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High-speed milling of light metals

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ABSTRACT

Purpose: Purpose of this paper: Introduction applicability of high-speed cutting of light metals is presented in this paper.
Design/methodology/approach:HSC is the result of numerous technical advances ensuring that milling has become faster than conventional milling and has gained importance as a cutting process. The advantages of the HSC milling are higher productivity owing to the reduction of machining times increase of the flow time of production, reduction of the number of technological operations, increase of the surface quality and longer service life of tools. The machining conditions for execution of the HSC (36000min-1 and feeding 20m/min) require modernly built machine tools to meet those machining conditions.
Findings: Continuous development of new materials is more and more dynamical, particularly, in the automobile, aircraft and electronic industry and in the manufacture of various mechanical parts. Also the achievements in the area of building of machines and tools, ensuring high cutting speeds (highly efficient machining) have contributed to development of the process.
Research limitations/implications: High quality of the surfaces, the quality of this so-called HSC milling can be compared to grinding.
Practical implications: High-speed milling of light metals from aluminium and magnesium is more and more frequently used in practice. This result is high quality of the surface and shorter machining times. In some cases when machining by grinding is specified, the latter is omitted.
Originality/value: The applicability of high-speed milling has proved to be successful, when aluminum and magnesium alloying materials are machined.
Keywords: Machining; High-speed milling; Light metals

1. Introduction applicability of HSC in cutting of light metals

The advantage of HSC milling are higher productivity owing to reduction of manufacturing times, increased flow time of production, reduced number of technological operations, increase in surface quality and longer service time of tools [1]. The HSC milling differs from the conventional milling, particularly, in the manner of formation of the chip, and its removal and tool geometry [2].

The applicability of this machining has proved to be successful, when very exacting materials, the so-called new materials, are machined. One of such widely used materials is aluminium with various alloying elements. The parts to be built in must be appropriate for exacting shapes, easy machinability, small mass and must overcome extreme operating conditions. To ensure the material to satisfy the mentioned requirements the alloy must be alloyed with elements meeting all conditions, e.g. the example for thermal resistance AlZnMgCu1,5-F51 ($R_m \approx 540$ N/mm^2 , AlMg3-F18 ($R_m \approx 215$ N/mm^2), AlMg4,5-Mn-F27 ($R_m \approx 305$ N/mm^2), AlCuMg1-F40 ($R_m \approx 5050$ N/mm^2).

