KVALITET OTKOVKA U FUNKCIJI POSTOJANOSTI ALATA PRI OBRADI RUKAVACA TOČKOVA MOTORNIH VOZILA

FORGING QUALITY IN THE FUNCTION OF THE CONSISTENCY OF THE TOOLS IN THE PROCESSING OF THE WHEEL SLEEVES OF MOTOR VEHICLES

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REZIME

Imajući u vidu da su rukavaci točkova motornih vozila izloženi jakim dinamičkim opterećenjima, te znajući da su to veoma odgovorni dijelovi konstrukcija, nameće se potreba za permanentnim istraživanjima uticaja pojedinih varijabli na proces izrade istih. Važnu ulogu ima pripremak koji se, u ovom slučaju dobija kovanjem iz odgovarajućeg čelika. Sam process kovanja, podrazumijeva pojavu određenih grešaka koje se mogu manifestovati na više načina. Takve greške, i pored rigorozne kontrole, teško je eliminisati u potpuinosti. U radu su tretirani pripremci sa greškama i njihov uticaj na postojanost alata, kao i analiza uticaja promjene procenta nekih elemenata na istu.

Professional paper

SUMMARY

Bearing in mind that the wheel sleeves of motor vehicles are exposed to strong dynamic loads, and knowing that these are very responsible parts of the constructions, the need for permanent researches of the influence of certain variables on the process of production of them is imposed. The prepared part which, in this case, is obtained by forging from the appropriate steel has an important role. The process of forging, implies the appearance of certain errors that can manifest in many ways. Such mistakes, despite rigorous control, are difficult to eliminate completely. The paper deals with prepared parts with errors and their impact on the consistency of the tools, as well as the analysis of the influence of the change in the percentage of some elements on the same.

1. UVOD

Postupak obrade metala kovanjem jedan je od najstarijih postupaka obrade metala deformisanjem zbog osobina koje ga karakterišu. Imajući u vidu da se kod metala pri njihovom zagrijavanju povećava plastičnost, postupak kovanja se najčešće izvodi u vrućem stanju. Kovanje u hladnom stanju moguće je za izradu otkovaka manjih dimenzija i relativno jednostavnijih geometrijskih oblika.

Prednosti ovog postupka u odnosu na ostale postupke obrade plastičnom deformacijom se ogledaju kroz vrlo visoku efektivnost, tačnost, i relativno dobar kvalitet obrađene površine.

Nedostaci se ogledaju kroz utrošak energije za zagrijavanje obratka i stvaranju sloja oksida na površinu usljed termohemijskih reakcija.

1. INTRODUCTION

The method of processing metal by forging is one of the oldest procedures of metal processing with deformation due to its characteristic features. Bearing in mind that in metals, during their heating, plasticity increases and thus the forging process is most often performed in a warm state. Forging in a cold state is possible for the production of forgings of smaller dimensions and relatively simpler geometric shapes. The advantages of this procedure in relation to other processes of plastic deformation processing are reflected through very high efficiency, accuracy, and relatively good quality of the processed surface. The disadvantages are reflected through the energy consumption for heating the workpiece and the formation of a layer of oxide on the surface due to thermochemical reactions.

Postoje tri osnovne grupe otkovaka [1]. Primjer otkovka rukavca motornih vozila, koje tretira ovaj rad, spada u drugu grupu.
Kako je postupak obrade rezanjem, često završna obrada nekih površina otkovaka, pri projektovanju ovakvih dijelova neophodno je voditi računa o mogućnosti njegove primjene.
Postojanost alata kod obrade metala rezanjem jedan je od važnijih faktora, kako sa ekonomskog aspekta, tako i sa aspekta postizanja odgovarajućeg kvaliteta.

There are three basic groups of forgings [1]. The example of the forging of the motor vehicle's wheel sleeve, which this paper deals with, belongs to the second group.
Since the machining process by cutting is often the final processing procedure of some surfaces, in designing such parts it is necessary to take into account the possibility of its application. The consistency of tools in processing metal by cutting is one of the most important factors, both from the economic aspect and from the aspect of achieving the appropriate quality.

