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Odločitveni kriteriji pri načrtovanju izdelave orodij
The Decisive Criteria in Design of Tool Making

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Aktualnost obdelave - izdelave orodij je izkazana za slovenski prostor kot alternativa, da se vgradi čim več znanja in dela v vsak izdelek. Prodaja takih izdelkov zagotavlja dober dobiček.

Opravljena anketa v naših orodjarnah kaže trenutno stanje glede velikosti orodij, uporabljenih materialov in postopkov za obdelavo ter cenovni pregled glede na zastopanost posameznih obdelav. Natančna analiza podjetja prispeva k dejanskemu načrtovanju ter osvetli vzroke za izgube in dobičke.

Kakovostni stroji, sodobna rezalna orodja in moderna tehnologija omogočajo izdelavo gravur v orodju s postopkom računalniško krmiljenega (RK — CNC) frezanja. Za trde materiale je izločilni kriterij trdota, 45 HRc za gravure, 64 HRc za gladilno poravnavanje plošč. Tako obdelavo lahko imenujemo tudi »frezanje v trdo«.

Odločitev za izbiro cenovno optimalnega postopka je torej v rokah tehnologa, ki pozna zahteve izdelka, hkrati pa mora z vidika stroškov načrtovati obdelavo, ki bo zagotavljala konkurenčnost na tržišču.

In Slovenia, tool making and tool machining has proven to be a topical issue as a way of building into a product more knowledge and work. Sales of this kind of products are offering good profits.

A questionnaire that was carried out in Slovenian tool making workshops shows the current stage in terms of tool size, tool materials used, machining procedures and costs per particular machining process. Each company's accurate costs analysis contributes to more realistic planning and highlights the reason for profits and losses.

High-quality machine tools, state-of-the-art cutting tools and newest technology enable the manufacture of engravings in the tool using the procedure of CNC milling. For hard materials the decisive criterion is hardness: 45 HRc for engravings, 64 HRc for fine milling — polish planing of plates. This kind of machining can also be termed »hard milling«.

The decision to select a procedure that is optimal in terms of costs is in the hands of the process planner who is knows the product's requirements, and has to plan the machining process so that the product will be price-competitive on the market.

0 UVOD

Glavna zahteva in težavnost odločitve za tehnologa sta izbrati najboljše postopke obdelave za izdelavo naročenega izdelka. Zato lahko v takem primeru govorimo o menedžmentu tehnologij, saj postopke obdelave, na primer preoblikovanje, odrezovanje, brušenje lahko opustimo oziroma nadomestimo z drugimi postopki.

Spremembe pri postopku izdelave izdelka so v veliki meri odvisne od vstopnega materiala in zahtev končnega izdelka. Zato je proizvodni čas in ceno izdelave mogoče zmanjšati z:

— uvajanjem izboljšav v posamezne obdelovalne postopke,

— elimininiranjem, nadomestitvijo ali s kombiniranjem postopkov,

— optimiranjem proizvodnih postopkov.

Optimizacija obdelovalnih postopkov se usmerja k večjim rezalnim razmerjem, povečanju kakovosti izdelkov, povečanju kompleksnosti izdelkov in povečanju prilagodljivosti postopkov. Povečanje prilagodljivosti obdelovalnih postopkov moramo

0 INTRODUCTION

The basic requirement and the problem posed to the technologist is to choose optimum machining procedures for the manufacture of the products required. So we can speak about management of technologies, since machining procedures such as forming, cutting and grinding may be omitted or substituted by other procedures.

Any change in the product manufacturing process is largely dependent on the incoming material and the requirements of the final product. The manufacturing time and price can therefore be reduced by the:

