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DEVELOPING NEW MATERIALS AND TOOL GEOMETRY FOR MACHINING SPECIAL ALUMINIUM ALLOYS ON AUTOMATED TURNING CENTERS

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ABSTRACT: *Today's demands for high end materials are very high. They are used almost everywhere where weight reduction and environmental sustainability are required. Weight reduction is very important for lowering the cost for raw materials. The environmental aspect of this action is to make, produce and cast a material without to health hazardous materials. Aluminium usually consists of pure Al and some other elements from which the most health hazardous is lead (Pb). On the other hand, lead is also the main ingredient which has the biggest effect on the machinability of Aluminium alloys – it greatly improves the formation of short chips and in doing so, it enables better surface finish. This research focuses on testing different Aluminium alloys and different tool geometries – to determinate the best option to replace an Aluminium alloy with a high concentration of lead with an alloy with low concentration or preferably no lead as a main ingredient and to determine which tool geometry is best suited for machining such an alloy on automated turning centers.*
KEYWORDS: *turning, Aluminium alloys, tool geometry*

INTRODUCTION

The search for new materials is daily present. Some research is conducted during long-term tests [KOVALČIK, ČUBAN, 2010], where the durability of work piece material and the cutting tool is tested. Others are conducted more swiftly because of the industry's demands. In all branches of production and engineering, building and manufacturing the researchers search for a material with better physical properties and ways to produce the raw material with minimum costs. Aluminium is a widely used alloy, divided into different classes. Each classification has its unique ability and different chemical compound. It is appreciated and widely used in space, automotive and aircraft building because of its lower density in comparison to steel. It makes it is also ideally for applications where weight reduction is needed. A major drawback is its high thermal conductivity – so it has to be applied somewhere where the temperatures are not that high or some other elements need to be added to the alloy to change some of the physical properties such as the thermal conductivity, module of elasticity or the machinability. A big issue represents the new ecological – environmental laws, which prohibits or limits the use of alloys with hazardous elements.

Lead (Pb) as the main element in Aluminium alloys contributes to a very good machinability of this alloy. In consequence, because of the limitations, other ways has to be found to assure fast and accurate machining of such material. Parts, made of Aluminium alloys usually need to be in very tight tolerances and the manufacturers can't allow costly throw outs. To assure quality machining different methods are used. These methods are:

- *Specially designed tool geometry – rake angles reaching from minimum 6° to maximum of about 20°,*
- *Use of cutting fluids,*
- *Adapted cutting parameters such as feed rate and cutting speed.*

RESEARCH WORK

Tool geometry is very important to assure the right formation of the chip (removed material).With extensive testing, a lot of researchers agree on the most useful geometry [MATSUMOTO, HASHIMOTO, LAHOTI, 1999] – the values for rake angle vary from 6°to 20°. In some cases the angle can be set as high as 25°. Also the flank angle has to be more than 0°. This is mainly because of the mechanical properties of the aluminium. To find the right combination for a certain type of alloy, lots of further tests are needed. Some of the tests were conducted during our research. The rake angle of 6° was the starting point of our investigation. In some previous tests, this geometry proved very useful. But during further investigation it was discovered that the work piece material was rich with lead. This material greatly improves the chip formation and therefore the adjustments to the geometry can be kept at minimum. Machining other aluminium alloys with different chemical composition is more challenging. The base for developing new geometry was at 6°angle for rake angle. The next difficulty was to determine the influence of a shaped tool with different depths of cut, figure 1. The geometry and shape varies and in some places the depth between two planes is at its maximum of 5 mm. At a certain *cutting speed, there is always a difference between cutting speeds at its outer and inner surface. In conclusion, this difference in the depth of cut can produce very different chips so with testing different cutting parameters the most useful data is going to be determined. The stock turning tool was tested before, without adjustments to its shape or geometry. We altered some tools to test the changes, but because of incorrect grinding, the results were not satisfying. The next set of tests was conducted with specially prepared cutting tools, grinded to shape and afterwards polished.*

For testing purposes two different tool geometries were prepared. The rake angle (γ) was changed, 6 and 12°. The flank angle (α) was always 6°. The angle of the tool (β) was 78° and 72°. The positive rake angle was chosen because of the better machinability and better end quality of the surface.

