Milling with cutting tools with irregular angular placement of inserts

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Summary: In the present paper is presented an analysis of face milling of planar surfaces using cutting tools with irregular angular placement of inserts along their periphery. In this paper are analyzed the advantages of tools with irregular pitch of inserts and new designs of face mills suitable for machining of planar surfaces. The results from the experiments with these tools will be published soon.

Key words: milling, central angle, irregular pitch

Introduction: The increasing demands for increase of productivity when machining different components and in the same time provision of prescribed accuracy and surface finish require development of new technologies and tools. The usage of modern materials for cutting tools, coatings, methods and tools provides an approach for effective solution of specific production problems.

Partial symmetrical or asymmetrical milling of planar surfaces with width of the workpiece less than the cutter diameter is characterized with increased impact loads on the inserts when entering in contact with the material to be machined. This causes vibrations which result in deviations in shape, surface finish and dimensional accuracy of the machined surfaces. The increased level of vibrations decreases tool life and deteriorates in time operational accuracy of machine tools.

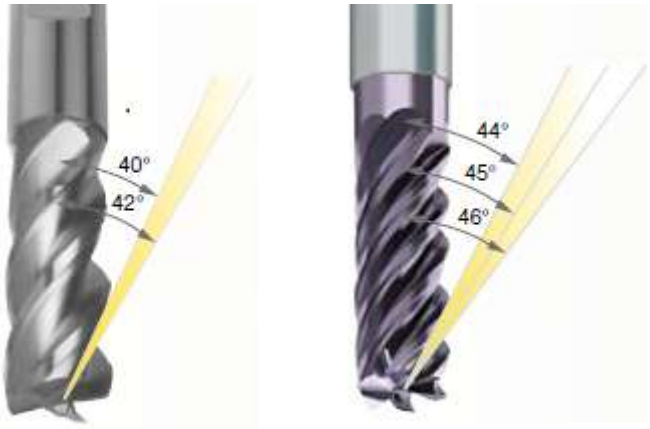
Presentation: Milling is characterized with varying cutting forces and volume of cut metal. This causes forced vibrations. They influence negatively the quality and accuracy of machined surfaces, productivity and tool life. One of the methods to increase stability in cutting and decrease the level of forced vibrations is application of milling tools with irregular pitch [1].

The influence of insert placement on forces acting upon the tools is clarified theoretically when drilling holes with trepanning drills [2].

The changes of frequency of insert entering into the machined material with milling tools with irregular placement of inserts along the periphery and application of optimal modes of machining decrease the level of forced vibrations and significantly decrease probability of formation of resonance. Some manufacturers offer solid carbide mills with different inclination angles ω_i of adjacent helical teeth. This approach is used by Gühring company for production of cylindrical face mills from RF 100 series, fig. 1 [3]. This new design of small diameter tools with different inclination angles provides required irregularity of teeth placement on tool's face. The angles of inclination of adjacent helical teeth are different and their values are in the range from 40^0 up to 42^0 with mills up to 4 teeth and from 44^0 to 46^0 with mills with 6 teeth. According to data provided by the company this provides cutting without vibrations, better quality of machined surfaces and opportunity to apply higher feed rates.

Another approach to decrease vibrations during machining used by some manufacturers of milling tools is provision of chamfers at the end of the cutting edges [3, 4], fig. 2. In this way they get stronger and the total length of their cutting edges along the cylindrical surface and tool's face is increased. These designs are characterized with improved thermal loading

of the tool, which increases tool's life. Better heat transfer gives opportunity to apply higher feed rates, thus increasing productivity and efficiency of milling.



a) RF 100A mill with 4 teeth

b) RF 100S/F mill with 6 teeth

Fig. 1 Different inclination angles of adjacent helical teeth of mills [3]

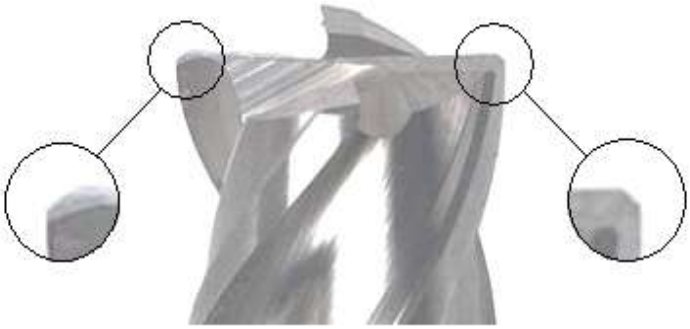


Fig. 2 Mill with chamfers at the end of cutting edges

The Japanese company Mitsubishi Materials Corporation also offers mills with varying angle of inclination of helical teeth. Its new series Impact Miracle is designed to reduce vibrations during cutting. The geometry of VFMHV mills is shown on fig. 3 [4]. As a result of varying angles of inclination ω_1^o and ω_2^o of adjacent helical teeth is accomplished the shown irregularity of placement of face teeth.