— introduction of improvements into particular machining processes,

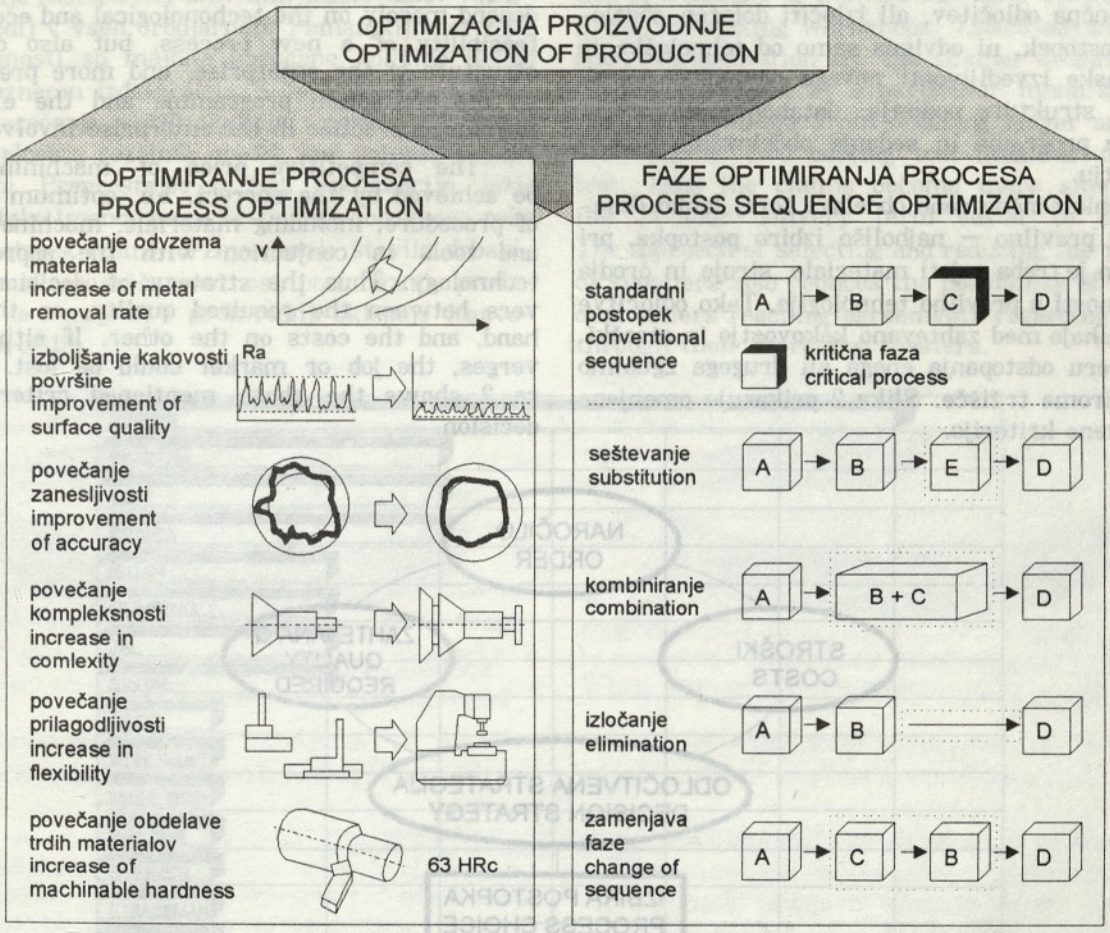
— elimination, substitution or combination of procedures,

— optimization of manufacturing processes.

It can be observed that the trend of optimization of machining processes is taking the direction of higher cutting ratia, improvement of product quality, increase of product complexity and flexibility of procedures. An increase in the flexibility of machining processes is to be understood as, for

razumeti, na primer kot zmožnost končne obdelave trdih (že toplotno obdelanih) materialov brez poznejšega grobega ali finega brušenja izdelka. Takšna prilagodljivost postopkov širi področje uporabe podobnih postopkov in zmanjšuje število postopkov, ki so bili prej potrebni za končno obdelavo izdelka. Optimizacijo vrstnega reda proizvodnje izdelka dosežemo z izločanjem, z zamenjavo ali s kombiniranjem določenih postopkov (sl. 1).

example, the ability to finish hard (already thermally treated) materials, without subsequent rough or precision grinding of the product. Such flexibility of procedures broadens the field of application of similar procedures and reduces the number of procedures which were formerly necessary for product finishing. The optimization of the product manufacturing order is achieved by elimination, substitution or combination of the defined procedures (Fig. 1).



Sl. 1. *Strategija za optimizacijo proizvodnje [1]*
Fig. 1. *Optimization of production [1]*

Standarden način proizvodnje izdelka, pri katerem je zaradi njegove funkcionalnosti zahtevana velika trdota (50 do 70 HRc), je groba obdelava vstopnega materiala, ki je v mehkem stanju, toplotna obdelava za doseganje želene trdote ter grobo in končno oziroma fino brušenje za doseganje zahtevane geometrijske oblike, kakovosti in natančnosti izdelka. Tako dolg postopek izdelave je potreben zaradi pomanjkanja (do pred kratkim) trdih, obrabno odpornih in žilavih rezalnih materialov, da bi lahko obdelovali trde materiale. Premalo pomembnosti smo posvečali togosti obdelovalnih strojev, njihovi natančnosti in potrebni veliki moči. Tradicionalna praksa je, da grobo obdelavo

Where in view of product functionality high hardness (50 to 70 HRc) is required, the conventional manufacturing method consists of rough treatment of the incoming material in the soft state; thermal treatment for achieving the desired hardness, then rough treatment, and finally, precision grinding to achieve the required geometry, quality and accuracy of the product. Such a long manufacturing process was (until recently) necessary due to the lack of hard, wear resisting and tough cutting materials, in order to be able to machine hard materials. Too little attention was paid to the rigidity of the machine tools, their accuracy and their required power. Generally, rough machining is performed on one machine tool and fine machining on another, the latter being

izvajamo na enem stroju, fino obdelavo pa na drugem stroju, ki je seveda bolj natančen. Če bi lahko izpustili grobo obdelavo ali grobo in/ali fino brušenje ter bi vstopni material že imel želeno trdoto, bi lahko nekatere obdelovalne postopke nadomestili z drugimi postopki obdelave. Tako bi imeli manjše stroške in krajše čase izdelave. Takšne prihranke lahko dosežemo z uvajanjem novih proizvodnih zamisli in z uporabo novih materialov za rezalna orodja.