2. KARAKTERISTIKE OTKOVKA

Otkovak rukavca motornih vozila, koji je predstavljen na slici 1., dobija se kovanjem u toplom stanju postupkom kovanja u ukovnjima. Masa otkovka je cca 1,4 kg i oblikuje se na kovačkom čekiću prostog dejstva.
Superlegure su dizajnirane za upotrebu u temperaturnom intervalu od 600° do 1150 °C u uslovima djelovanja visokih opterećenja i agresivnih medija, zbog čega moraju imati visoke vrijednosti otpornosti na puzanje, koroziju i oksidaciju [1].
Materijal je srednjeugljenični čelik specijalnog sastava koji je po svojim karakteristikama najbliži čeliku EN-1C55 što odgovara čeliku oznake DIN-C55. Međutim, radi poboljšanja određenih karakteristika dodavani su pojedini elementi u manjim procentima. Tačan hemijski sastav čelika za izradu otkovaka dat je u tabelama 1 i 2.
Treba napomenuti da su nešto različiti hemijski sastavi grupe A i grupe B otkovaka jer su različiti proizvođači istih.

2. CHARACTERISTICS OF FORGINGS

The forging of the motor vehicle sleeve, which is presented in Figure 1., is obtained by forging in a warm condition by the procedure of hammering in forging molds. The mass of the forging is approx. 1.4 kg and it is done on a hammer with free action. The material is a middle-carbon steel of special steel structure, which is by its characteristics the closest steel EN-1C55 which corresponds to the steel of the mark DIN-C55. However, in order to improve certain characteristics, some elements were added in smaller percentages. The exact chemical composition, of steel for making forgings is given in Tables 1 and 2. It should be noted that there are somewhat different chemical compositions of group A and group B forgings because they have different producers.

Tabela 1. Hemijski sastav čelika otkivaka iz grupe A
Table 1. The chemical composition of the steel forging from group A

% C	**% Si**	**% Mn**	**% P**	**% S**	**% Cr**	**% Mo**	**% Ni**
0,55	0,21	0,71	0,015	0,014	0,18	0,03	0,10
% Al	**% V**	**% B**	**% Ti**	**% N**	**% Cu**	**% Sn**	
0,033	0,003	0,0002	0,001	0,009	0,13	0,008	

Tabela 2. Hemijski sastav čelika otkivaka iz grupe B
Table 2. The chemical composition of the steel forging from group B

% C	**% Si**	**% Mn**	**% P**	**% S**	**% Cr**	**% Mo**	**% Ni**
0,55	0,25	0,72	0,016	0,013	0,16	0,04	0,13
% Al	**% V**	**% B**	**% Ti**	**% N**	**% Cu**	**% Sn**	
0,031	0,003	0,0003	0,001	0,007	0,15	0,009	

Mehaničke karakteristike su date u tabeli 3. a dobijeni su ispitivanjem na epruvetama od materijala otkovka

The mechanical characteristics are given in Table 3 and were obtained by analysis of the test tubes of the forging materials.

Tabela 3. Mehaničke osobine čelika otkovaka iz grupe A i B
Table 3. Mechanical properties of steel forgings from groups A and B

TIP	Zatezna čvrstoća RM (N/mm^2)	Konvencionalna zatezna čvrstoća Rp0,2(N/mm^2)	Istezljivost A (%)	Kontrakcija Z (%)	Tvrdoća HB
A	791-821	425-429	14,0-14,5	40,0-45,0	216-241
B	790-803	427-433	14,5-15,0	43,0-44,0	211-239

Slika 1. *Otkovak za izradu rukavca točka motornog vozila*
Figure 1. *A forging for the making of wheel sleeves of motor vehicles*

2.1. Greške na otkovcima

Kako je ranije navedeno, pri postupku kovanja dolazi do formiranja raznih oksida na površini otkivka. Oksidi se stvaraju u toku procesa kovanja i nijedan od postupaka njihovog otklanjanja nije u potpunosti efikasan. Zato je neophodno stalno kontrolisati izradu otkivaka i otklanjanje raznih nepravilnosti.

Svaka pojava grešaka ima višestruko nepovoljno djelovanje na proces izrade rukavaca i na kvalitet gotovog rukavca.

Specifičnosti postupka kovanja ukazuju na to da je sam proces veoma teško pratiti. Česta pojava je dobijanje otkivaka sa greškama. Najmanje negativne posljedice nastaju kada se otkriju greške prije obrade rezanjem. [2]

S obzirom da se radi o velikim serijama izrade otkivaka teško je primijeniti neke složenije metode kontrole svakog otkivka.

Najjednostavnija metoda kontrole kvaliteta otkivaka je vizuelna metoda. Ona otkriva nepravilnosti otkivaka, a primjeri grešaka koje se mogu otkriti vizuelnom metodom dati su na slici 2.

