (liste pregledov). Kriteriji sprejemljivosti za odkrite poškodbe se definirajo s posebnim dokumentom, v katerem so podane slike poškodb in etaloni z dopustnimi kriteriji sprejemljivosti teh poškodb. Spremljajoča dokumentacija so običajno preglednice, ki vsebujejo: mesto pregleda, vrsto poškodbe, največje dopustne velikosti poškodb, kakor tudi število dopustnih napak.

Namen celovitega pregleda je ocena kriterija sprejemljivosti poškodb posameznih delov motorja, ker daje odgovor na vprašanje, v kakšnem stanju je preizkuševani motor. Na temelju ocene teh kriterijev sprejemljivosti se sprejme odločitev o nadaljnjem tehničnem saniranju poškodb in nadaljnji uporabi motorja.

Ocenitev kriterija sprejemljivosti poškodb delov motorja se lahko izvede takole:

- primerjava poškodbe z etalonom – ta kriterij predpostavlja obstoj etalona, ki je rezultat dolgotrajnega spremljanja in opazovanja razvoja poškodbe ter prirejanja mej poškodb, pri katerih motor še zadovoljivo deluje;
- primerjava poškodb s sprejetimi dopustnimi vrednostmi, podanimi v ustreznih preglednicah;
- primerjava poškodb s slikami, skicami, načrti, fotografijami in podobnimi dokumenti.

Poškodbe se pogosto ocenjuje z upoštevanjem več kriterijev, da bi se na ta način zmanjšala možnost napake.

5 SKLEPNE UGOTOVITVE

Stanje tehničnega sistema označujejo številni parametri delovnega postopka. Poudariti je treba, da vsi parametri nimajo enakega vpliva na stanje sistema. Izbira razpoznavnih parametrov, ki bodo nadzorovani, se izvaja na temelju poteka podatkov o delovanju sistema. Čeprav na tehnično razpoznavanje lahko gledamo z različnih vidikov, nobeden izmed njih ne obstaja neodvisno drug od drugega, vsaka oblika tehnične diagnostike vsebuje več vidikov. Tipični primer za to je

acceptability criteria for damage. These criteria could be helpful in the production of calibration pieces that would serve for analysis in the process of adopting the acceptability criteria for damage to the engine parts.

It is necessary to note all the data and results, acquired during endoscope examinations, in certain forms in order to follow and adopt acceptability the criteria for damage to the engine parts. The acceptability criteria for the observed damage are defined using a certain form, which contains the accompanying illustrations and calibrations with permitted acceptability criteria. The accompanying documentation usually contains tables with the place of examination, the type of damage, the maximum permitted scope of damage as well as the amount of allowed damage.

The main goal of the whole examination is the evaluation of the acceptability criteria for damage to the parts of the engine, since this answers the question about the state of the examined engine. Based on the evaluation of these acceptability criteria, a decision can be made about further technical repair and continued use.

The evaluation of the acceptability criteria for damage to parts of the engine can be performed in the following ways:

- By comparing the damage with a calibration. This criterion predicts the existence of the calibration, which is derived from a long-term follow-up and the observation of damage development and the adoption of the limits for the amount of damage with which the engine can still function properly,
- By comparing the damage with set allowed values given in tables,
- By comparing the damage with pictures, sketches, photos and other similar documents.

The evaluation of damage is, in most cases, performed using several criteria, so that a possible error could be reduced.

5 CONCLUSIONS

Many parameters of a working process characterise the condition of a technical system. However, it is important to note that not all parameters of this working process have an equal influence on the system condition. The choice of diagnostic parameters that is to be controlled is made on the basis of the history of the data about the work of a system at hand. Even though technical diagnostics can be seen from several aspects, none of them can exist independently from the others, since each type of technical diagnostics contains several other endoskopska metoda, ki je hkrati glede na način dela - neposredna, glede na rezultate – poglobljena, glede na izvajanje – primerna. Lahko je tudi glede na uporabo občasna ali stalna, glede na obseg pa delna ali popolna.

Vlaknoskopi so posebej zanimivi zaradi svojih značilnosti. To so prilagodljivi inštrumenti, ki imajo takšno upogljivost, da ne omogočajo samo neposredni, temveč tudi bočni pogled in imajo možnost neposredne povezave z računalnikom in zaslonom, s čimer se doseže največji nadzor postopka razpoznavanja.

Med endoskopskim razpoznavanjem ladijskega motorja je mogoče nadzorovati posebne pomajkljivosti in poškodbe, to so: iztekanje hladilne tekočine, korozija, mehanske poškodbe, poškodbe galvanske zaščite, deformacije, vsedline nečistoč in koksa, kakor tudi tuje predmete.

Iz rezultatov, pridobljenih z endoskopom, poznavanja konstrukcije ladijskega motorja oz. delov, ki jih razpoznavamo, njihove tehnično-tehnološke značilnosti in razmere, v katerih obratujejo, se lahko predlagajo določene dejavnosti pri vzdrževanju ter časovni koraki za prihodnje preglede.

aspects. A typical example is the endoscope method, which is, at the same time, direct in terms of the working manner, deepening according to the results and objective according to the performance. It can also be either periodic or permanent, according to its application as well as either partial or complete according its scope.

Fibre scopes are particularly interesting because of their characteristics. They are flexible instruments that have the ability to bend, which enables not only a direct, but also a lateral view and offers the possibility of a direct connection with a computer and a monitor, which in turn allows maximum control of this diagnostic process.

During an endoscope diagnosis of a ship's engine, the control of possible defect and damage phenomena is incorporated, such as leakage of a cooling fluid, corrosion, mechanical damage, damage to galvanic protection, deformations, deposits of dirt and coke as well as the presence of extraneous objects.

On the basis of the results acquired with an endoscope and a familiarity with a ship's engine construction and its parts that are diagnosed as well as their technical and technological characteristics and the conditions in which they work, one can propose certain maintenance activities and certain time intervals for future examinations.

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