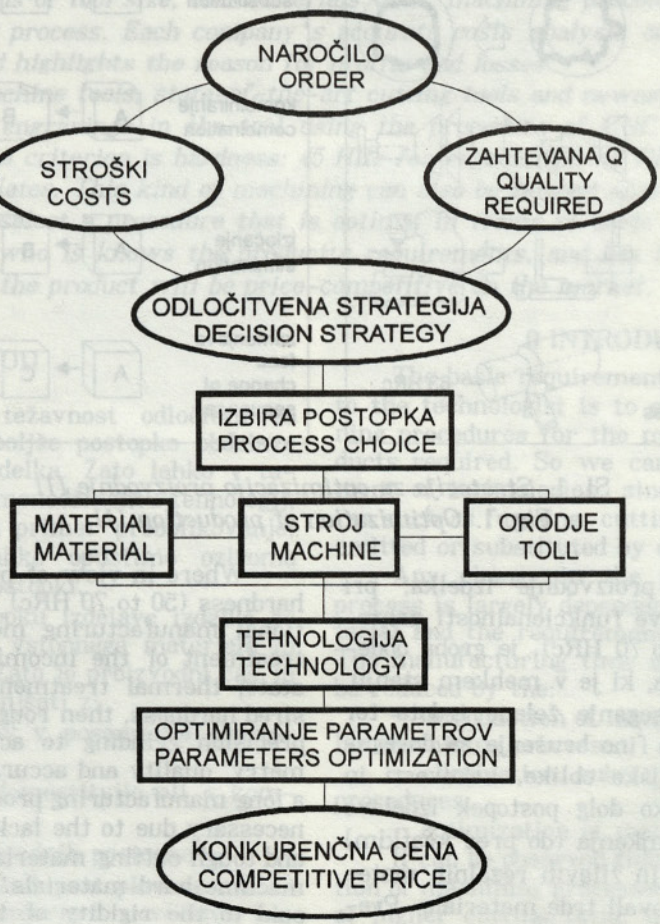
Končna odločitev, ali izločiti določen obdelovalni postopek, ni odvisna samo od tehnološke in ekonomske izvedljivosti novega postopka, ampak tudi od strukture podjetja, natančneje od proizvodnega programa in sedanje obdelovalne prakse v podjetju.

Konkurenčno ceno obdelave torej lahko dosežemo s pravilno — najboljšo izbiro postopka, pri katerem je treba zajeti materiale, stroje in orodja v skladnosti s pravilno tehnologijo. Tako odločitve vedno nihajo med zahtevano kakovostjo in stroški. V primeru odstopanja enega ali drugega zgubimo delo oziroma tržišče. Slika 2 prikazuje omenjene odločitvene kriterije.

more precise. If the rough machining or the rough and/or the precision grinding could be omitted and the incoming material already had the required hardness, some of the machining processes could be replaced by others. Costs could thus be reduced and the manufacturing time shortened. Such savings could be attained by introducing new manufacturing concepts and by application of new materials for cutting tools.

The final decision on whether a certain machining process should be eliminated does not depend merely on the techonological and economic feasibility of a new process, but also on the structure of the enterprise, and more precisely, on the production programme and the existing machining practice in the enterprise involved.

The competitive price of machining can be achieved by the correct, i.e. optimum choice of procedure, including materials, machine tools, and tools in conjuction with the appropriate technology. Thus the strategy of decision wavers between the required quality, on the one hand, and the costs on the other. If either diverges, the job or market could be lost. Figure 2 shows the above mentioned criteria for decision.



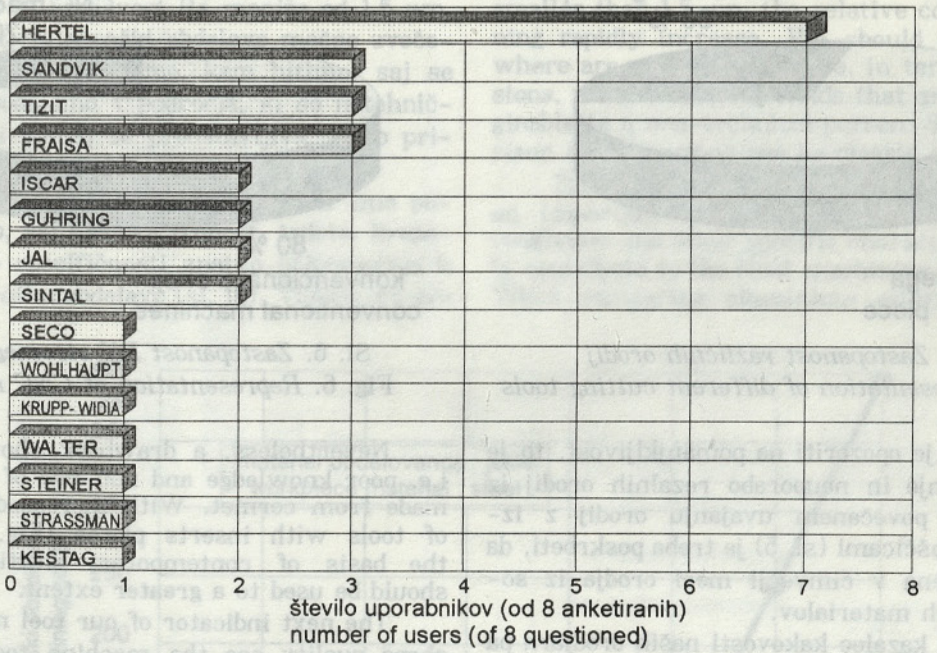
Sl. 2. *Odločitveni kriteriji, ki vplivajo na ceno obdelave*
Figure 2. *Decisive criteria effecting price of machining*