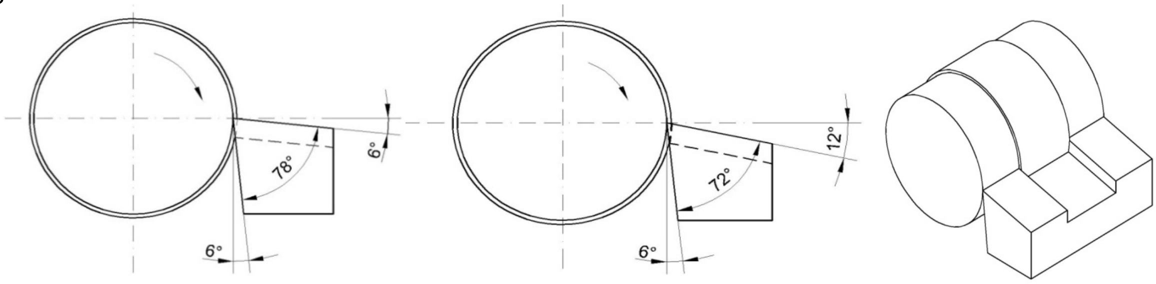


Figure 1: The basic tool geometry

CUTTING FLUIDS

In machining industry, the cost for coolants and lubricants already approaches 20% of the whole production costs per series. When comparing the cost for cutting tools (milling heads, drills, inserts ...), the cost for cutting fluids already exceed the cost for tools. In high-volume machining, cutting tools represent approximately 5% of the total machining costs. Comparing those values, one comes to an important question if the use of cutting fluids is economically meaningful. Although the costs are very high, it does have some advantages of using the cutting fluids. These advantages are:

- *Better end quality of the surface finish,*
- *Lowering the temperature of the cutting tool and work piece,*
- *Extending the tool durability – life expectancy,*
- *Reduction of contact time between tool and work piece,*
- *Lowering the heat load on the tool, work piece and machine centre.*

Because of above mentioned advantages and the demands for quality in the production, the tests were conducted with the use of cutting fluids.

The cutting fluid can be applied in different ways such as flood application, trough – tool application or as mist. Some researchers use different methods among them is near dry machining [ATTANASIO, GELFI, GIARDINI, REMINO, 2006] and high pressure cooling [KRAMAR, KOPAČ, 2009]. These techniques are applied to different materials but they are still in development phase, therefore the decision was made to use flood application.

PREPARATIONS AND TESTING

Two different Aluminium alloys were casted and prepared as cylindrical work pieces in a Slovenian company, Impold.o.o. Alloys with the designation AC41 and AC62 were casted, both of them developed for the sole purpose of replacing the old alloy with lead. The difference between them is in their chemical structure and in the procedure that they were artificially altered – aged. Table represents their main chemical compounds of each of the alloys.

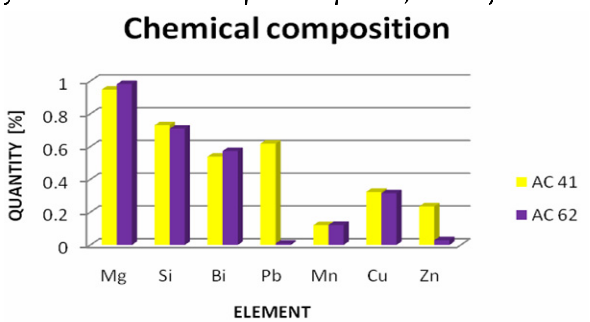


Figure 2: Chemical composition of work piece material

Table 1: Cutting parameters

AC 41		AC 62	
v_c [mm/s]	f [mm]	v_c [mm/s]	f [mm]
1630	0.02	820	0.02
2030	0.0315	1020	0.0315
2530	0.04	1280	0.04
4050	0.05	2050	0.05
/	0.071	/	0.071
/	0.1	/	0.1
/	0.14	/	0.14
/	0.16	/	0.16