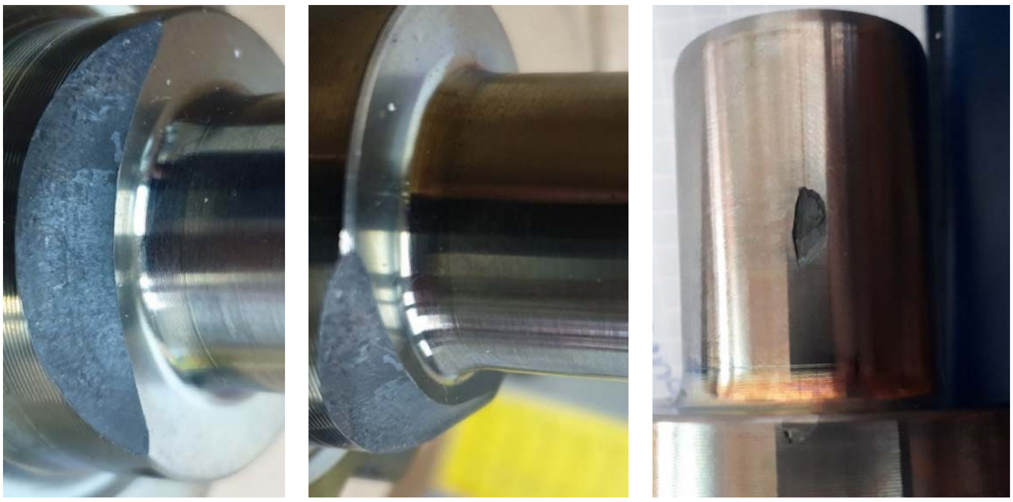
2.1. Errors in forgings

As stated earlier, during the forging process, various oxides on the surface of the forging are formed. Oxides are created during the forging process and none of the procedures for their removal are completely effective. Therefore, it is necessary to constantly control the production of forgings and to eliminate various irregularities. Each occurrence of errors has multiple adverse effects on the process of fabrication of the wheel sleeves and on the quality of the finished sleeve. The specificities of the forging process indicate that the process itself is very difficult to follow. A common occurrence is getting forgings with errors. The least negative consequences occur when errors are detected before cutting. [2] Considering that it is a large series of forging production, it is difficult to apply some more complex methods of controlling each forging. The simplest method of controlling the quality of the forgings is the visual method. It reveals the irregularities of the forgings and examples of errors that can be detected by the visual method are given in Figure 2.

Posljedice ovakvih grešaka se završavaju sa završetkom procesa kovanja.
Sa aspekta ekonomičnosti, daleko veće posljedice ostavljaju greške koje se ne mogu detektovati vizuelnom kontrolom. Takve greške je moguće otkriti samo pomoću neke od metoda kontrole bez razaranja materijala (primjer ultrazvučna metoda), koje su same po sebi skuplje i dugotrajnije od vizuelne metode, a zahtijevaju i više vremena pa ih je u praksi teško provoditi uz primjenu na 100 %-tnom uzorku kontrole, već na manji broj dijelova, što daje pretpostavku da se i dijelovi sa greškama nađu u grupi „dobrih“ dijelova. Takvi dijelovi se dalje upućuju na sljedeći korak u proizvodnji rukavaca -obradu rezanjem.
Pri zahvatu reznog klina i otkivka koji u sebi ima razne oksidne uključke obavezno dolazi do loma reznog klina alata. U ovom slučaju to je strugarski nož sa izmjenjivom tvrdom pločicom. Na slici 3 su prikazani dijelovi sa takvom greškom nakon zahvata uzdužnog struganja.

The consequences of such mistakes end with the completion of the forging process. From the aspect of economy, far greater consequences are left by errors that can not be detected by visual control. Such errors can only be detected by using some of the methods of control without the destruction of the materials
(for example the ultrasonic method), which are themselves more expensive and longer lasting than the visual method, and require more time which is why in practice they are difficult to implement with application at a 100% control sample, but on a smaller number of parts, which gives the assumption that parts of the errors are in the group of "good" parts. Such parts are being sent to the next step in the production of sleeves-processing by cutting. While the cutting wedge cuts through the forging, which involves various oxide inclusions, the cutting wedge of the tool must get broken. In this case, there is a rotary knife with a removable hard board. Figure 3 shows parts with such error after the longitudinal scraping procedure.

Slika 2. *Izgled otkivka sa greškama otkrivenim vizualnom metodom*
Figure 2*. The appearance of a forging with errors detected with the visual* method



Slika 3. *Izgled dijelova sa greškom nakon obrade struganjem*
Figure 3. *The appearance of parts with error after scraping processing*

Ako se pažljivo pogleda hrapavost površine zahvata prije nego što rezni klin dodirne uključak i nakon što je rezni klin došao u zahvat sa uključkom, može se zaključiti da je došlo do loma vrha reznog klina jer se i vizuelno uočavaju „brazde“ na dijelu površine nakon zahvata, što je posljedica loma reznog klina, odnosno, posljedica promjene geometrije reznog klina.

