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GENERALIZED APPROACH TO THE DESIGN OF BORING HEADS

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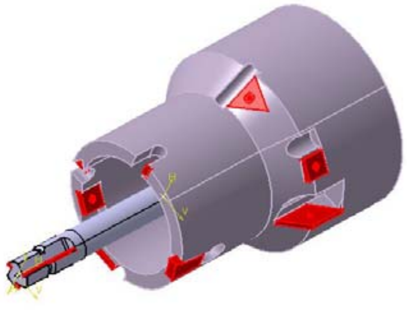
Abstract: *The paper presents the representative model of the boring heads obtained from the generalized model of the cutting tool. The model contains axle and hole type surfaces, some of the edges having adjustment facilities. By particularization, a large range of constructive solutions could be obtained. Starting from force estimation using a generalized model of boring head forces, the constructive solutions can be optimized from different criteria and points of view.*

Key words: *boring heads, reamer, chamfer, generalized model, representative model, stress state.*

1. INTRODUCTION

A cutting tool consists of three parts: an active area, the body and a clamping part. Sometimes, cutting tools contain intermediate elements. Cutting tools movements can be simple, related with the coordinative system inherent to the cutting tool or complex (multiple movements), related with other axes (cutting tools become more complex, they no longer belong to a single category because of machine tool development which includes many axes).

In order to discover new constructive solutions and recognize the known ones, we can start the study from the constructive and cinematic model of the generalized cutting tool. The generalized model consists of an ideal tool body with several stages that can present multiple movements and regulation possibilities, as well as active elements with different shapes and positions.



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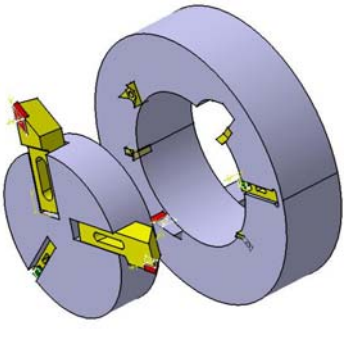

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Fig.1. Representative model of boring heads with inserts: *a* - tool body of axle and frontal type; *b* - tool body with intermediate elements and hole type.

The paper presents a representative model of boring heads, obtained through a first level of particularization of the generalized model of the cutting tool.

Constructive solutions of boring heads can be obtained by a creative particularization (second level of particularization) of the representative model of the boring heads.

In order to optimize the shape of boring heads from the uniformity point of view, we have developed the model of the cutting forces related to the representative model.

The most interesting constructive solutions were optimized through several analyzing criteria and perspectives.

2. REPRESENTATIVE MODEL OF BORING HEADS WITH INSERTS

The representative model of boring heads with inserts is obtained by particularization of the generalized tool model. This representative model consists of several cylindrical and conical bodies (Fig. 1) placed on the same axis (z axis). The main shape of the tool body can be of either the axle type or the hole type. On the cylindrical and conical shapes, there are placed inserts with a cutting role and pads with the role of guiding the cutting tool into the hole. The cutting inserts can be placed on the cylindrical and conical shapes in radial position or in tangential positions (the tangential inserts can be placed on the frontal part or on the cylindrical and conical shapes). The body rotates around the z-axis (as main movement) in order to perform the chipping process and translates along the same z-axis with the aim of bringing new raw material in front of the inserts [2]. Analyzing the representative model of boring heads, we can underline the classification possibilities and the constructive solution related with each criteria (Table 1).

