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The Influence of Milling Tool Geometry on the Quality of the Machined Surface

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Abstract

One of the most important things for a milling is know which material would to be machined. Different milling conditions are required for each type of material and it is not possible to use just one type of milling tool if we want to have the best efficiency. Therefore different setting of tool geometry is used for different materials.

In end mills change of rake angle has an effect on plastic deformation, chip making and forces from machining. For changing surface quality, friction and toughness of mill, we must change the clearance angle on the tool. The next angle, which we can find, on the tool is the edge angle and it is given by the previous two angles. The helix angle, which sets which direction the chip goes out, depends on vibration or the number of edges, which will be in the cut.

Three end milling variations, which have different degrees of geometry change, were suggested. They are based on current end mill from hard metal. More information and results are available in the article.

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Introduction

The following article gives concise information related to the requirements of manufacturing in relation to efficiency of the milling process, with reference to reducing machining costs in the organization Novem Car Interior Design k.s. The main products researched in the environment are car interiors, in the main wooden veneers, aluminum and carbon structures, known as sandwich materials [5] The milling process is often complex and the production is discussed in the research and development. The way how to achieve better results would be develop new end mill with different tool angles than current cutter and which has higher efficiency It should be from hard metal material with diameter 8 millimeter and length 60 millimeter from sorts in [1]. There is not possible to use any end mill from known supplier, they have not any suggestion for used part sandwich material [2]. In [4], the authors also show the influence between different of helix angle on cutters, just there is used serrated end mill. For the perform testing was selected one of the machines. In the conclusion the solutions and results are displayed.

Nomenclature

ABS	Akrylonitrilbutadienstyren
PUR	Polyuretan
HM	Hard metal
mm	Millimetre

1. The method used

For the experiment was selected five axis machine MAKA M1. It is usual used for wood milling. It has 2 engines and 2 moving tables in axis Y. Milling conditions are for every variations same and are shown in Table 1. Rough part, which was picked out, is called Miko Audi D4 and it is part of middle panel in the car Audi A8. As was written in introduction, it is made from ABS plastic, wood, aluminium, PUR and glue. It is currently milled by HM end mill with diameter 8 mm, length 60 mm and two edges. That was used like a base for 3 variations of tools for this experiment. Each variation would show the influence of each angle on each parameter.

Fig. 1. The work part.

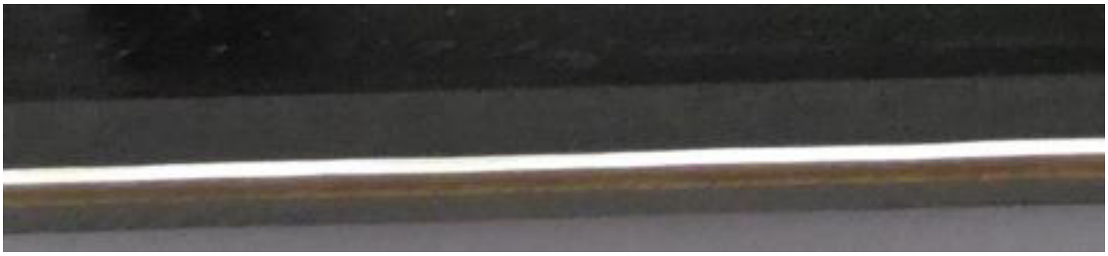

Fig. 2. Cut of part.

Table 1. Milling conditions.

	Values
Finish operation working feed	4860 - 6500 mm/min
Rough operation working feed	3600 - 5400 mm/min
Turns	38000 ot/min

2. Technical solutions

For achieve of the better results and efficiency were developed 3 new variations. They have continuously changed geometry parameters for better check of differences between them. In the first step was used neutral geometry, which means, that helix angle has 0°, so it is straight edge cutter. Then, in variation 2 was half angle, so 7,5°, than is used on the standard end mill and at last were changed also helix angle, against standard cutter, with rake and clearance angle.

2.1. Standard end mill

Current end mill which is used for chosen part has concrete life time and his change happened due the bad cut surface or uncut material (it push material under the cutter but it stay in position). In table is possible to see geometry set up.

Table 2. Standard cutter geometry.

	Standard
Rake angle	13°
Clearance angle 1	22°
Facet	0,7 mm
Core diameter	3,3 mm
Helix angle	15°
Clearance angle 2	35°
Production time	8,5 min
Price	11,55 €

2.2. Variation 1

In variation 1 was good to see the helix angle influence (from 15 degree to 0 degree), because it defined the way of the outgoing cut material and also on that depend the forces by milling. And with forces is connected, how fast the end mill going to wear. Therefore was expected lower chips press under the end mill and milling material should not be pulled or pushed into cutting area.

Table 3. Variation 1 geometry.

	Variation 1
Rake angle	13°
Clearance angle 1	22°
Facet	0,7 mm
Core diameter	3,3 mm
Helix angle	0°
Clearance angle 2	35°
Production time	9,5 min
Price	11,94 €

Fig. 3. The end mill variation 1.

2.3. Variation 2

In variation 2 the helix angle was also changed but in another direction (from 15 degrees to 7.5 degrees). It was expected that this change will has an influence on the displaced chips and wear of milling edge also.