Jedan ovakav obradak dovodi do zaustavljanja procesa obrade jer se navedeni dio obrađuje na CNC mašinama u automatiziranom odvijanju procesa, te je neophodno izvršiti zamjenu alata (sječiva rezne pločice ili postaviti drugu pločicu ako su oštećeni svi njeni vrhovi).

2.2. Postojanost reznog alata

Jedna od primarnih karakteristika alata kod obrade rezanjem jeste njegova postojanost. Postojanost alata podrazumijeva vrijeme trajanja alata u procesu obrade rezanjem. Vrijeme trajanja alata je ukupno vrijeme koje alat provede neposredno u zahvatau sa materijalom, pri obradi rezanjem, pri čemu se dobija obrađena površina odgovarajućeg kvaliteta.

Ovakve i slične definicije su veoma uopštene i teško ih je primijeniti za pojedine vrste alata za obradu rezanjem.[3] Imajući u vidu da postoji više vrsta reznog alata za obradu rezanjem, kako sa aspekta vrste materijala od kojeg je izrađen, tako i sa aspekta njegove namjene ne postoji neka univerzalna mjera za postojanost alata već se određuje za konkretan slučaj.

U ovom primjeru riječ je o strugarskom nožu za uzdužno struganje sa izmjenjivim trougaonim i kvadratnim tvrdim pločicama.

Proizvođač datih pločica je definisao postojanost istih za obradu navedenih otkovaka.

Istraživanje je pokazalo da rezni dio noža kad dođe u dodir sa uključkom koji je obrađen u dijelu 1.1. ovog rada, obavezno pretrpi lomove i takva pločica je neuoptrebljiva (na dijelu koji je bio u zahvatu) te je potrebna njena zamjene ili, u najboljem slučaju njeno zaokretanje za 120^0, odnosno 90^0, što dovodi do zaustavljanja procesa obrade rezanjem, i zahtijeva dodatno vrijeme za obavljanje potrebnih aktivnosti.

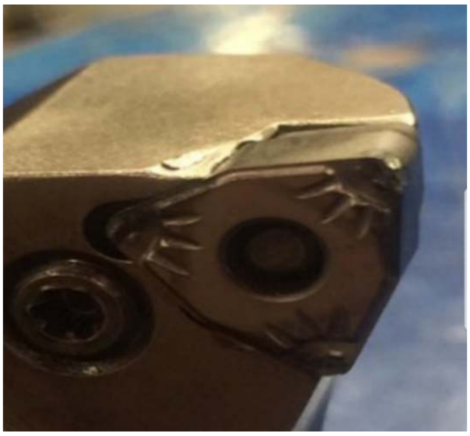
Na slici 4. su prikazane neke od pločica koje su bile u zahvatu sa takvim otkovkom gdje se vidi izgled polomljene pločice. Od čega zavisi veličina loma pločice je teško utvrditi.

If one carefully looks at the roughness of the surface of the engagement before the cutting wedge touches the inclusion and after the cutting wedge has come in contact with the inclusion, it can be concluded that there was a break of the tip of the cutting wedge because of the visible "furrows" on the part of the surface after the procedure, which is a consequence of a breakage of the cutting wedge, that is, the consequence of the change in the geometry of the cutting wedge. One such procedure leads to the stopping of the machining process because the said part is machined on the CNC machines in the automated unfolding of the process, and it is necessary to replace the tool (cutting blades or install another tile if all its tips are damaged).

2.2. Consistency of cutting tools

One of the primary characteristics of the tools in processing by cutting is its consistency. The consistency of the tool implies the duration of the tool in the cutting process. The duration of the tool is the total time that the tool carries out directly in the material handling, in cutting processing, whereby the processed surface of the appropriate quality is obtained

Such and similar definitions are very general and difficult to apply to certain types of cutting tools.[3] Bearing in mind that there are several types of cutting tools for cutting processing, both from the aspect of the type of material from which it is made, and from the aspect of its purpose, there is no universal measure of tool consistency but is determined for the particular case. In this example, it is a cutting knife for longitudinal scraping with interchangeable triangular and square hard tiles. The manufacturer of these tiles has defined the consistency of them for the processing of the mentioned forgings. The research showed that the cutting part of the knife when it came into contact with the inclusion mentioned in section 1.1. of this paper must suffer fractures and such a tile is unattainable (on the part that was in the process), and its replacement is needed or, at best, its rotation for 120^0 or 90^0, which leads to the stopping of the cutting process, and requires additional time to perform the necessary activities. In Figure 4, some of the tiles that were engaging with such a forging are shown, showing the appearance of the broken tile. What the size of the tile fracture depends on is difficult to determine.