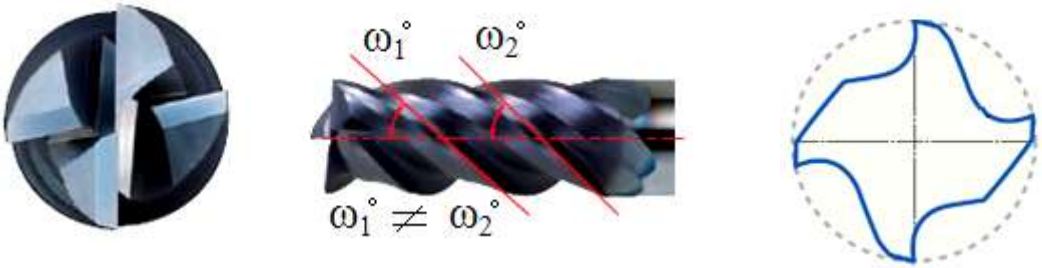
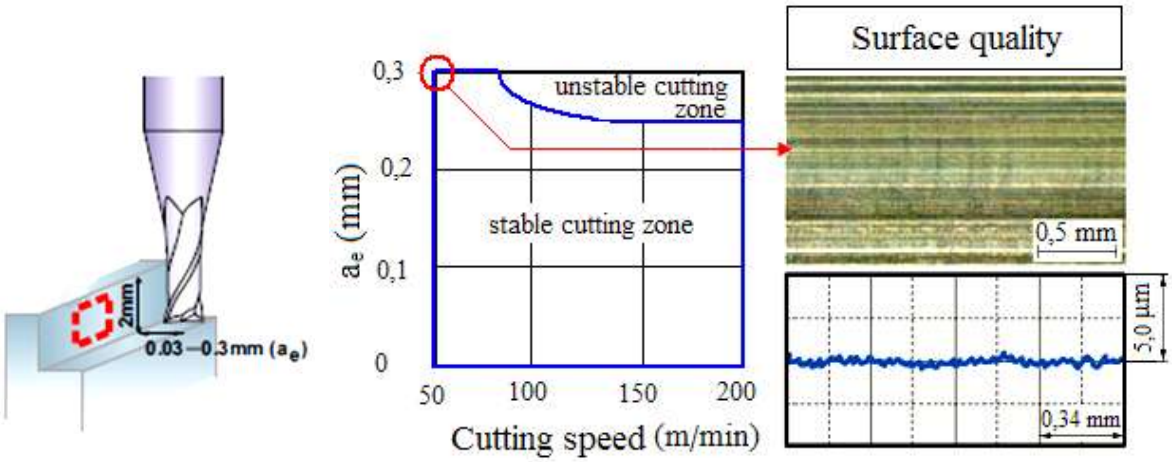


Fig. 3 Mill with variable angle of inclination of adjacent helical teeth [4]

The studies of Mitsubishi company show that with face unidirectional milling of hardened workpieces with 52 HRC with VF2MVD0200 and diameter of ϕ2 mm, fig. 4a [5] the vibrations during cutting are significantly reduced - fig. 4b. The experiments are made with cutting speed 50 … 200 m/min and feed rate f_z = 0.02 mm/tooth, depth of cut 2 mm and cutting width in the range 0.03 up to 0.3 mm.



а) б)

Fig.4 Area of stable cutting with face milling with a VF2MVD0200 mill [5]

Besides solid mills with variable angle of inclination of adjacent helical teeth, Mitsubishi Materials Corporation produces also tools with irregular placement of inserts along tool's periphery. In production environment reduction of vibrations and increase of machined surface quality is achieved. The angular displacement of teeth for these tools to different central angles is not a big one, as it will result in change of the section of the cut layer, thus the load on different teeth will be different. Excluding reduction of vibrations the acyclic impact of teeth with the material causes reduction of noise level.

The Swedish company Sandvik Coromant offers in its catalogue mills from Coromill series, fig. 5 [6] with irregular pitch of inserts along tool's periphery. The company produces tools of this type with diameters ranging from ϕ38 up to ϕ201 mm, respectively with 4 up to 19 inserts.