1 TRENUTNE RAZMERE V SLOVENSKIH ORODJARNAH

V letu 1993 je bila v osmih slovenskih orodjarnah, ki so bile izbrane sistematično, opravljena obširna strokovna anketa, nato pa rezultati obdelani in prikazani v povzetku [2]. V nadaljevanju želim predstaviti le nekaj rezultatov te ankete, ki so v neposredni povezavi z obravnavano problematiko tega prispevka. Razpredelnica na sliki 3 prikazuje zastopanost številnih izdelovalcev rezalnih orodij v vseh orodjarnah. Pomanjkljivost take zastopanosti so majhne naročene količine orodij posameznemu izdelovalcu. S tem izgubimo možnost naročanja večjih količin enemu ali dvema izdelovalcema rezalnih orodij, kar prinese popust pri ceni. Preprostejše so tudi reklamacije, lažja pot do tako imenovanega 24-urnega dobavnega roka itn. Postopek izbire in zmanjšanja števila dobaviteljev tudi zmanjša možnost posameznih prodajalcev, da z mojstri v proizvodnji sklepajo dogovore o naročilih.

1 PRESENT CONDITIONS IN SLOVENIAN TOOL MAKING WORKSHOPS

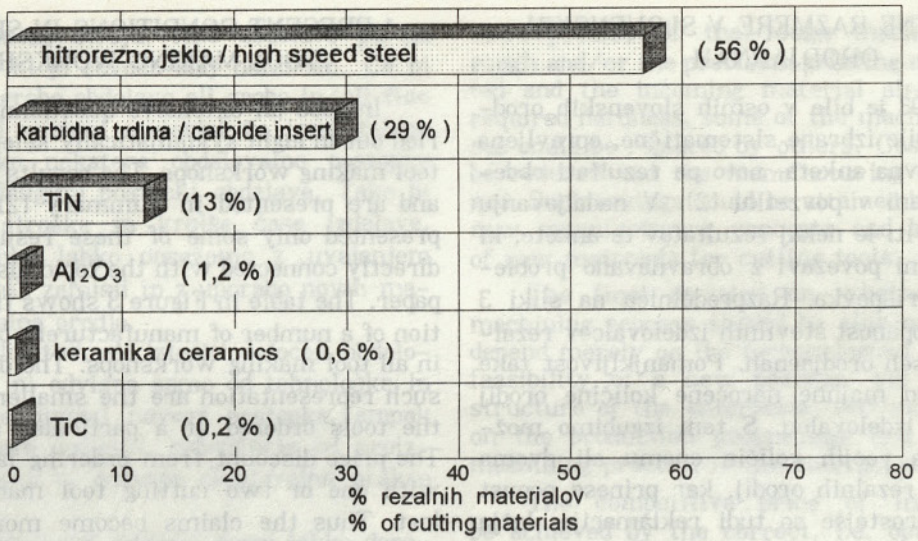
In 1993 an extensive questionnaire was carried out in eight systematically selected Slovenian tool making workshops. The results were analysed and are presented in Summary [2]. Below, are presented only some of these results which are directly connected with the topic discussed in this paper. The table in Figure 3 shows the representation of a number of manufacturers of cutting tools in all tool making workshops. The disadvantage of such representation are the smaller quantities of the tools ordered at a particular manufacturer. The price discount from ordering larger amounts with one or two cutting tool manufacturers is lost. Thus the claims become more simple and the 24-hour delivery term easier to achieve. The approach of selecting and reducing the number of suppliers also reduces the possibility of individual sellers reaching agreements regarding orders through their workshop masters.



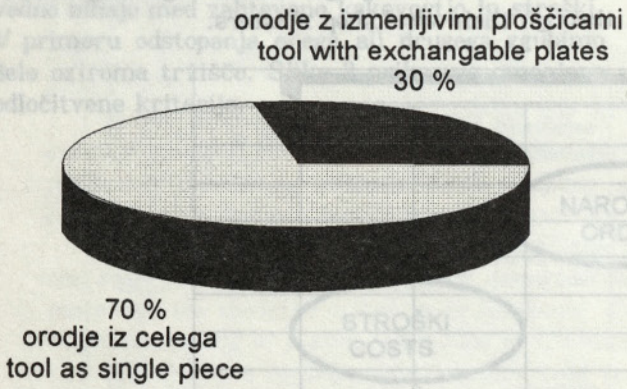
Sl. 3. *Zastopanost proizvajalcev rezalnih orodij*
Fig. 3. *Representation of cutting tool manufactures*

S slike 4 je razvidna zastopanost različnih materialov, iz katerih so izdelana rezalna orodja. Razvidna je očitna prevlada hitroreznih jekel, kar je povezano s podatkom, da je v orodjarnah še velik odstotek orodij iz celega (sl. 5). Razveseljivo je dejstvo, da se vedno bolj uveljavljajo rezalna orodja, oslojena s TiN, ki zelo izboljša lastnost orodju, če gre za nanos PVD [3]. Rezalne sile in s tem poraba moči, ki vpliva na ceno, so manjše, kakovost obdelane površine boljša, obstojnost orodja pa znatno daljša.