Slika 4. *Izgled polomljenog vrha pločice*
Figure 4. *The appearance of the broken top of the tile*

3. ANALIZA REZULTATA

Upoređivanjem srednjih vrijednosti navedenih mehaničkih osobina otkovaka grupe A sa srednjim vrijednostima mehaničkih osobina iz grupe B, može se vidjeti da nisu velika međusobna odstupanja.

Istraživanje je pokazalo da su rezni alati manje trajali kod obrade rezanjem otkovaka iz grupe B, što govori o tome da su male promjene hemijskog sastava dovele do stvaranja oksida na površini otkovka koji nepovoljnije utiču na postojanost alata.

S obzirom da se radi o serijskoj proizvodnji, podaci o postojanosti alata su prikupljani sedam dana za četiri zahvata, dva su uzdužna obrada i dva zahvata za poprečnu obradu.

U tabeli 4. date su preporučene vrijednosti postojanosti četiri alata A1, A2, A3 i A4. Navedene postojanosti su definisane kroz broj komada na kojima se izvodi dati zahvat.

Na grafikonima 1, 2, 3 i 4 su prikazane dnevne potrošnje alata za obradu otkovaka iz grupe A i B. Vidi se da je dosta veća potrošnja alata iz grupe B iako je veoma mala razlika u hemijskom sastavu materijala. Analiza je rađena na osnovu ukupne istrošenosti alata, što podrazumijeva i habanje pri obradi otkovaka koji nemaju izražene nepravilnosti u vidu uključaka.

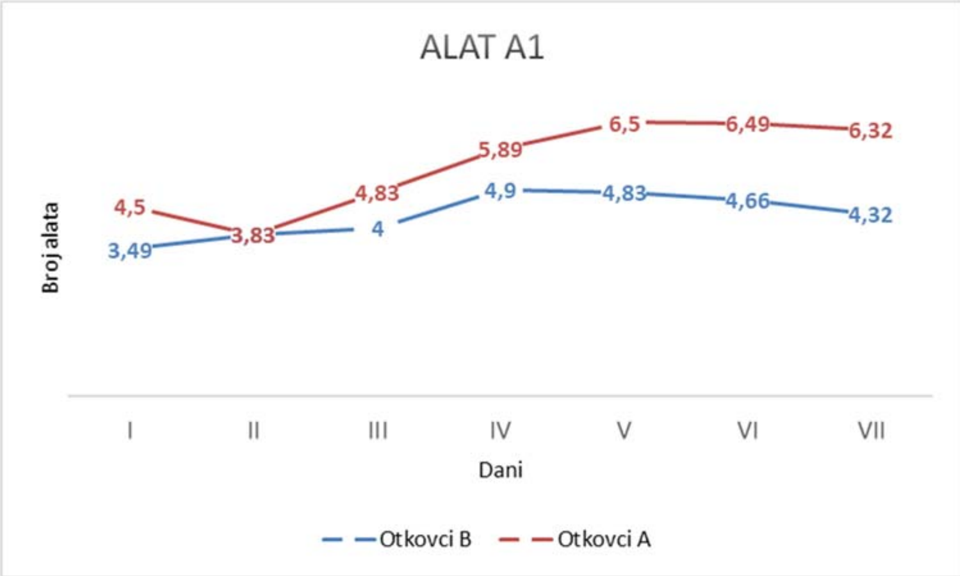
3. ANALYSIS OF THE RESULTS

By comparing the mean values of the abovementioned mechanical characteristics of forgings from Group A with the mean values of the mechanical properties of forgings from Group B, it can be seen that there are not large mutual deviations. The research showed that the cutting tools were less lasting in the processing of cutting group B forgings, which suggests that small changes in the chemical composition led to the formation of oxides on the surface of the forgings that adversely affect the tool's consistency. Since this is a serial production, the data on the consistency of the tools were collected seven days for four operations, two are longitudinal processing and two for transversal processing. Table 4 gives the recommended values of the consistency of four tools A1, A2, A3 and A4. The mentioned consistency is defined by the number of pieces on which the procedure is performed. Charts 1, 2, 3, and 4 show the daily consumption of processing tools from group A and B forgings. It can be seen that there is a much higher consumption of tools from group B, although there is a very small difference in the chemical composition of the material. The analysis was based on the total utilization of the tools, which also implies the wear while processing forgings that do not have any irregularities in the form of inclusions.

