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ADVANCED MODULAR TOOLS FOR GEARS MACHINING

Abstract: Gears manufacturing belongs to the most complex and sophisticated processes found in industry. Traditional gears treatment methods require special machines and tools, which usually are made of high speed steel. However, in other types of machining for many years tool with replaceable carbide insert, have been used. Currently leading tool manufacturers also offer tools for gears cutting with replaceable carbide inserts, which allows a significant increase in productivity. These tools are custom-made and designed to the requirements of the customer. Some examples are showed in article.

1. Introduction

Gear wheels are very frequently used in industrial practice of machine parts. Due to transfer of high power and good cooperation, gears are usually used as transmissions components in various types of machinery. For example they are used in cars gearboxes.

Gears machining processes are some of the most difficult and most costly manufacturing processes. This is due, inter alia, the need to have expensive specialized gear machine, the use of complicated special tools, appropriate control and measurement equipment and the hiring of highly qualified staff. The most commonly used are spur gears with straight teeth. Depending on the destination and the required production volume of such gears, they can be produced by various methods depending on the required accuracy and performance, and available in a given industrial plant machinery and equipment. Most of the gears is used in a responsible transmission components and requires careful manufacturing with great accuracy which is associated with application of appropriate methods of machining – form cutting or gear generating.

In the methods of form cutting the tools contour corresponds to the outline of gear teeth. During machining the tool removes the material from workpiece and leaves the sides of two adjacent teeth. Examples of methods of form cutting are: form milling, form grinding, broaching. In a gear generating methods the outline profile of gears teeth is obtained by the synchronized movement of the tool and the workpiece. Teeth profile is received as result of a subsequent position of the cutting tool edge. Examples of gear generating methods includes chiseling, hobbing, grinding.

2. Tools for gears machining

Gear cutting requires special tools. Tools design is depended for gear data and is specific for cutting method. Some of the most popular tools are hobs, disc cutters, Fellows shapers, and rack cutters. Previously used gear processing tools were made of high-speed steel HSS, which, thanks to the relatively high plasticity, allows to build a uniform shape tools, but is characterized by a lower hardness compared to new super hard tools materials. Tool example for gear milling is shown on figure 1. This results in the need to use low machining parameters which translates to relatively low productivity of gear machining

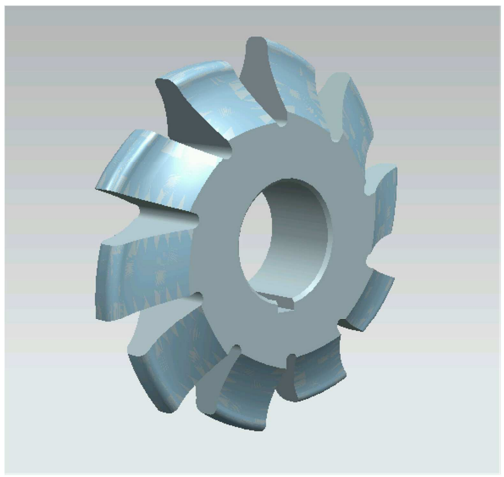

Fig. 1. 3D CAD model of uniform tool for gear milling [own design]

However, in modern lathes and milling machines for long time a modular tools with indexable inserts have been used. Insert can be made of cemented carbide or ceramic, diamond, Cubic Boron Nitride, which are characterized by a much greater hardness and allow to use higher cutting speed and significantly improve productivity.

In recent years, manufacturers of tools also began to offer tools for gear machining with indexable carbide inserts (Fig. 2) [4, 5, 7, 8, 9].

Fig. 2. Gear tools with replaceable carbide inserts [11]

Such tools are more difficult to implement, but they have a lot of advantages [4, 5, 8,10]:

- much greater durability of the blades than HSS tools,
- shorter machining time of teeth,
- do not requires sharpening.

Due to its high hardness this cutting tools can be used after heat treatment (quenching) and it can replace the grinding process.

Disadvantages of the tools are:

- inaccuracy teeth outline, which is obtained with a few or a dozen inserts,
- relatively high price.

Characteristics of some types of new tools are shown in table 1.

Tab. 1. Gear cutting tools for production of cylindrical gears [13]

Type of tool	**Gear hob**	**Large Roughing disc cutter**	**Medium Disc cutter**	**Small disc cutter**
Modules	4–9 mm	12–22 mm	4–8 mm	2–12 mm
Diameters	90–210 mm	210–500 mm	63–250 mm	66–140 mm
Large volume production	+++	++	-	-
Small/medium batch production	-	++	++	+++
Different gears with only one tool body	-	-	++	+++

In view of the fact that the outline of the tool is not perfect and is only some approximation of the involute profile of the teeth, therefore this type of tool are recommended primarily for roughing teeth. Manufacturers also offer tools of a full involute profile but only for small modules, about 4-8 mm (Fig 3.).

In the industry can be seen trends to increasing the flexibility of the production, which is associated with the small batch production. It also requires the right tools, which are designed for the needs of the individual customer-specific manufacturer's products [5].