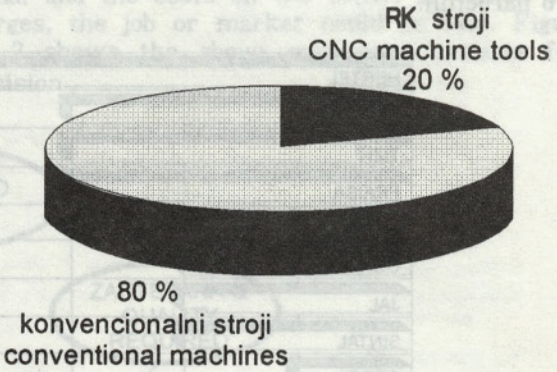
The Figure 4 shows the representation of various cutting materials from which cutting tools are made. The prevailing role of high-speed cutting tools is obvious, which is connected with the fact that a high percentage of tools in the tool making workshop are made as a single piece, Figure 5. It is worth noting that cutting tools coated with TiN (improving the tool character, provided PVD coating is used) are increasingly favoured. The cutting forces and thereby the power consumption, which influences the price, is reduced, the quality of the machined surface improved and the tool life largely prolonged.



Sl. 4. *Zastopanost različnih rezalnih materialov*
Fig. 4. *Representation of different cutting materials*



Sl. 5. *Zastopanost različnih orodij*
Fig. 5. *Representation of different cutting tools*



Sl. 6. *Zastopanost RK strojnega parka*
Fig. 6. *Representation of CNC machinery*

Treba pa je opozoriti na pomanjkljivost, to je na nepoznavanje in neuporabo rezalnih orodij iz kermeta. Ob povečanem uvajanju orodij z izmenljivimi ploščicami (sl. 5) je treba poskrbeti, da bodo uporabljena v čimvečji meri orodja iz sodobnih rezalnih materialov.

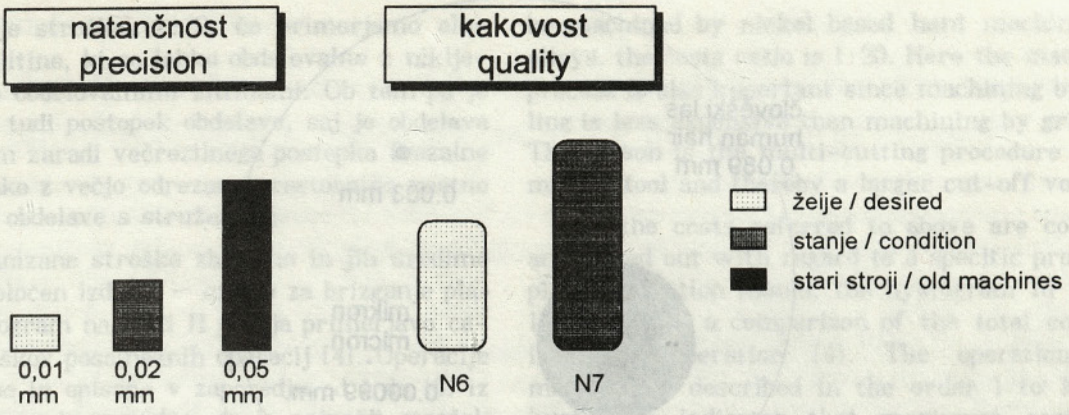
Naslednji kazalec kakovosti naših orodjarn pa so obdelovalni stroji, ki jih uporabljajo. Vse premalo je sodobnih — novih RK strojev (sl. 6), ki ob uporabi na primer istosmernega frezanja znatno pripomorejo h kakovosti izdelka. Velik del običajnih strojev, ki so med drugim tudi že precej stari, pa zahteva vsaj, da se na njih izvaja reden nadzor natančnosti. Fakulteta za strojništvo v Ljubljani ponuja možnost za meritve geometrične natančnosti ter statične in dinamične meritve.

Rezultati nenatančnih strojev se pokažejo v doseženih izmerah izdelka, kakor tudi pri kakovosti obdelane površine (sl. 7). Kakor vidimo odstopa za cel kakovostni razred od zahtev razvitega sveta.

Nevertheless, a drawback should be noted, i.e. poor knowledge and non-use of cutting tools made from cermet. With increased introduction of tools with inserts plates (Fig. 5) tools on the basis of contemporary cutting materials should be used to a greater extent.

The next indicator of our tool making workshops quality are the machine tools they use. Contemporary new CNC machine tool using climb milling for example, largely contribute to product quality, are not sufficiently used (Fig. 6). The majority of conventional machines, mostly old, require a planned precision control. The Faculty of Mechanical Engineering in Ljubljana offers the possibility of geometrical precision measurement as well as static and dynamic measurements.

The results of non-precision machines are shown in the obtained measurements of the product, as well as in the quality of the machined surface (Fig. 7). It is evident that the prevailing conditions are a litle behind the requirements of the developed world.