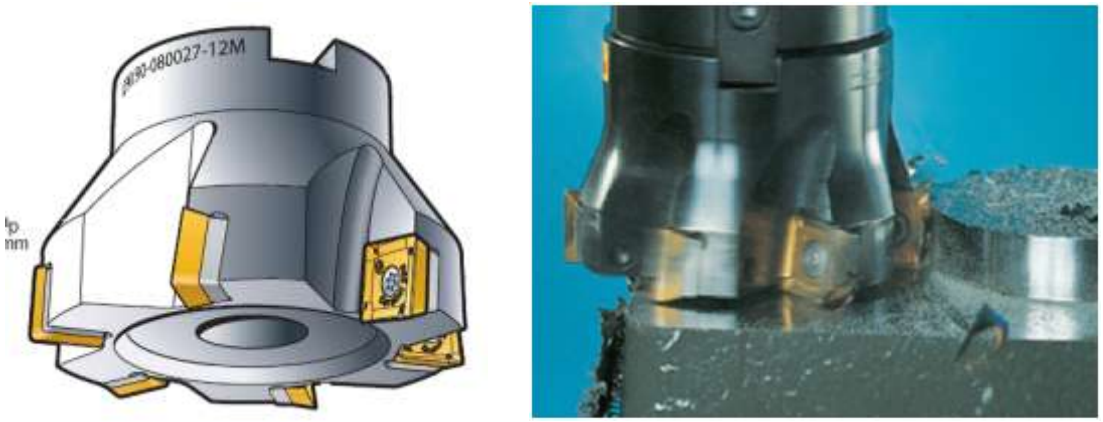


Fig. 5 Coromill milling cutter produced by Sandvik Coromant [6]

To increase the quality of milled plain surfaces for linear roller bearings in medium batch production in Petrov PM – PLC Company in the Technical University of Sofia were designed and produced by the Italian company SAU [7] new milling tools with irregular pitch of inserts, fig. 6.

a) 3D drawing of a mill with irregular teeth pitch

b) produced mill with irregular teeth pitch

Fig. 6 A mill with irregular teeth pitch

During the design of the shown tools was used know-how of the Italian company SAU and due to this reason no information can be revealed for their technical performance. On fig. 7 is shown the clamping of the inserts with irregular teeth pitch to mills body.

The tools were designed by the authors using CAD modeler SolidWorks and were produced by SAU Company under contract with Development and Research branch of the Technical University of Sofia. The authors would like express their gratitude for the financial support by the management of Development and Research Branch.

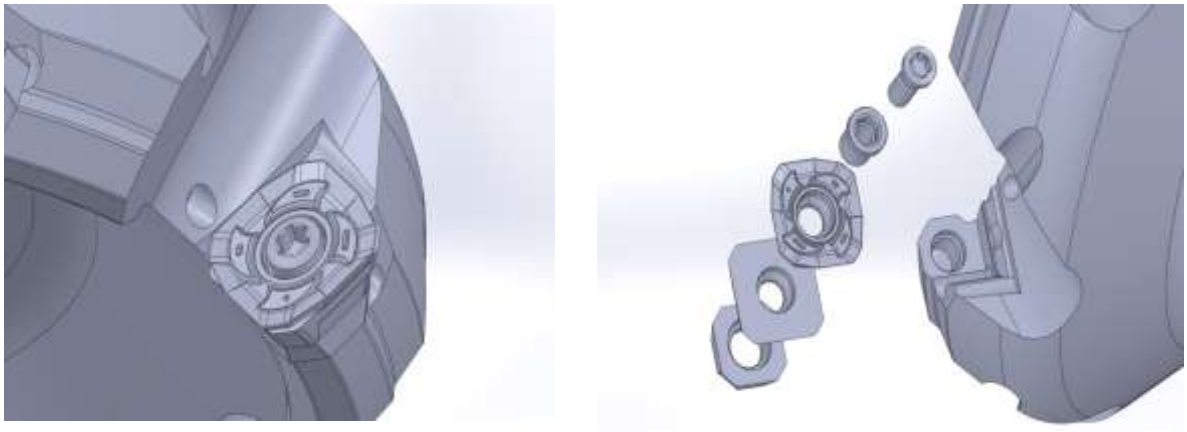


Fig. 7 Clamping of an insert to mill's body

Conclusion: It's expected milling of plain surfaces with the new tools of SAU company to provide reduction of vibrations and probability of resonance formation due to absence of cyclic impact loads on cutting inserts when entering into the material. Decrease of vibrations and impact loads on tools will improve accuracy of shape of milled surfaces and reduction of deviations from flatness. This will significantly increase productivity and quality of linear roller bearings produced by Petrov-PM PLC, Bulgaria, having in mind their application for provision of accurate linear motion of moving units in contemporary machine tools. Optimization of cutting conditions will provide expected increase of service life of the new milling tools.

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