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Multi-operative modular tool for cutting and mechanical hardening

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Multi-operative modular tool for cutting and mechanical hardening

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Abstract. It is well known the important role of the tools for mechanical processing in manufacturing within the present context of the rush for profitability and technical optimization for an environmentally friendly industrial production. Modularization of tools is a way to ensure their versatility being at the same time economically advantageous. In this paper, two milling cutters are adapted in order to be used also for surface hardening. The third tool described here is a newly designed modular tool that, according to needs, can be used to perform rough, finish milling or mechanical hardening.

1. Introduction

The processing of plane/flat surfaces by various technological processes is very common in the manufacturing industry. It stands out particularly the milling process through which can be generated surfaces in a wide dimensional range.

Due to the permanent need to ensure the competitiveness of manufactured components, it is continuously necessary to design and manufacture more efficient technological equipment able to reduce the processing time without affecting the quality of the products. In this respect, a great interest was demonstrated in recent years for reconfigurable manufacturing systems (RMS) easily adaptable to frequent requirement changes [1–7]. Convertibility, defined as “the capability of transforming the functionality of existing systems and machines to fit new production requirements” is one of the core characteristics of RMS [3] along with scalability, diagnosability, customization, modularity and integrability. For Wiendahl et al. [6] the essential features of RMS are modularity and integrability. Integrating multiple processing technologies in a single machine tool could lead to higher productivity with lower costs. Brecher et al. [7] emphasise the importance of reducing process complexity by performing different operations in one workplace and, if possible by a single clamping of the tool. Designing multipurpose tools as are those presented by the authors ensures convertibility, integrability and modularity of milling and mechanical hardening tools.

Three cases of constructive flexibility of the active part of milling cutters are described in this paper. The design of the first tool, a Romascon type milling cutter, is modified to improve milling performances and to allow an easy transformation in a press hardening tool. The second tool is a commercially available robust face milling cutter for which it is provided a solution that allows reconfiguration into a hardening tool. The third solution presented is a new concept for a tool with two subassemblies that can be interchanged with little effort, one subassembly for rough milling and the other one for press hardening.

2. Reconfiguration of existing milling cutters

2.1. Redesign of Romascon milling cutter

The newly designed tool is a front milling cutter (Romascon type) provided with blade-shaped teeth as shown in figure 1. The Romascon milling cutters were patented in Romania more than half a century ago by professor Vitalie Belous and are still used and appreciated for being robust, easy to manufacture and having brazed carbide inserts suitable for re-sharpening [8, 9].

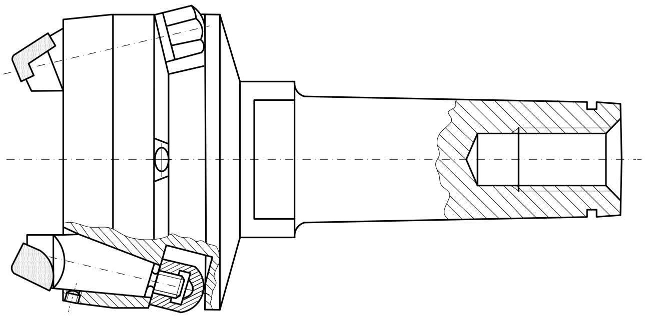

Figure 1. General appearance of Romascon milling cutter.

In the initial phase of operation, the tips of all teeth are arranged in the same frontal plane (AB), on the diameter D_1 (figure 2). To use a general purpose milling cutter for removing a thick layer of material in a single pass, working with higher values of the cutting depth a_p, a new design is proposed as follows.

A milling cutter is generally considered a tool with an even number of teeth/blades. Half of them will be replaced with longer blades, their tips (in the mounted state) reaching the level of point C. It is important that the replacement must be done alternatively: a tooth remains with the tip in the initial position (so in the frontal plane AB) and the tooth immediately following will have the tip at the level of the CD points (figure 2). As a result of this repositioning, it results that the second milling plane generated by the longer teeth/blades will appear; their tips will be located on a milling diameter $D_2 < D_1$. This new active area will allow the removal of a layer of BD thickness in the workpiece material. A total cutting depth will be obtained on the entire active area of this constructive configuration:

$$a_{p\,total} = a_{p1} + a_{p2}\ \text{(mm)} \tag{1}$$

where a_{p1} – axial cutting depth related to milling with the initial teeth positioning of the cutter;

a_{p2} – axial cutting depth corresponding to milling with longer teeth (a_{p2} = BD).

The cutting process will take place in better conditions if the cutting depth a_{p1} is equal to approximately two-thirds of the total cutting depth is adopted.