For testing, different work piece diameters were chosen. Because of that, the cutting parameters needed to be adopted and changed during the testing, table 1.Some cutting parameters were in previous similar tests optimised. Other researchers also use different methods to optimize the cutting parameters and conditions [ČUŠ, ŽUPERL, 2006], [NIAN, YANG, TARNG, 1999], [TOSUN, OZLER, 2004]. Their approach differs in the methods used to optimize certain parameters.

For certain tests the Taguchi's method was used for optimization of multiple parameters. The results achieved with the help of this method were just for orientation – because of the newly developed alloys and the uncertainties in the material behaviour, the risk was too great to use them without precaution. The modified values from table 1 were combined; the right combination for a certain test is in table 2 and 3 with the according figure 3. Other possibilities for optimization of cutting parameters are being also considered. The main disadvantage of theoretical optimization is the need for large amounts of experimental data. This data needs to be collected and the results from this tests are going to be included into others optimization experiments.

Also two different tool geometries were prepared, one with the rake angle of 6°, the other with a rake angle of 12°. The flank angle is in both cases the same = 6°, figure. Tests were conducted one after another with no special time breaks. The first test was always conducted with the smallest values for cutting speed and feed rate – this was a precaution to prevent overload of the cutting tool or breakage of the work piece or cutting tool. During all tests, the cutting tool and work piece were cooled with special cutting fluid. The quantity used to cool was about 3 litres per minute – the cutting fluid was then cleaned and reused. The total amount of the fluid in the system was 30 litres and was during the tests not changed.

Table 2: AC62 alloy

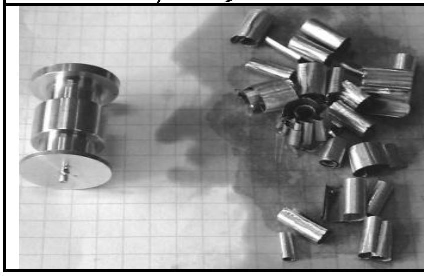
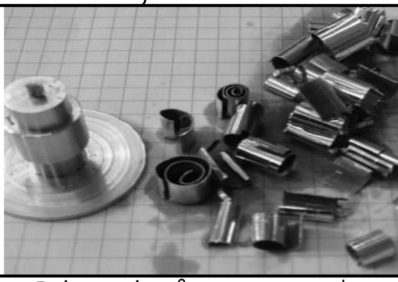
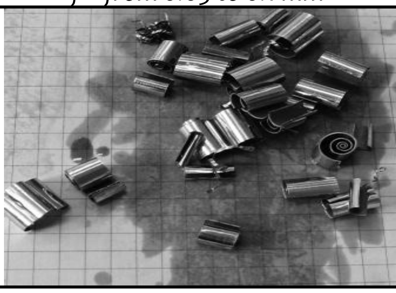
Rake angle 6°, v_c = 1020mm/s; f = 0.05 mm	Rake angle 12°, v_c = 1020mm/s; f = 0.071 mm
	

Table 3: AC41 alloy

Rake angle 6°, v_c = 1630mm/s; f = 0.1 mm	Rake angle 6°, v_c = 2030mm/s; f = 0.1 mm	Rake angle 6°, v_c = 2530mm/s; f = 0.16 mm
		
Rake angle 12°, v_c = 1630mm/s; f = 0.1 mm	Rake angle 12°, v_c = 2030mm/s; f = from 0.05 to 0.1 mm	Rake angle 12°, v_c = 2530mm/s; f = from 0.1 to 0.16 mm
		

To determine the power consumption and to determine the machine for the tests, equation 1 was used.

$$P_c = \frac{k_c \cdot a_p \cdot f \cdot v_c}{60000} \qquad (1)$$

Depth of cut (a_p) was maximum 10 mm, feed rate (f) and cutting speed (v_c) are in table 1, the specific cutting energy coefficient (k_c) was chosen from an appropriate table for aluminium. When all combinations were calculated, the maximum needed power was estimated to 14 kW. Accordingly to this value, a turning machine was chosen.