Table 4. Variation 2 geometry.

	Variation 2
Rake angle	13°
Clearance angle 1	22°
Facet	0,7 mm
Core diameter	3,3 mm
Helix angle	7,5°
Clearance angle 2	35°
Production time	8,5 min
Price	11,55 €

Fig. 4. The end mill variation 2.

2.4. Variation 3

And in the third variation the helix was changed the same as for variation two, plus change of rake angle (from 13 to 18 degrees) with clearance angle which have together an influence on the sharpness of the cutting edge. As this is sharper edge.

Table 5. Variation 3 geometry.

	Variation 3
Rake angle	18°
Clearance angle 1	25°
Facet	0,7 mm
Core diameter	3,3 mm
Helix angle	7,5°
Clearance angle 2	35°
Production time	7,5 min
Price	11,13 €

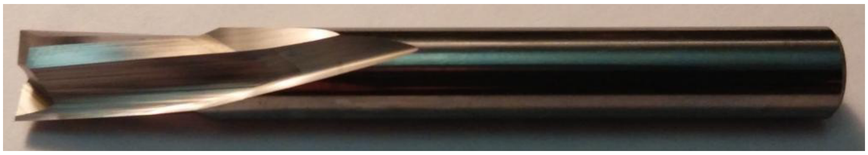

Fig. 5. End mill variation 3.

3. Results after milling

End mills were changed in machine after the cut surface was not in good quality. It means that it had not be smooth or it was damaged. For each variation were controlled every milled part with surface by machine operators which are responsible for analyzing of first step quality after milling. Some defects would be repaired, but even that is also unaccommodating, because operator's time is not being used effectively and efficiently. In the cleaning process time management is vitally important.

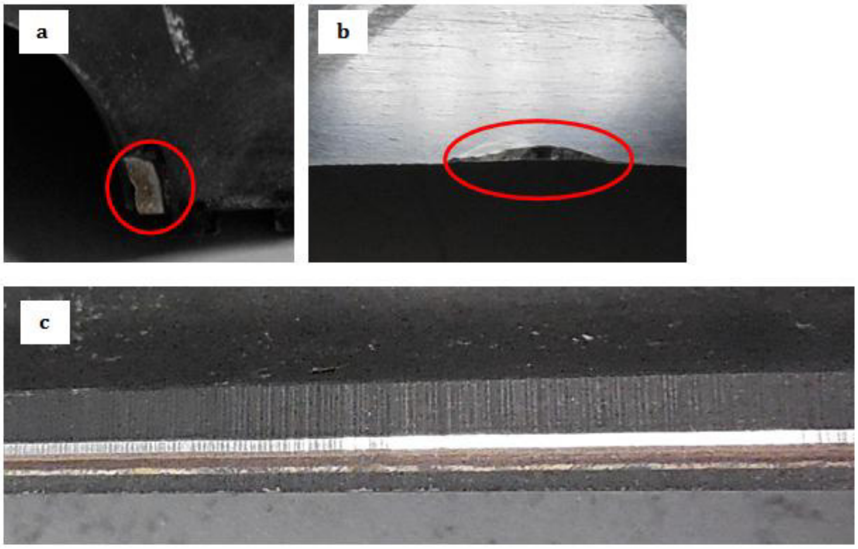

Fig. 6. (a) reason variation 1; (b) reason variation 2; (c) reason variation 3.

Figure 5 shows concrete reasons of end mill change. On figure 5 (a) (b) is reason for variation number 1 and 2. It is damaged surface on part, there were nipped PUR lack. It probably happened because edge lost sharpness and pressure on part was higher so inside of it cumulate a tension, until it release and make these defects. In case of figure 5 (c) is show the change reason for variation 3, surface was not smooth as is requested. It is probably because cutting edge was very worn and diameter of cutter were changed. Next reason is that this set up of geometry was not stabile by milling with used milling conditions so the cutter start vibrate and make shown surface.

In the table 6 is presented results summarization from experiment. Price of one part means how many we pay for one produced part. It is compared just for end mill price and produced parts by concrete variation. On that is based the last column, efficiency which show, if any variation was better than standard cutter or not. If it is over 100% then it was better.

Table 6. Results summary.

	Milled by tests [pcs]	Standard [pcs]	Change reason	End mill price [€]	Price of one part [€]	Efficiency [%]
Variation 1	139		Damaged PUR	11,94	0,09	154
Variation 2	40	90	Damaged PUR	11,55	0,29	44
Variation 3	63		Bad surface	11,13	0,18	70

Conclusion

The best variation, as table 6 shows, was variation 1 with straight cutting edge. It produced for 49 pieces more than is standard, price is for 0,39 € higher but despite that cost per one part is much lower and efficiency much higher. On second place, with lower price but lower milled parts is variation number 3. On the last position is variation number 2 which has the lowest produced parts, same price as standard end mill and very low efficiency. On the paper is shown, that change of helix angle on end mill to the 0 degree has good influence on the life time of cutter and sandwich material surface quality. So problem to find some more efficient solution were positively resolved. For the future were suggested to use end mill as variation 1 because it should make the milling costs lower due to its higher efficiency.

Acknowledgements

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