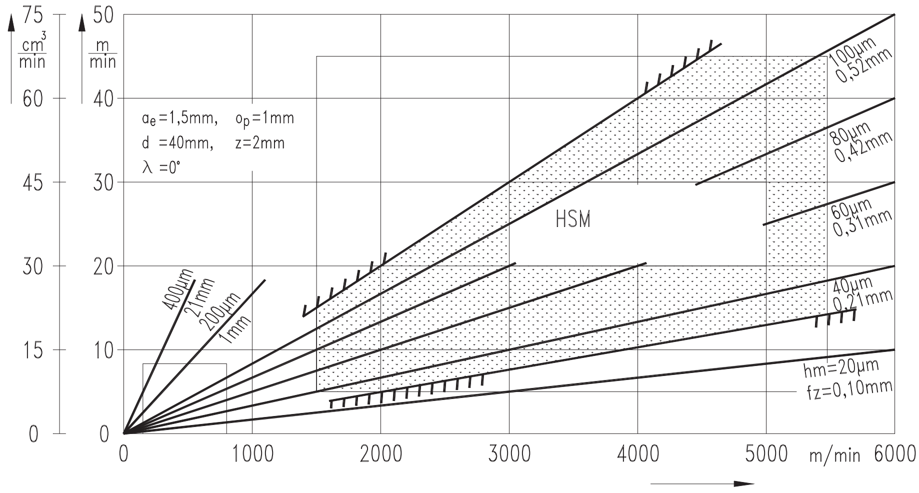

Fig. 1. Working area of high-speed milling

Table 1.
Machining values for light metals

	Aluminium			Magnesium
	Alloying casts		Wrought alloys	Alloying casts
	Si ≤ 12%	Si > 12%		
Circular milling				
v_c [m/min]	1300	1200	4700	1500 - 5500
f_z [mm]	0,43	0,47	0,04 - 0,2	0,16 - 0,23
v_f [mm/min]	9000	9000	2000 - 10000	13000 - 20000
Cutting material	KT - K 10	PKD	KT - K 20	KT - K 10
Boundary conditions	a_c = 1,5 mm D = 40 mm z = 2		a_c = 50 mm D = 50 mm z = 2	a_c = 1,5 mm D = 40 mm z =2
Face milling				
v_c [m/min]	1500 - 4500			1500 - 4500
f_z [mm]	0,02 - 0,15			0,02 - 0,15
v_f [mm/min]	3000 - 12000			3000 - 12000
Cutting material	KT - K 10			KT - K 10
Boundary conditions	a_p = 1,5 mm D = 40 mm z = 2			a_p = 1,5 mm D = 40 mm z = 2

AlCuMgPb-F37 (Rm ≈ 470 N/mm2) is used in the area of materials for machining on automation machines [3]. Aluminium, alloyed with cast steel GK - AlSi6Cu4 is used for cylinder heads on the internal combustion engines and GD-AlSi12Cu9 for various housings. One third of all materials are represented by light-weight materials, such as MgAl8Zn1 used for the manufacturing of car rims. The purpose of alloying materials is to reach better properties then the basic materials. The advantage of light metals is their machinability:

- Smaller specific cutting force and smaller required power.
- Shear strain with short chips.

The increase in the service life of tools depends very much on the cutting materials used. High quality of the surfaces, the quality of this so-called fine milling can be compared to grinding. The cutting speed and feeding can be very high in case of light metals so that economical effects of high speed milling is reached [4, 5]: it varies between 1000 and 7500m /min (see Figure 1).

2. Machining parameters

High values of the cutting force in high-speed milling have not been confirmed due to increased temperature according to physical laws. The findings show that the temperature increases with the chip thickness and cutting speed [6]. Precise defining of the HSC milling does not make sense, since high-speed milling is derives from milling, where the feeding speed for certain machining operation is so high that it prevents the passage of high temperatures to the workpiece or tool.

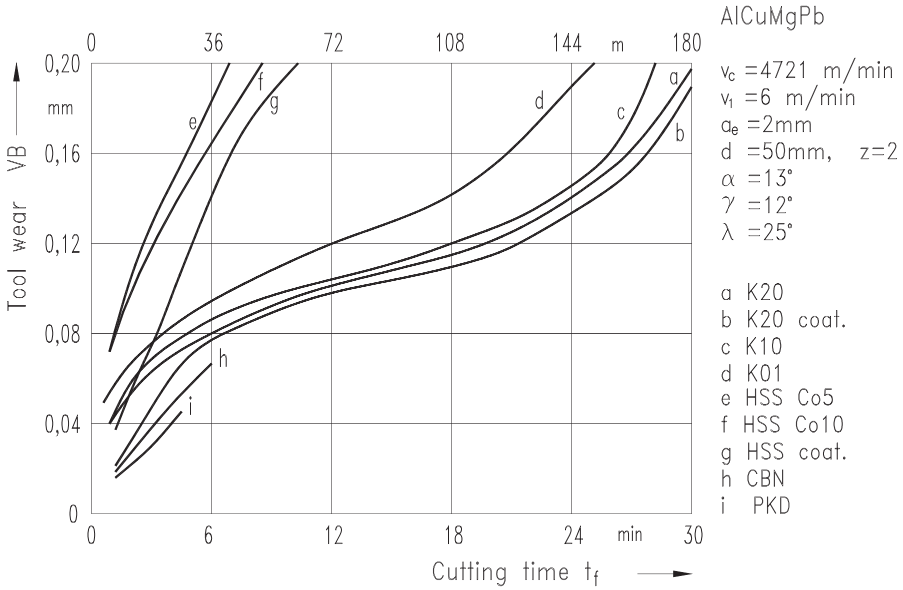

Fig. 2. Tool wear during milling of aluminium alloys

This is based on the findings about thermal conditioning and change in structure, when milling aluminium alloys with small chip thickness and/or feeding speed. The basic technological parameters for light metals are given in Table 1.