Sl. 7. *Doseganje natančnosti — kakovosti*
Fig. 7. *Precision quality*

2 POMEMBNI VPLIVNI DEJAVNIKI NA STROŠKE IZDELAVE

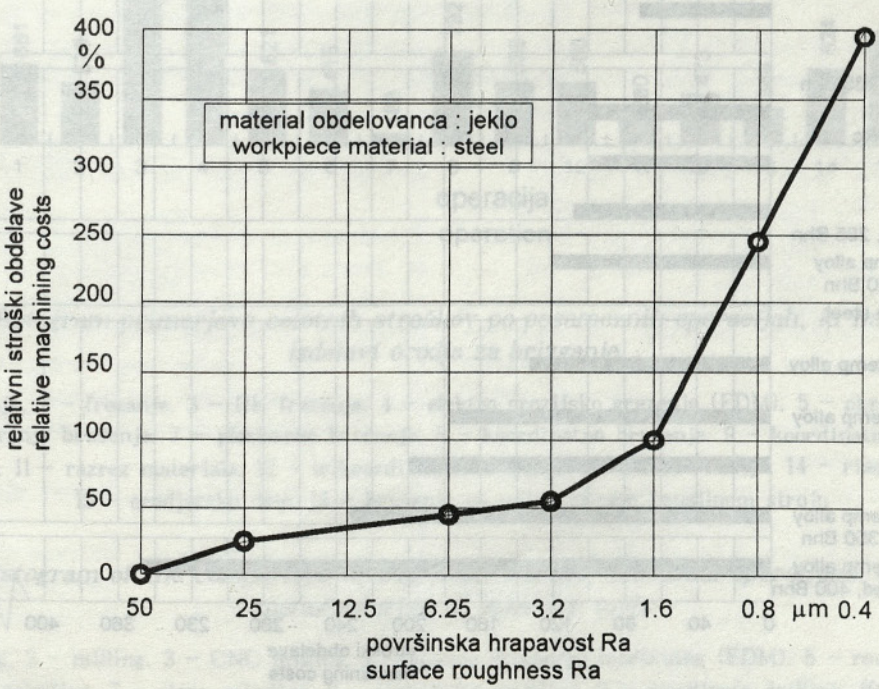
Zvečevanje stroškov obdelave je močno odvisno od želje po boljši površinski hrapavosti (sl. 8). Ko se namreč približujemo kakovosti obdelane površine, kjer je hrapavost Ra manjša od 1,5 μm, se začno relativni stroški obdelave močno zvečevati. Ob tem se vprašajmo, kam hitimo, saj se dimenzijsko podajamo v področja, ki so netehničnemu človeku komaj še predstavljiva. Tako primerjavo izmer nazorno pojasnjuje slika 9.

Poprej omenjen obdelovani material ima pomembno vlogo, saj njegova trdnost, trdota, hrapavost in druge specifičnosti znatno pripomorejo h končnemu strošku obdelave (sl. 10). Vidimo, da gre

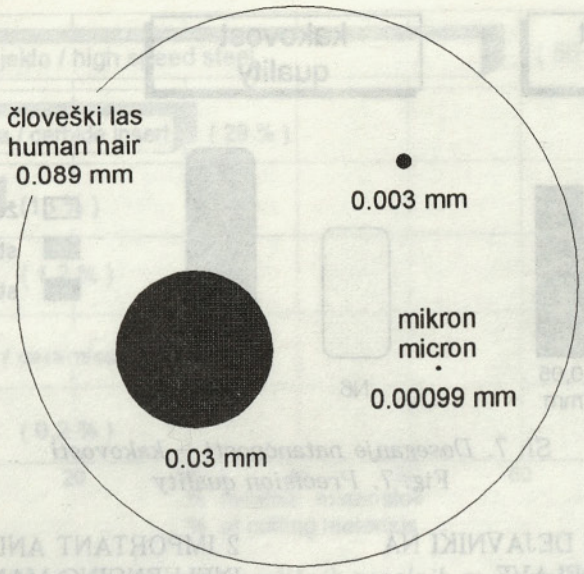
2 IMPORTANT AND DECISIVE FACTORS INFLUENCING MANUFACTURING COSTS

The trend of machining costs increase is largely dependent upon the demand for a better surface finished (Fig. 8). When approaching a quality of the machined surface, in which roughess Ra is smaller than 1.5 μm, the relative costs of machining rapidly increase. We should ask ourselves where are we running since, in terms of dimensions, we are entering fields that are hardly imaginable to a non-technical person. Such a comparison of dimensions can be clearly seen in Fig. 9.