RESULTS

The heat, produced during the cutting procedure need to be transferred as fast as possible from the cutting point. The best way to do this is by producing short chips and to cool the cutting point with cutting fluid. The shortest chips and therefore the best chip in our tests occurred – results are shown in table 2 and table 3.


Figure 3: Bad results with long, continuously chips

Pictures show the best results during our testing. The shortest chip was in length 8 mm, the longest was > 500 mm. The longest chips were immediately removed from the results. From the short ones; the shortest was measured and picked out.

DISCUSSION

Both Aluminium alloys, developed and casted in Impold.o.o., have similar chemical composition; the main difference is in the quantity of lead (Pb). The presence of lead assures the formation of short chips. Also the tool geometry is very important. The tests reviled how the rake angle influences on the cutting parameters. The greater the rake angle is, the greater the feed rate can be and consequently the production time shortens. Further on, the cutting parameters are also very important. Because there is no such extensive data base of cutting parameters for Aluminium as for steel, most of the parameters were chosen randomly. After the initial results, these were then used as a starting point for other tests with similar alloys. Considering the best results, for further testing and starting point we can orientate on these cutting parameters. Further optimization of cutting parameters is facilitated and it is less time consuming. Therefore one can concentrate on other things, including the tool geometry. From the cutting parameters, the main influence has the feed rate. Seen in the tests, there are a lot less good results using constant feed rate and changing cutting speed than when using constant cutting speed and changing feed rate. Every alloy needs its own parameters, but for orientation these numbers can be used. Also at all tests cutting fluid was used to assure proper cooling and lubrication of the tool and work piece. Figure 4 shows the damaged work piece at to high cutting speed, respectively feed rate. The work piece broke off. The tool was not damaged.


Figure 4: Damaged work piece

CONCLUSIONS

The material AC 62 has a big potential in further developing and machining on automated turning centres, mainly because of its low concentration of lead. Reviewing the literature, in oncoming tests the tool geometry is going to be changed. Researchers propose the use of rake angles greater than 15°. The next series of alloys will be machined with the rake angle of minimum 15°. Also in next tests more complex tool geometry is going to be applied to determine the relevance of the cutting parameters modification for automated turning centres.

REFERENCES

[1] KOVALČIK, J.; ČUBAN, J.: Long-term tool life tests of american made nitride ceramic insert's used to turn grey cast iron work-piece materials, Tome VIII, Fascicule 1, (ISSN 1584 – 2665), pp. 123-128, 2010.

[2] ATTANASIO, A.; GELFI, M.; GIARDINI, C.; REMINO, C.: Minimalquantitylubrication in turning: Effect on toolwear. Wear. 260, 333–338, 2006.

[3] ČUŠ, F.; ŽUPERL, U.: Approach to optimization of cutting conditions by using artificial neural networks, J Mater ProcessTechnol, 173(3), 281 – 290, 2006.

[4] MATSUMOTO, Y.; HASHIMOTO, F.; LAHOTI, G.: Surface integrity generated by precision hard turning, CIRP Ann 48(1), 59 – 62, 1999.

[5] KRAMAR, D.;KOPAČ, J.: Highpressurecooling in themachiningofhard-to-machinematerials = Odrezavanje težko obdelovalnih materialov z visokotlacnim hlajenjem, Stroj. vestn., vol. 55, no. 11, str. 685-694, 2009.

[6] NIAN, C. Y.; YANG, W. H.;TARNG, Y. S.: Optimization of turning operations with multiple performance characteristics, Journalof Material Processing Technology 95, 90-69, 1999.

[7] TOSUN, N., OZLER, L.: Optimization for hot turning operations with multiple performance characteristics, Int. J. Adv. Manuf. Technol, 23, 777-782, 2004.

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