3. Cutting force and power

Calculation of cutting force according to DIN 6584

$$p_{cm} = \frac{a_p \cdot a_e \cdot v_f \cdot K_{cm}}{60 \cdot 10^6} \qquad (1)$$

- ap - chip width [mm]
- a_e - chip depth [mm]
- v_f - feeding speed [mm]
- K_{cm} – mean specific cutting force [N/mm^2]

$$v_f = f_z \cdot z \cdot n \qquad (2)$$

- f_z - feeding per tooth
- z -number of teeth
- n – number of revolutions
- Chip volume depending on time unit (Specific volume of chip)

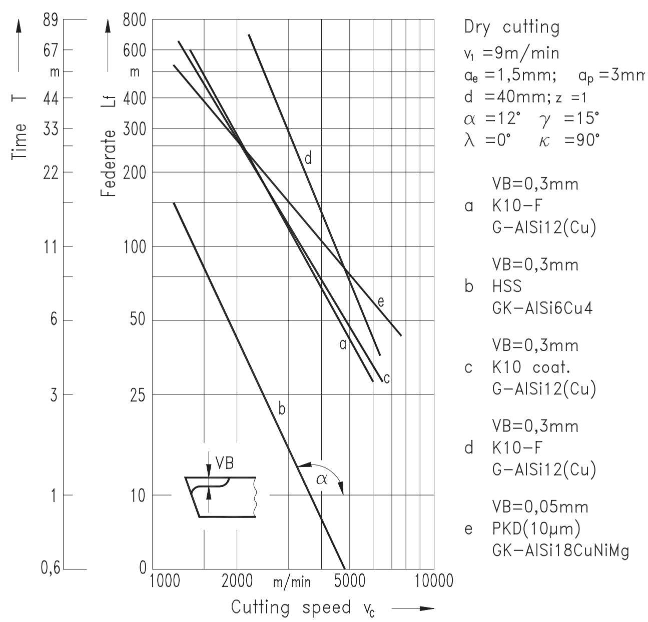

Fig. 3. Resistance of milling cutter in machining the aluminium alloyed with silicone [9]

4. Materials of cutting tools

High-speed steels as cutting materials are not suitable for high-speed milling of light metals. Alloys with different cutting materials and their wear are shown in Figure 2.

With the case of the polycristal diamond or CBN the resistance of the cutting insert is strongly increased [7, 8] and it is shown in Figure 3.

5. Tool geometry

As far as tool geometry is concerned it is desirable that it should have high resistance and optimal cutting capacity [10].

The makers offers end- milling cutters of up to 12mm diameter. For machining of light metals mainly the milling cutters with two cutting edges are used [11, 12].

The number of revolutions must be very high so that a satisfactory surface quality is reached and adhering of chips to the shear surface is avoided [13, 14].

6. Area of application

High- speed milling is suitable for:

- Mounting parts in aircraft and automobile industry and in building the engines from aluminium alloys with the volume of up to 95%.
- Small parts to be machined with tools of small diameters.
- Machining of beams from aluminium alloys.
- Various housing for additional machining
- Various parts whose surface must be of high quality.
- The basic rule, when deciding on high-speed milling, is the cost-effectiveness of the prices expressed in time savings [15,16].
- Racionalization is possible where the machine tools allow it; in particular the machine rigidity and the number of spindle revolutions are important.
- High-speed milling is particularly suitable for machining the parts previously manufactured according to another machining process.

7. Conclusions

HSC is the result of numerous technical advances ensuring that milling has become faster than conventional milling and has gained importance as a cutting process.