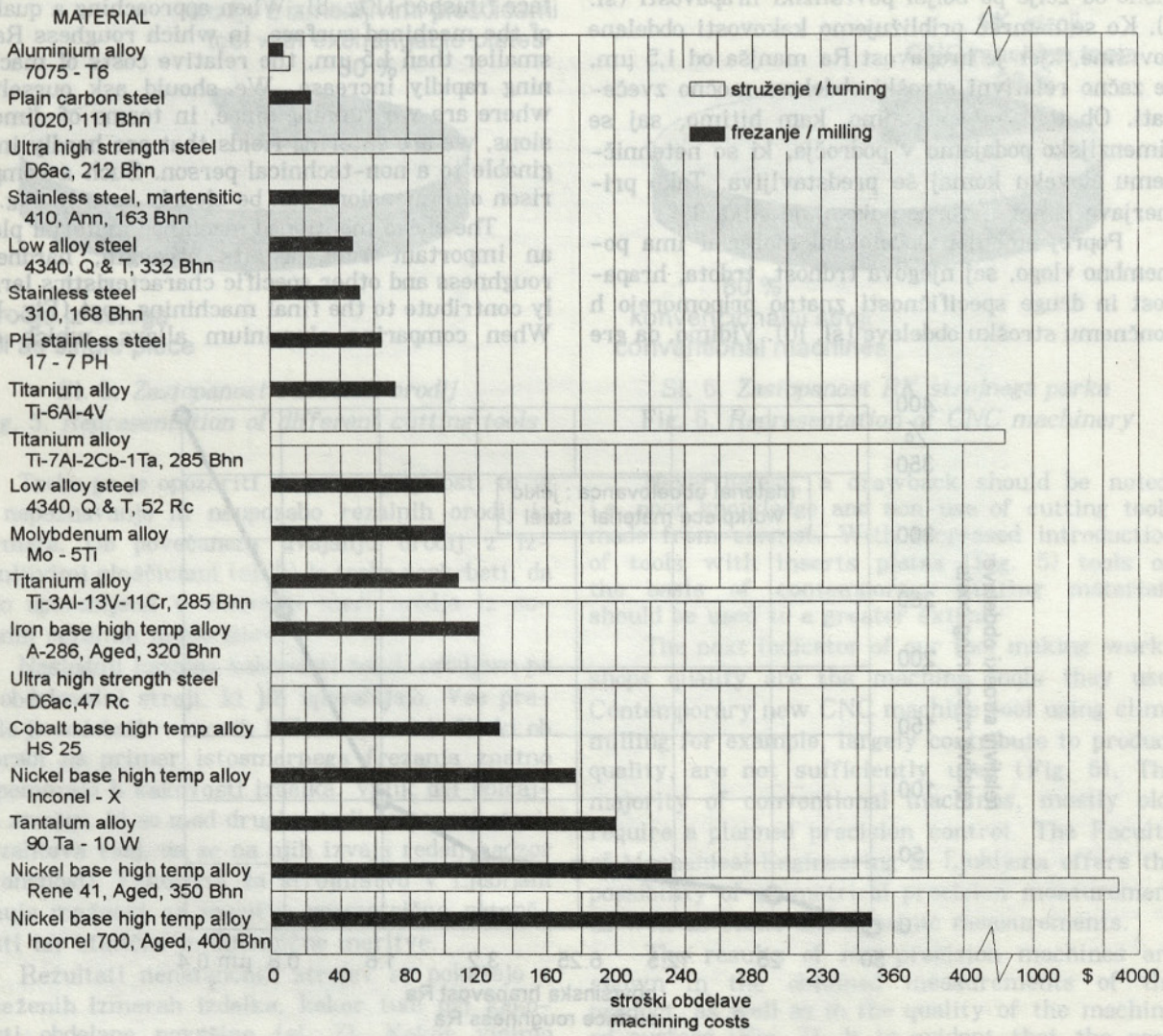
The above mentioned machined material plays an important role, as its strength, hardness, roughness and other specific characteristics largely contribute to the final machining cost (Fig. 10). When comparing aluminium alloys, which can



Sl. 8. *Relativni stroški obdelave in površinska hrapavost jekla*
Fig. 8. *Relative machining costs and surface roughness of steel*



Sl. 9. *Primerjava mikrona z drugimi dimenzijami*
Fig. 9. *Comparison of micron with other dimensions*



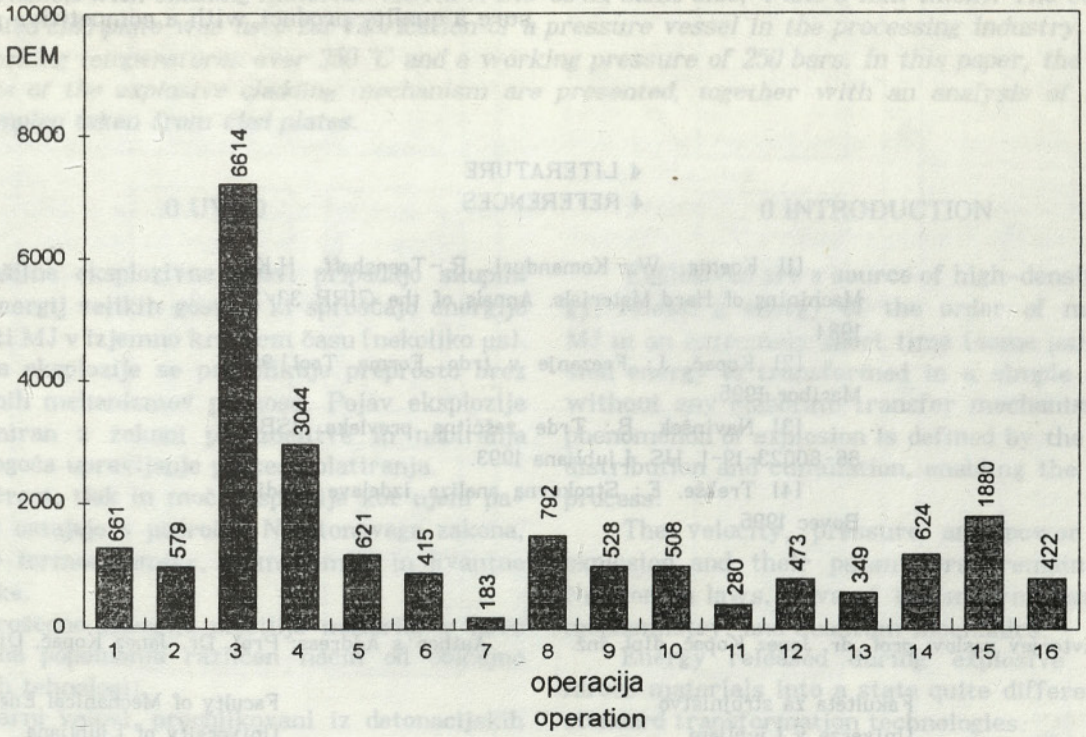
Sl. 10. *Relativni stroški obdelave trdih in mehkih materialov*
Fig. 10. *Relative costs of hard and soft material machining*