Table 1

Analyzing criterion of the boring head representative model

Criterion	**Constructive solution – examples**
Main shape type	Axle type, hole type
Edge position	On the cylindrical shape, on the frontal shape, on the conical shape, on multiple shapes
Component parts	Monoblock, with brazed inserts, with changeable inserts fixed on the tool body, with changeable inserts fixed on intermediate rigid elements, with changeable inserts fixed on intermediate adjustable elements.
Position of the active elements	Radial, tangential on the frontal shape, tangential on the cylindrical shape
Insert shape	Triangle, square, rhomb, special
Clamping system	Using tool body elasticity, with central screw, with wedge
Edge number	one, two,…

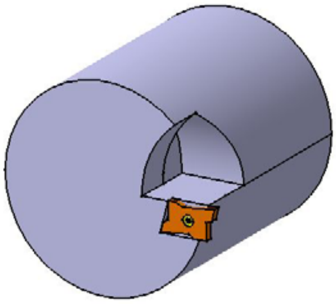

Fig. 2. Reamer with multi-edge insert placed on the frontal face.

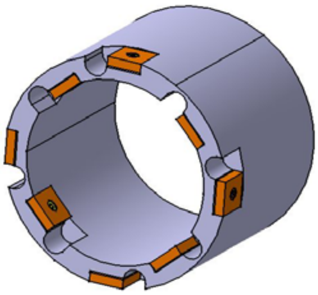

Fig.3. Reamer with tangential inserts clamped on the cylindrical face.

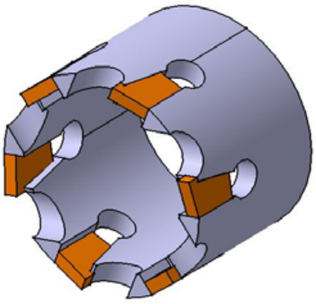

Fig.4. Reamer with inserts clamped by the elasticity of the tool body on the frontal face.

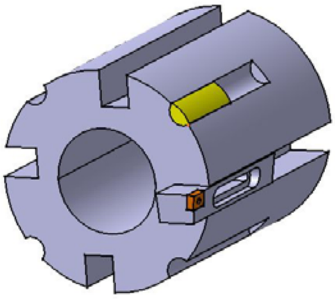

Fig.5. Reamer with axial adjustable intermediate body.

3. MODERN CONSTRUCTIVE SOLUTIONS

In the following, we shall present some constructive solutions obtained by particularization of the representative boring head. These are:

- Reamer with multiple edge insert clamped on the frontal face (Fig. 2).
- Reamer with tangential inserts clamped on the cylindrical face (Fig. 3).
- Reamer with inserts clamped by the elasticity of the tool body on the frontal face (Fig. 4).
- Reamer with axial adjustable intermediate body (Fig. 5).
- Reamer with radial adjustable intermediate body (with radial or tangential inserts).
- Chamfer with inserts clamped by the elasticity of the tool body.
- Chamfer with axial multiple edges inserts (Fig. 6).
- Chamfers with adjustable intermediate body with radial or tangential inserts (Fig. 7).
- Chamfer with adjustable intermediate body and insert clamped by the elasticity of the tool body [3] (Fig. 8).

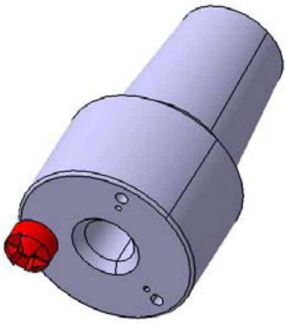

Fig.6. Chamfer with axial multiple edges inserts.

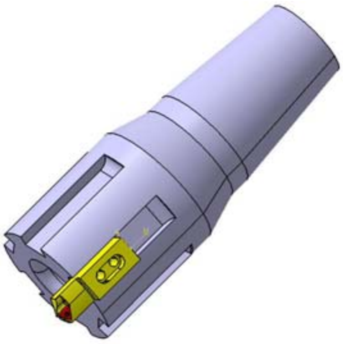

Fig.7. Chamfers with adjustable intermediate body with radial or tangential inserts.