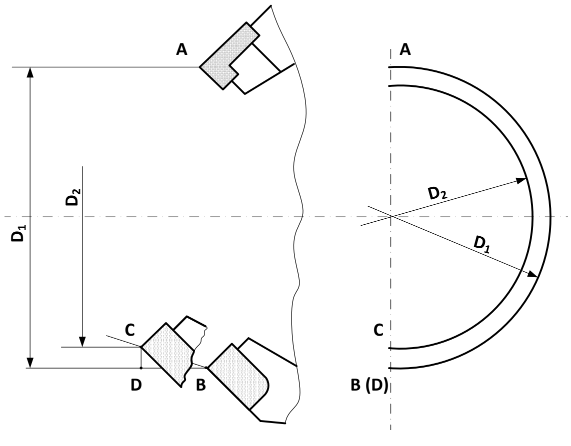

Figure 2. Romascon milling cutter reconfiguration.

Through constructive flexibility, several advantages are obtained, such as:

- Chip fragmentation on width, therefore better conditions for the formation and removal of chips;
- Reduced specific cutting force due to the fact that chip thickness is doubled in comparison with the one related to the work with the unmodified milling cutter;
- Lower values of torque, so lower specific energy consumption.

2.2. Reconfiguration of face milling cutter

Increasing the degree of use by modularizing the active part of the tools can be applied to other milling cutters, e.g. a face milling cutter with each tooth/blade fixed with two screws (figure 3).

The modularization of this tool consists of completing its design with a prismatic mark of thickness *a* having the shape of a plate (pos.1). This modification can only be done on a face mill with an even number of teeth because the new mark is to be placed every two teeth as in Romascon type milling cutter. In consequence, half of the total number of teeth of the milling cutter, those radially repositioned, will have the tips located on a diameter $D_1 > D_2$, being the first to come into contact with the workpiece, then after the distance *a* (in the feed direction), the other teeth enter the cutting. Those teeth, located on the diameter D_2 must have the tips at a distance *b* on the axial direction from those of the teeth arranged on the diameter D_1. From the point of view of the cutting parameters, *b* has the significance of the cutting depth for the teeth with the tips on the diameter D_2.

Besides the advantages of modularization, this modified milling cutter (figure 3) with large diameter and numerous teeth has other benefits**:** more uniform cutting forces and more favourable cutting conditions and a better surface roughness.

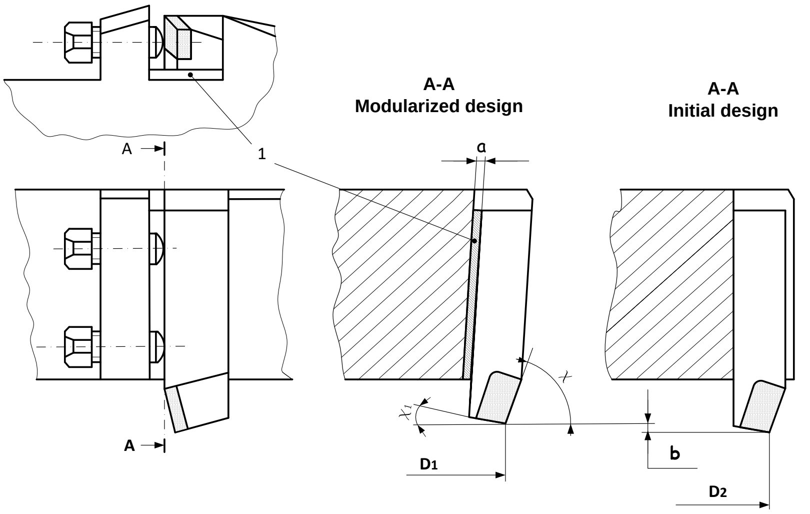

Figure 3. Modularization of face milling cutter.

Another major advantage of the previously presented milling cutter is that it can be reconfigured to a press hardening tool. This can be obtained if the repositioned teeth are replaced with a subassembly that contains a constructive element (e.g. a ball) that allows the pressing of the flat surface of the workpiece. It will be therefore a specific subset of the finishing process by pressing [10] designed to increase surface quality parameters: surface roughness, hardness/microhardness of the surface layer, dimensional accuracy, etc. Also, by applying plastic deformation at the surface, wear resistance and corrosion resistance of the workpiece are ameliorated.

2.3. Multi-operative original tool design

In this section is presented an original design of a combined tool for cutting and press hardening.

According to figure 4, this equipment is made of two different parts with distinct functions: one part for milling (pos.1) and the other part for press hardening (pos.2).

