A new approach to application of end milling cutters of compound hard metal

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Abstract. The results of designing end milling cutters having a hard metal cutting point and a shank made of structural steel are shown. The shank and a cutting point are directed and connected. It allows reducing the requirements in expensive integral hard metal milling cutters and defining the field of rational application of integral and compound mills.

1. Introduction

By the time of hard metal appearance the design of end and key milling cutters changed constantly by means of equipping a mill body made of structural steel with hard metal cutting elements. These milling cutters were equipped with soldered-on blades, with mechanical fastening hard metal cutting blades. Each of these solutions was rational for those times and had its drawbacks. Updating NC (numerical control) metal-working machinery necessitated a machining productivity increase that caused the creation of compound hard metal milling cutters, the entire cutting point of which was made of hard metal and it was jointed with a steel shank either by means of soldering or by welding. Growing requirements to productivity and machining accuracy resulted in the creation of integral hard metal milling cutters. Initially they were expensive and were used only in those cases when the productivity or accuracy of machining was not ensured by compound milling cutters.

After that, due to various reasons, the application of compound milling cutters either decreased, or reduced to zero. It happened first of all because of the decrease in the set of purchased metal-cutting tools.

Even the idea of compound milling cutters with reference to milling cutters of a small diameter disappeared. Thus, for instance, if at the end of GOST (All-Union State Standard) 18372-73 in the part of “Hard Metal End Milling Cutters” there was as yet a record of the possibility of compound milling cutters application, then in its modern substitution GOST 32405-2013 in the part of “Integral Hard Metal End Milling Cutters” there is not any record of compound hard metal milling cutters at all.

Such a situation, in the judgment of the authors, resulted in excess expenditures for metal-cutting tools. Thus, for instance, during machining billets of parts made of aircraft industry material, the application of integral hard metal milling cutters is justified during machining high-test titanium alloys. But, when milling grooves, pockets, projections and so on in parts billets made of less durable titanium alloys, stainless steel or aluminum alloys the application of compound milling cutters is quite possible.
2. Methods and materials

One of the ways of the problem solution of the tool costs decrease at the expense of the hard metal decrease is the application of updated compound end milling cutters. Updating is possible due to the fact that general mechanical engineering requirements to accuracy are not so high in case of grooves, projections, pockets and so on. Even in the aircraft industry these requirements are not high. It allows without detriment to a machining quality admitting a divergence for a compound end milling cutter to a larger value, than that for an integral end milling cutter. It is necessary that the optimization should be carried out only for a part of the shank in the length of a milling cutter, reasoning from the required quality of machining and updating of the area of the shank joint with the hard metal point of the milling cutter to ensure a required strength and rigidity of the joint (Figure 1).

This is the approach that is assumed as a basis of this paper.

As a reason for using such an approach is the analysis of reasons for the failure of integral end milling cutters. The analysis has shown that for such milling cutters operating in alternating changing dynamically milling conditions at high-speed machining geometrically-complex surfaces the cyclical strength of hard metal is insufficient. It is clear even from the statistics of milling cutter failures: milling cutters are withdrawn from the operation in 73…90 cases out of 100 not because of point wear, but, owing to a shank fracture in the integral milling cutter. Such examples are shown in Figure 2 for milling cutters with the 140 mm length and the diameter of 16 mm (three right samples) and the length of 110 mm and the diameter of 12 mm (left sample). The investigation of the surface of
failure has shown that it was an endurance failure on a tough-brittle mechanism by means of the multi-
cyclic branching growth of intercrystal main cracks.

Figure 2. Characteristic examples of the integral hard metal milling cutters failure caused by tough-
brittle destruction of the shank (three left cases) or by the area of the shank transition into the point

Dynamometric investigations (simultaneous registration of constituents of cutting force and
vibratory displacements in three mutually perpendicular directions) have shown [1], that a normally
directed constituent of cutting force changes within the limits of (1600…3000) H under manufacturing
conditions of aircraft materials machining with such milling cutters. A small value is obtained during
chamfering in aluminum sheets, a greater value can result under complex profile of milling pockets in
titanium alloys, intermediate values are calculated when machining aluminum-lithium alloys, stainless
steel.

The application of numerical simulation with the use of standard computation programs through
the method of finite elements of stress fields, Figure 3, and values of deformations (rod deflection
imitating the body of the integral or compound milling cutter), Figure 4, allowed obtaining design
charts of milling cutter comparative deformations, Figure 5.

Figure 3. The image of stress fields of the model of a compound hard metal end milling cutter body
under the influence of the normal constituent of cutting force.

Figure 4. The image of values of area travels (sections) for the body of a compound hard metal end
milling cutter under the influence of the normal constituent of cutting force.
Figure 5. The results of numerical modeling of the deformation value for a milling cutter operation end: the right line – for a compound milling cutter, the shank of which is made of material R18 (high-speed steel (ISO 1.3302, field of application K30 – K40), and the point is made of hard metal TC8 (S6-5-3)(ISO 1.3343); the left line – for an integral hard metal milling cutter made of hard metal TC8 (S6-5-3)(ISO 1.3343).

Figures 3, 4 and 5 are shown only as examples: a milling cutter 140 mm long with the diameter of 16 mm is fixed in the chuck for the shank length of 40 mm, in case of the compound milling cutter a hard metal point is made for the length of 40 mm, in this case the presence of chip grooves at the point and the design of the joint of the shank with the point are not taken into account. The deformation simulation in the rupture-test machine, Figure 6, confirmed the adequacy of design charts of milling cutter comparative deformations.

Figure 6. The plant for simulation of the milling cutter body deformation depending on an effort.

The physical and numerical simulation of the milling cutters deformation allowed differentiating the fields of possible application of integral and compound hard metal milling cutters, revealing the field of preferred application of integral milling cutters, defining the field of integral and compound milling cutters competition. These fields are defined as preliminary for the time being, as the number
of considered fulfilled variants of the produced compound milling cutters is still limited. Only saving in hard metal is taken into account, the cost of inputs assuring the shank and point coupling is not assessed. But now it is clear that possible savings should be within 30…60 % of hard alloy.

3. Results
1. Compound hard metal milling cutters are the alternative to integral hard metal milling cutters when they are applied with consideration of general engineering requirements to accuracy of the produced part surfaces. The alternative is more vivid, when the deflection of a milling cutter body is less under the influence of cutting forces, that is, the more partial load modes of cutting are used.
2. Without damage to the quality and machining productivity, compound milling cutters allow saving more than one third of hard metal used for manufacturing of the integral hard metal milling cutter.
3. For integral hard metal milling cutters the preferable field of application is highly productive machining of hard-to machine materials.

4. Conclusion
The authors have borrowed common geometrics of the point of hard metal end milling cutters and considered [2-6] the possibility of manufacturing the shanks of structural metal for milling cutters.

By the example of manufacturing of the shank with the use of tool steel R 18 (as an example of the structural material with high physical-stress-strain properties) and manufacturing of the point with the use of hard metal TC 8 the authors have shown the rationality of compound milling cutters application at least from the position of hard metal savings.

It is useful to proceed with the works for the identification of rational fields of compound milling cutters application taking into account variants of the shank and point coupling, geometrics of chip grooves and so on.

References
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