Tabela 4. Preporučene vrijednosti postojanosti alata
Table 4. Recommended value of tool consistency

Oznaka alata	A1	A2	A3	A4
Postojanost [kom.]	6x100=600[1]	6x250=1500	6x150=900	8x100=800[2]

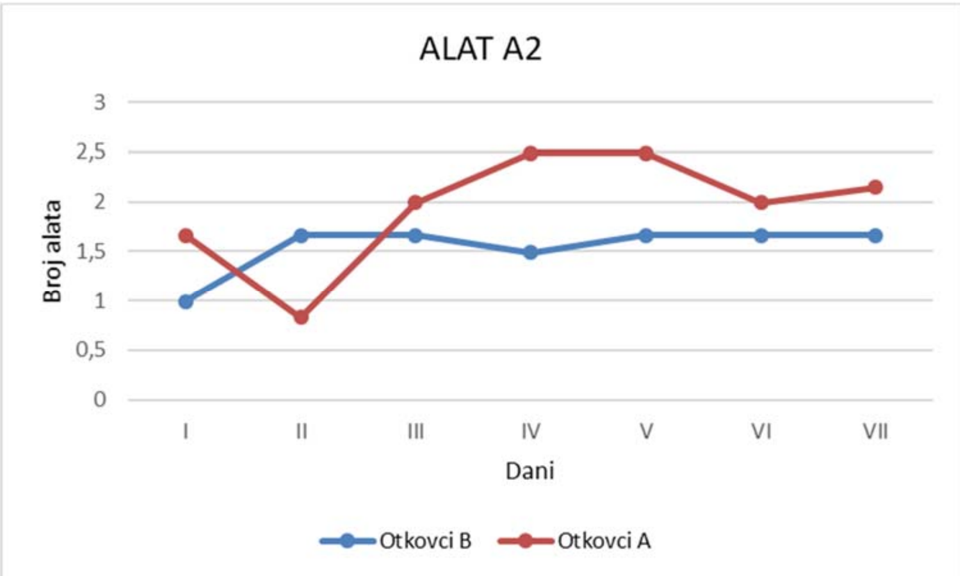
[1] Šest vrhova pločice po 100 kom
[2] Jedina kvadratna pločica



Grafikon 1. *Prikaz dnevne potrošnje alata A1 za obradu otkovaka*
Chart 1*. Displaying the daily consumption of the A1 tool for processing forgings*

Na grafikonu 2 je vidljivo da je drugi dan potrošnja alata pri obradi otkovaka iz grupe A manja od potrošnje alata za obradu otkovaka iz grupe B. To se desilo zato što se javio otkovak sa greškom koji je prouzrokovao lom dva vrha rezne pločice.

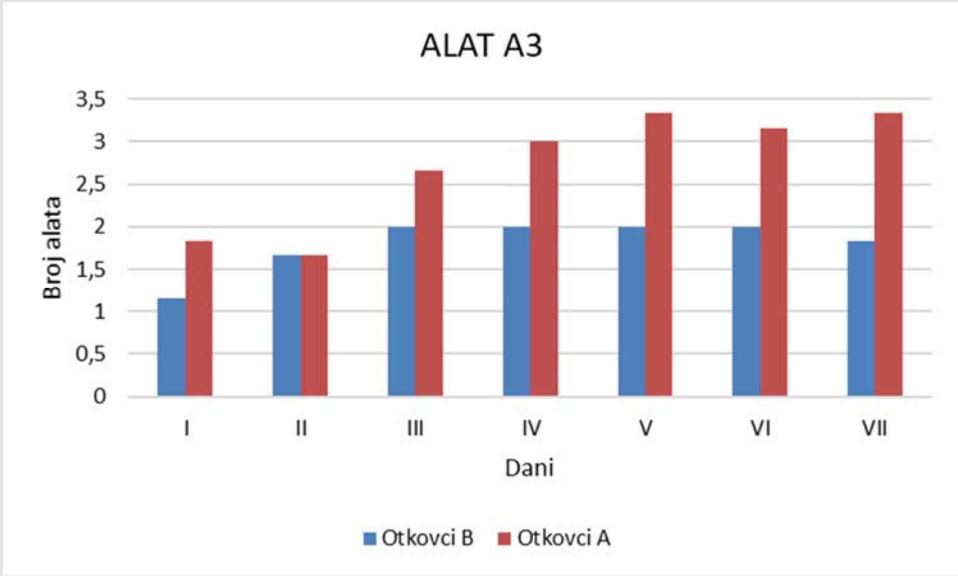
Chart 2 shows that the second day the consumption of tools for processing Group A forgings is less than the consumption of tools for processing group B forgings. This happened because a forging with a fault caused the fracture of two tops of the cutting tile.