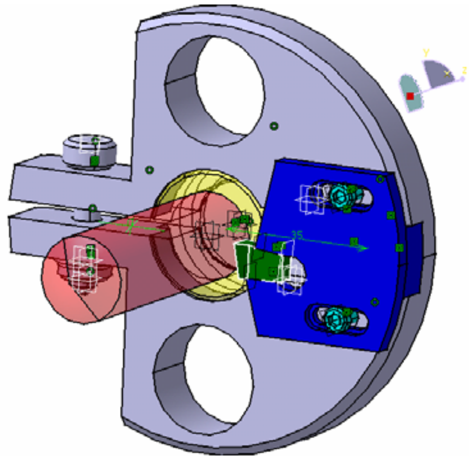

Fig.8. Chamfer with adjustable intermediate body and insert clamped by the elasticity of the tool body.

4. OPTIMIZATION OF THE NEW SOLUTIONS

The optimization criteria are:

- material economy;
- uniformity of stress with minimal value of the stresses from different perspectives: cutting tool parameters, material with high performance, the type and form of the clamping system etc;
- minimum and uniform forces determined by insert position;
- modularity;
- ability to maintain cutting characteristics and power;
- different and large utilization area from the efficiency perspective.

There are several aspects that can be optimized: insert shape, clamping system and tool body. One of the optimization method starts with the cutting force estimation. After that, the studies can continue with the static or/and dynamic equilibrium analysis and/or the finite element method analysis.

In the following, we shall present some studies on:

- The clamping system realized as the result of the elasticity of the tool body;
- The design of chamfer inserts; the analysis from the stress state perspective.

4.1. Generalized force and moment model

The aim of a generalized force model is the rapid estimation of the cutting force and moment of different particular constructive solutions of boring heads.

The value and variation of the forces depends on the insert number and their position on the tool body (on the frontal, cylindrical, conical shape, etc.). The general expressions are presented in the following [4].

Tangential cutting forces F_{iy} and the friction forces on the support and guide pads P_{iy} cause the torque M_c. The expression of the torque is:

$$M_c = \sum_{i=1}^{n} r_i \cdot F_{iy} + \sum_{j=1}^{m} R_j \cdot P_{jy} = \sum_{i=1}^{n} r_i \cdot a_{pi} \cdot f_i \cdot k_{ci} + \sum_{j=1}^{m} R_j \cdot B_j \cdot H_j \cdot k \cdot \mu \quad , \qquad (1)$$

where the specific cutting force k_c was established in an experimental way [4, 5], r_i - radius of the inserts cutting area position and R_j - radius of the pad position

Axial forces F_{iz} and the friction forces on the support and guide pads P_{iz} give rise to an opposite feed force F_f. The expression of this force is:

$$F_f = \sum_{i=1}^{n} F_{iz} + \sum_{j=1}^{m} P_{jz} = \sum_{i=1}^{n} a_{pi} \cdot f_i \cdot k_{cfzi} \cdot \mathbf{sin}\, \kappa_{ri} + \sum_{j=1}^{m} B_j \cdot H_j \cdot k \cdot \mu \quad . \qquad (2)$$

The sum of the radial forces F_{ix} that appear on the cutting inserts of a symmetric boring heads is theoretically equal to zero. Otherwise, the hole will result at a larger diameter.

In the case of asymmetrical boring heads (especially for deep hole boring) when the condition of zero radial force sum cannot be fulfilled, the support and guide pads are used in order to balance the boring head radial load. The condition is:

$$\sum_{i=1}^{n} \vec{F}_{ix} + \sum_{j=1}^{m} \vec{P}_{ix} = 0 \qquad (3)$$

The friction coefficient between the support and guide pads and the raw material (k) is difficult to be determined accurately. In this case, the previous equation cannot be solved with precision. The solution is the design of a boring head at which the resultant of the radial forces should fall between the support pad and the guide pad. However, bringing it closer to the support pad can determine an oversize hole.