Leading manufacturers of tools already offer tools (custom made tools)-for specific modules, a number of teeth, gear diameter, etc. Design of flank inserts depends on gear data.

Tools have modular construction, so that many standard parts can be used, i.e. holders, sockets, and interchangeable indexable inserts of different materials mostly cemented carbide.

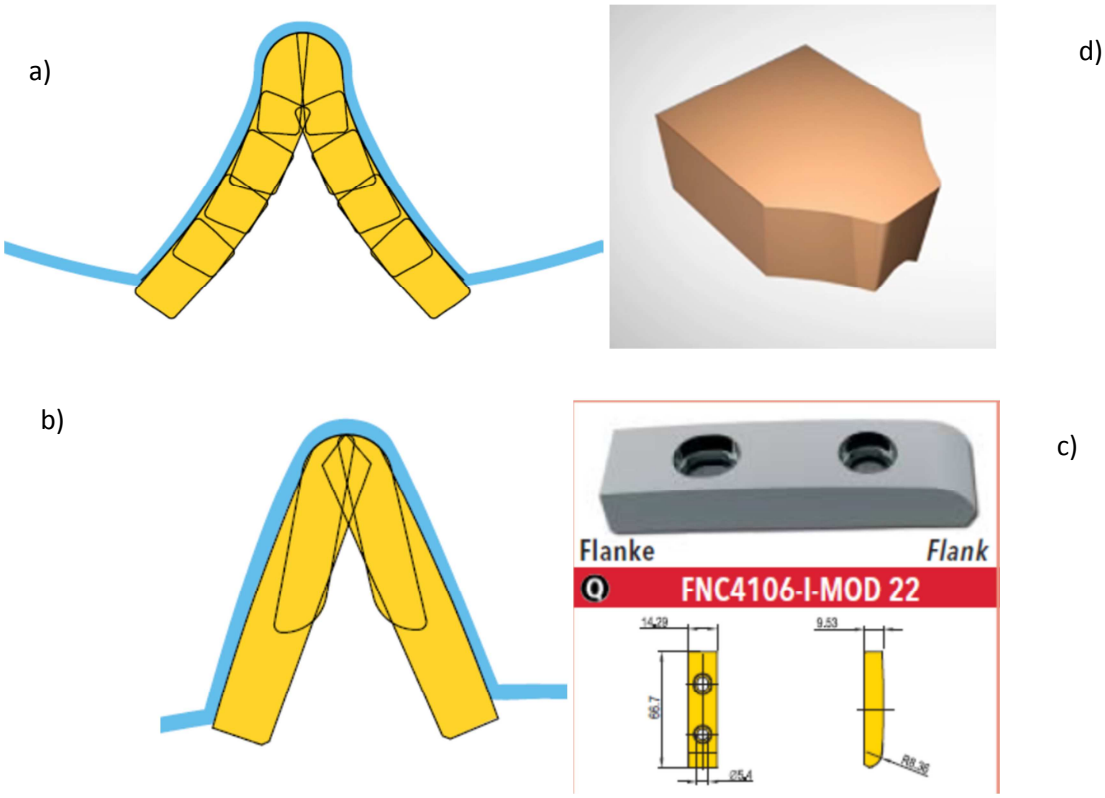

Fig. 3. Examples of flank profile a) for external gear, b) for internal gear, c) flank insert [12] d) insert with full involute profile [13]

In the design of tools advanced CAD systems have been used. Also rapid prototyping techniques can be used to build the model of the tool and its verification, as well as for demonstration purposes (Fig. 4) [1, 13]. Modern rapid prototyping technics can have great influence on production processes and this is known as rapid manufacturing [2, 6].

Fig. 4. Custom model of tool obtained with 3D printing technics [13]

In the figure 5 an example of a gear cutting is shown. This is method of form milling with disc cutter on a horizontal milling machine. Tool shape have profile nearing as the profile of the treated teeth. Because the profile is dependent on the size of the tooth (module) and the number of teeth and the pressure angle, the scope of this tool is limited to a specific module and the limited range of the number of teeth on a gear. Treatment of this method involves making a single notch between teeth flank. After one notch was cut, wheel is rotated by the angle corresponding to the pitch of teeth and another notch is cut, etc. until all the teeth are made.

Fig. 5. Rough gear cutting with Coromill 170 [13]

This is roughing method intended for the machining of large modules gears, which requires removal of large amounts of material. Regular allowance is left on the teeth side. After roughing another treatment is needed for finishing the teeth e.g. grinding.

3. Conclusion

Gear machining processes are among the most difficult and the most labor-intensive processes occurring in the machine industry. New modular tool can be used even on old machines, and they can contribute to a significant increase in the efficiency of gears machining. Modern machines allows to take full advantage of the new tools [3, 4, 5].

In particular, modern five-axis numerical controlled milling machines can cut whole gears using standard indexable tools [3]. Outline of teeth is obtained by the calculation of the tool trajectory in 3D space. Such an approach is especially beneficial in the case of processing of a gears with curved line of the teeth. [3]. More examples of the use of the new tools can be found on the websites of manufacturers [10, 11, 12, 13].

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