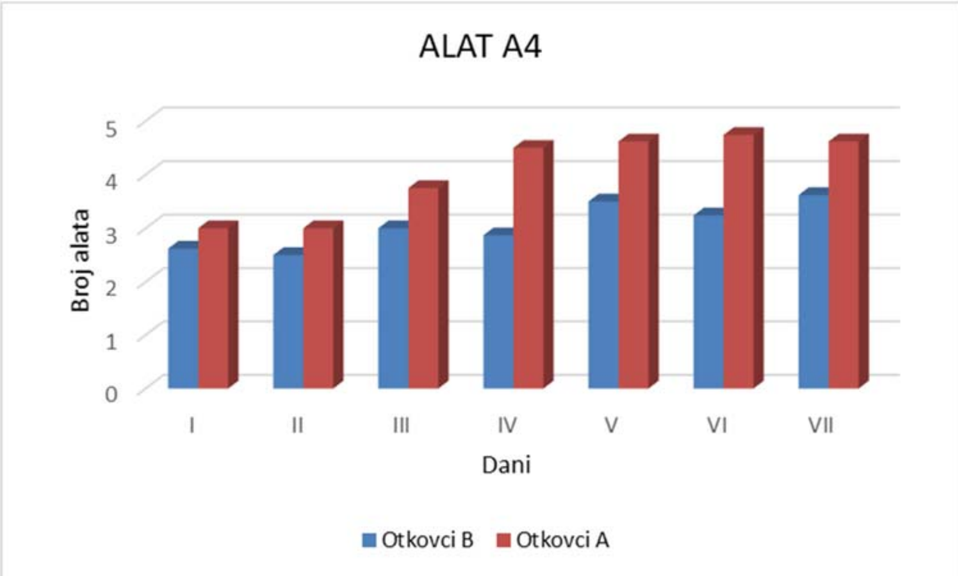
Grafikon 2. *Prikaz dnevne potrošnje alata A2 za obradu otkovaka*
Chart 2. *Display of the daily consumption of the A2 tool for processing the forgings*

Na trećem grafikonu se vidi da je drugog dana bila ista potrošnja alata iz obje serije, i tog dana došlo je do pojave otkovka sa greškom.

The third chart shows that in the second day the consumption of tools from both series was the same, and on that day there was an error with the forging.



Grafikon 3. *Prikaz dnevne potrošnje alata A3 za obradu otkovaka*
Chart 3. *Display of the daily consumption of the A3 tool for processing the forgings*



Grafikon 4. *Prikaz dnevne potrošnje alata A4 za obradu otkovaka*
Chart 4. *Display of the daily consumption of the A4 tool for processing the forgings*

Da bi se odredilo iskorištenje alata, mora se uzeti neka relevantna vrijednost koja neće zavisiti od broja komada. Zato je neophodno uzeti procentualno iskorištenje alata koje se računa na osnovu formule 1, gdje su:

- PI -procenat iskorištenja alata,
- NO1 -broj obrađenih komada alatom A1,
- NPO1 -broj komada koje bi trebalo obraditi po preporuci proizvođača sa alatom A1 (Tabela 4),
- nA-Broj alata utrošenog za izvođenje date operacije.

Dobijeni rezultati procenta iskorištenja alata dati su u tabeli 5.

In order to determine the use of the tools, some relevant value must be taken that will not depend on the number of pieces. It is therefore necessary to take the percentage of the utilization of the tools calculated on the basis of formula 1, where:

- PI -percentage of tool utilization,
- NO1 - number of processed pieces with tool A1,
- NPO1 - the number of pieces to be processed according to the manufacturer's recommendation with the A1 tool (Table 4),
- nA- Number of tools used to perform the given operation.

The obtained results of the percentage of tool utilization are given in Table 5.