In the central zone, there is a cylindrical bore with a diameter d similar to that of commercially available face milling cutters, so clamping the combined tool on a traditional machine tool or on a numerically controlled one is possible using a standard tool holder.

Milling is performed with the two inserts 3 which are mechanically fixed in the milling cutter 1, and the plastic pressing/deformation occurs under the action of a spherical deforming part (ball) 4. As can be observed in figure 4, the initial positioning of the support-piece 5 is done with the spacer 6 and the fine adjustment of the *z* dimension is carried out using the pressing subassembly 2. The optimal value of positional dimension *z* is influenced by many factors like surface roughness before press hardening, shape and size of the deforming part, press hardening process parameters, physical and mechanical properties of the workpiece, etc.

In literature [11], the following relation has been established for the calculus of *z* taking into account surface roughness parameter R_z:

$$z = 1.35\left(R_z^{initial} - R_z^{final}\right) * 10^{-3} \text{ (mm)} \tag{2}$$

where $R_z^{initial}$ and R_z^{final} are values of measured R_z before and, respectively, desired R_z after press hardening.

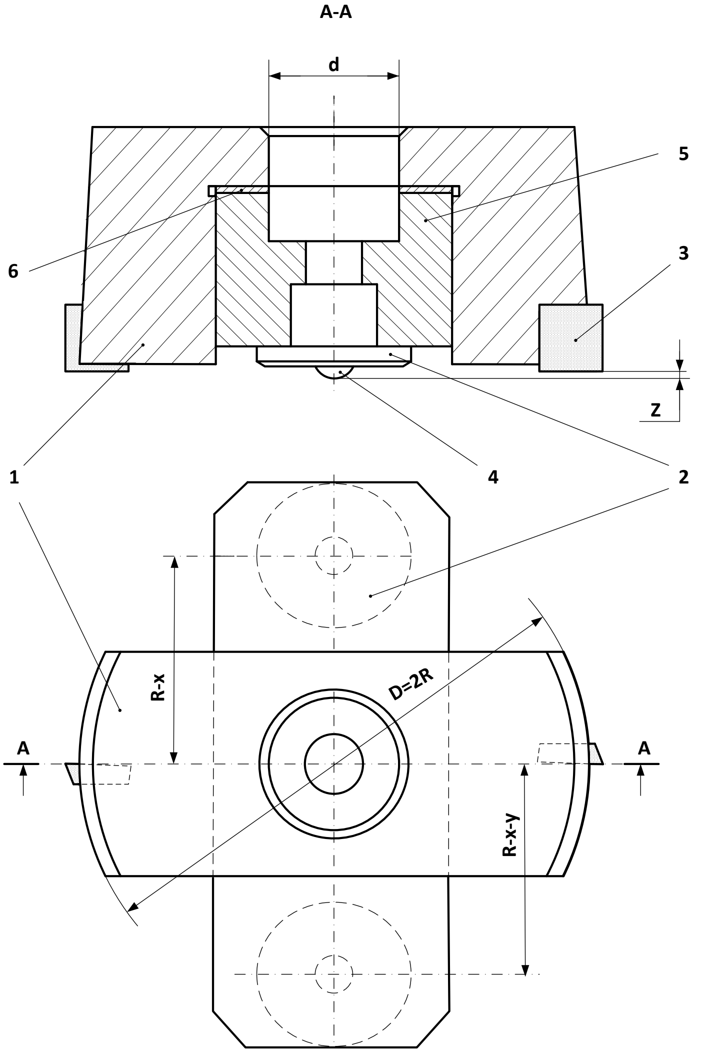

Figure 4. Modular milling and press hardening tool: milling cutter (1), pressing subassembly (2), inserts (3), ball (4), support-piece (5) and spacer (6).

For the purpose of obtaining very smooth surfaces with superior accuracy, the two deforming subassemblies were positioned differently: one subassembly is at a distance R-x, in relation to the axis of symmetry of the combined tool and the other at a smaller distance, respectively R-x-y. Therefore a first pressing action will be performed by the more distant subassembly (R-x), and then a second pressing action will be performed by the ball of the subassembly which is closer to the axis of symmetry of the combined tool.

3. Conclusion

The authors provided three solutions for modularity and convertibility of milling cutters that could be used on a regular milling machine. Two of them are adaptations of existing tools increasing their performance and making them easily convertible into press hardening tools. The third multipurpose tool is an original concept that in the future is intended to be manufactured and tested.

By implementing in the processes of mechanical processing the technological equipment proposed in this paper, technical-economic effects superior to those based on current technologies could be obtained.

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