za razmerje stroškov 1:20, če primerjamo aluminijeve zlitine, ki so lahko obdelovalne z nikljevimi težko obdelovalnimi zlitinami. Ob tem pa je pomemben tudi postopek obdelave, saj je obdelava s frezanjem zaradi večrezilnega postopka frezalne glave in tako z večjo odrezano prostornino znatno cenejša od obdelave s struženjem.

Če nanizane stroške zberemo in jih uredimo glede na določen izdelek — orodje za brizganje plastike, histogram na sliki 11 podaja primerjavo celotnih stroškov posameznih operacij [4]. Operacije so označene in opisane v zaporedju od 1 do 16, iz histograma pa je razvidno, da je največji strošek računalniško krmiljeno frezanje.

be machined by nickel based hard machinability alloys, the costs ratio is 1:20. Here the machining process is also important since machining by milling is less expensive than machining by grinding. The reason is the multi-cutting procedure of the milling tool and thereby a larger cut-off volume.

If the costs referred to above are collected and sorted out with regard to a specific product - plastic injection mould, the hystogram in Figure 11 represents a comparison of the total cost per individual operation [4]. The operations are marked and described in the order 1 to 16, and hystogram indicates that maximum costs are represented by CNC milling.



Sl. 11. *Histogram primerjave celotnih stroškov po posameznih operacijah, ki nastanejo pri izdelavi orodja za brizganje*

1 — struženje, 2 — frezanje, 3 — RK frezanje, 4 — elektro erozijsko grezenje (EDM), 5 — okroglo brušenje, 6 — notranje brušenje, 7 — ploskovno brušenje, 8 — koordinatno brušenje, 9 — koordinatno vrtanje, 10 — kaljenje, 11 — razrez materiala, 12 — trikoordinatno merjenje, 13 — konstrukcija, 14 — risanje na HP 710, 15 — orodjarsko delo, 16 — brušenje na univerzalnem brusilnem stroju

Fig. 11. *Hystogram of the comparison of the total cost per individual operations, effected with manufacturing of injection tools*

1 — turning, 2 — milling, 3 — CNC milling, 4 — electro discharge machining (EDM), 5 — round grinding, 6 — inside grinding, 7 — plane grinding, 8 — coordinate grinding, 9 — coordinate drilling, 10 — hardening, 11 — material cut-off, 12 — 3D measuring, 13 — design, 14 — design with HP 710, 15 — hand work in tool shopwork, 16 — grinding on universal grinding machine

3 SKLEP

Novi rezalni materiali, sodobni obdelovalni stroji in svetovne zahteve po veliki natančnosti izdelkov nas silijo v neizprosen boj s tekmeci. Ob tem mora naše delo potakati usklajeno glede na optimalne proizvodne stroške. Zato moramo obvladati vodenje proizvodnje, da z racionalizacijo izločimo tiste operacije, ki pomenijo znaten strošek, kajti tam je mogoče z ustreznimi tehnološkimi spremembami ustvariti znaten prihranek. V obravnavanem primeru zmanjšamo strošek RK frezanja z uvedbo istosmernega frezanja, uporabo obračalnih ploščic iz kermeta, zvečanjem parametrov dela in podobno.

Analiza stanja, vodenje proizvodnje in racionalizacija izbranih operacij zagotavljajo kakovosten izdelek s konkurenčno ceno.

3 CONCLUSION

New cutting materials, contemporary machine tools and world demands for higher precision of products, force us into a very tough competition. Having this in mind, our work should be coordinated with regard to the optimum production costs. We have therefore to master production management in order to eliminate by help of streamlining those operations that represent a substantial cost. By adequate technological modifications a considerable saving can be attained. In relation to the case under consideration, the cost of CNC milling is reduced by the introduction of climb milling, the use of exchangable plates from cermet and increasing of work parameters and similar.

Production analysing, proper management and rationalization of chosen machining processes assure a quality product with a competitive price.

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