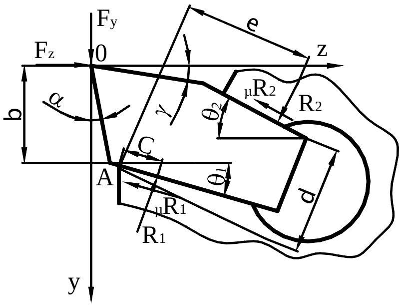

Fig. 9. Equilibrium analysis of the clamping system realized due to the elasticity of the tool body.

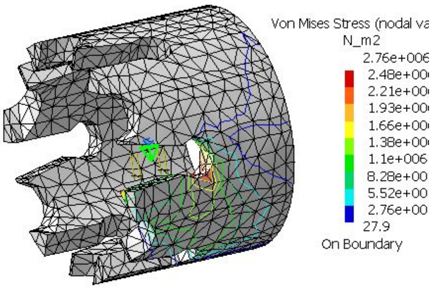

Fig.10. Stress state analysis of the reamer tool body with inserts clamped by the elasticity of the tool body.

The division of the large cutting edge into several cutting edges placed in a different position on the body tool reduces the values of the radial forces on the guide pad.

4.2. The clamping system realized as a result of the elasticity of the tool body

The clamping system by the elasticity of the tool body is very economic from the space point of view. It requires precise shapes of the elements in order to assure the safe clamping and dynamic stability. Our purpose was to establish the optimal shape of the inserts and of the pocket [1]. The solving of the equilibrium equations (Fig. 9) indicated that the inserts and toolholders must have special gradients in order to assure a safe clamping. The best values are $\theta_1 = 2\ldots15°$ and $\theta_2 = 2\ldots6°$.

Another study was made in relation with the tool body. The finite element method indicates the stress state for different shapes of the pocket in the curve area. This area can be round or can present splits with different lengths. The study allowed the choice of the best solution.

4.3. The design of chamfer inserts; analysis from stress state perspective.

The need of high productivity determines the construction of complex tools that can realize complex shapes during the same operation. In the case of the tool that contains both a bore or reamer (axle type) and a chamfer body (hole type), the chamfer insert must have a special form with the active part like a bill (Fig. 11). In this figure a radial insert, a tangential one on the frontal shape and a tangential insert on the cylindrical shape are presented.

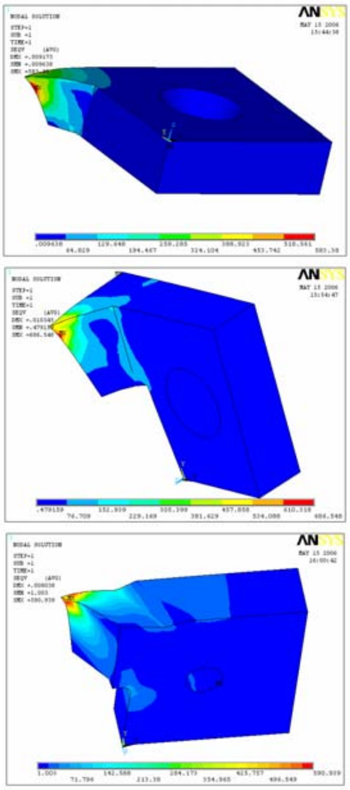

Fig.11. Von Misses stresses for chamfer inserts.

The finite element method allows the estimation of the stress state and the deformations in every case. The cutting force was 600N and the clamping force - 300N. The results are:

- For the radial insert - Von Misses maximum stresses - 518 MPa; Maximum deformation - 0.0087mm;
- For the tangential on the frontal shape insert - Von Misses maximum stresses - 686 MPa; Maximum deformation - 0.0094mm;
- For the tangential on the cylindrical shape insert- Von Misses maximum stresses - 590 MPa; Maximum deformation - 0.0062 mm;

10. CONCLUSIONS

This type of research leads us to new modern and original constructive solutions of boring heads. Each constructive solution can be optimized from different perspectives and analyzing criteria.

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