The advantages of the HSC milling are higher productivity owing to the reduction of machining times increase of the flow time of production, reduction of the number of technological operations, increase of the surface quality and longer service life of tools. High-speed milling of light metals from aluminium and magnesium is more and more frequently used in practice.

This result is high quality of the surface and shorter machining times. In some cases when machining by grinding is specified, the latter is omitted [17]. The machining conditions for execution of the HSC (36000min^{-1} and feeding 20m/min) require modernly built machine tools to meet those machining conditions.

References

[1] Y. Liu, L. Zuo and C. Wang, Intelligent adaptive control in milling process, International Journal of Computer Integrated Manufacturing 12 (1999) 453-460.

[2] J. Balic, A new NC machine tool controller for step-by-step milling, Int. J. Adv. Manuf. Technol. 18 (2001) 399-403.

[3] L.A. Dobrzański, K. Golombek, J. Kopac and M. Sokovic, Effect of depositing the hard surface coatings on properties of the selected cemented carbides and tool cermets, Journal of Materials Processing Technology 157-158 (2004) 304-311.

[4] U. Zuperl, F. Cus, B. Mursec and T. Ploj, A hybrid analytical-neural network approach to the determination of optimal cutting conditions, Journal of Materials Processing Technology 157-158 (2004) 82-90.

[5] Y.S. Tarng, M. C. Chen and H. S. Liu, Detection of tool failure in end milling, Journal of Materials Processing Technology 57 (1996) 55-61.

[6] J. Kopac, M. Sokovic and S. Dolinsek, Tribology of coated tools in conventional and HSC machining, Journal of Materials Processing Technology 118 (2001) 377-384.

[7] J. Kopac, Advanced tool materials for high-speed machining, Proceedings of the 12th International Scientific Conference Achievements in Mechanical & Materials Engineering AMME'2003 (2003) 1119-1128.

[8] L.A. Dobrzański, J. Mikuła, D. Pakuła, J. Kopač, M. Soković, Cutting properties of the ceramic tool materials based on Si3N4 and Al2O3 coated with PVD and CVD process, Proceedings of the 12th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2003, Gliwice, 2003, 249-252.

[9] L.A. Dobrzański, A. Śliwa and W. Kwaśny, Employment of the finite element method for determining stresses in coatings obtained on high-speed steel with the PVD process, Journal of Materials Processing Technology (2005), 1192-1196.

[10] F. Cus and J. Balic, Optimization of cutting process by GA approach, Robot. Comput. Integr. Manuf. 19 (2003) 113-121.

[11] U. Zuperl and F. Cus, Optimization of cutting conditions during cutting by using neural networks, Robot. Comput.-Integr. Manuf. 19 (2003) 189-199.

[12] F. Cus, M. Milfelner and J. Balic, Determination of cutting forces in ball-end milling with neural networks, Proceedings of the 11th International scientific conference Achievements in mechanical & materials engineering, AMME`2002, (2002) 59-62.

[13] S.J. Huang and C.C. Lin, A self-organising fuzzy logic controller for a coordinate machine, International Journal of Advanced Manufacturing Technology 19 (2002) 736-742.

[14] H. El-Mounayri, H. Kishawy and J. Briceno, Optimization of CNC ball end milling, A neural network-based model, Journal of Materials Processing Technology 166 (2005) 50-62.

[15] B. Mursec, F. Cus and J. Balic, Organization of tool supply and determination of cutting conditions, Journal of Materials Processing Technology 100 (2000) 241-249.

[16] S. Stute and F.R. Goetz, Adaptive Control System for Variable Gain in ACC Systems, Proceedings of the Sixteenth International Machine Tool Design and Research Conference, Manchester England, 1975 117-121.

[17] U. Zuperl, F. Cus and M. Milfelner, Fuzzy control strategy for an adaptive force control in end-milling, Journal of Materials Processing Technology, 164-165 (2005) 1472-1478.