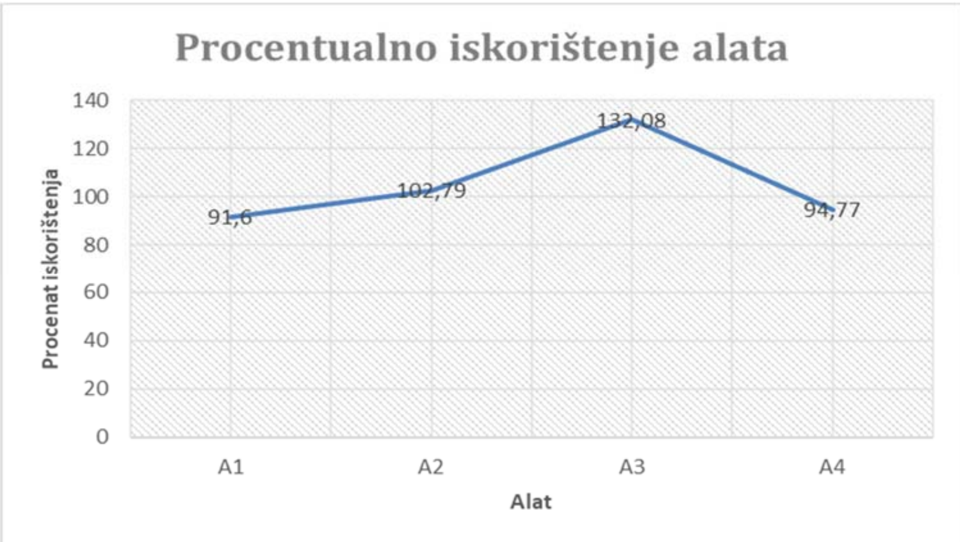
$$PI = \frac{NO1}{NPO1 * nA} * 100\% \quad (1)$$

Tabela 5. Procentualno iskorištenje alata
Table 5. Percentage of tool utilization

Alat	A1	A2	A3	A4
% iskorištenja	91,60	102,79	132,08	94, 77

Iz tabele 5, vidi se da je procenat iskorištenja alata relativno veliki. Razloge toga treba tražiti u dvije činjenice. Prvo, proizvođači alata svojim preporukama na neki način garantuju za kvalitet pločica reznog alata i drugo, materijal otkovka kao i kvalitet gotovog otkovka podliježe strožijim kontrolama.
Često se zna dogoditi da se vrati kompletna serija isporučenih otkovaka ako se utvrdi da nisu odgovarajućeg kvaliteta posmatranog po hemijskom sastavu i sa aspekta neželjenih uključaka u samom otkovku.
Na grafikonu 5 je prikazano procentualno iskorištenje alata u posmatranom periodu od sedam dana.

From Table 5, it can be seen that the percentage of tool utilization is relatively large. The reasons for this should be in two facts. First, the toolmakers with their recommendations in some way guarantee the quality of their cutting tool tiles and, secondly, the material of the forgings and the quality of the finished forging are subject to more stringent controls.
It is often possible that a complete series of delivered forgings is returned if it is determined that they are not of the appropriate quality observed by the chemical composition and from the aspect of unwanted inclusions in the forging itself.
Chart 5 shows the percentage utilization of tools in the observed seven-day period.



Grafikon 5. *Procentualno iskorištenje alata*
Chart 5. *Percentage of tool utilization*

4. ZAKLJUČAK

Hemijski sastav čelika otkovaka kao pripremka za izradu rukavca točkova motornih vozila igra važnu ulogu za postojanost reznog alata. Iz naprijed navedenog vidi se da vrlo mala promjena procenta nekih elementa (samo za 0,01 %), uslovljava relativno veliku razliku u postojanosti alata.

4. CONCLUSION

The chemical composition of steel for forgings as a preparation for the manufacture of wheel sleeves plays an important role for the consistency of the cutting tool. From the above, it can be seen that a very small change in the percentage of some elements (only 0.01%) causes a relatively large difference in the tool's consistency.

Pokazalo se da se obavezno lomi rezni klin ako dođe u zahvat sa uključkom u otkovku. Eksperiment je izvođen neposredno u samom procesu proizvodnje na CNC mašinama u stvarnom okruženju.
Relevantniji podaci bi se dobili kada bi se ispitivanje izvodilo u laboratorijama. Također, precizniji podaci o postojanosti alata u funkciji promjene procenta nekog od elementa mogli bi da se dobiju ako bi se kontrolisano mijenjao procenat samo jednog elementa, što ovdje nije slučaj, već su istovremeno mijenjani procenti više različitih elemenata.
Validan naučni pristup bi bio primjena metodologije planiranog eksperimenta.

It turned out that the cutting wedge is bound to break if it comes in contact with the inclusion in the forging. The experiment was performed directly in the production process on CNC machines in the real environment.
More relevant data would be obtained if testing was carried out in laboratories. Also, more precise data on the consistency of the tool in function of the change of the percentage of an element could be obtained if the percentage of only one element is changed, which is not the case here, since at the same time the percentages of several different elements are changed.
A proper scientific approach would be an application of methodology of the planned experiment.

5. REFERENCES

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