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CALCULATION OF THE MULTI-BLADE ROTARY-FRICTION TOOL'S CUTTING CUPPED CUTTER TO STRENGTH IN THE ANSYS WB SURROUNDING

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Key words: *heating cupped cutter, cutting cupped cutter, strength, stiffness, cutting force, radial displacement, deformation*

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CALCULATION OF THE MULTI-BLADE ROTARY-FRICTION TOOL'S CUTTING CUPPED CUTTER TO STRENGTH IN THE ANSYS WB SURROUNDING

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The authors developed the design of a special multi-blade rotary-friction tool. The multi-blade rotary-friction tool is equipped with two cupped cutters – heating and cutting. The heating cupped cutter is made of medium-carbon structural steel of any brand, and the cutting cupped cutter is made of steel R6M5. The final formation of the treated surface and its quality is provided by the cutting cupped cutter. This article presents the results of the calculation of the strength of the cutting cupped cutter multi-blade rotary friction tool.As a result, the following were established: when processing steels 30HGSA cutting force components reach the maximum value than when processing materials 40HN2MA, St.45, and St.3c (calm); strength and rigidity of the cutting cupped cutter is sufficient for processing optimal cutting conditions: nsp = 1000 rpm; S = 0.42 mm/rot; t = 1.0 mm.

Key words: heating cupped cutter, cutting cupped cutter, strength, stiffness, cutting force, radial displacement, deformation

INTRODUCTION

Rotating cupped cutters are the most important element of many rotary and rotary-friction processing tools [1,2,3]. The strength and durability of cutting tools determine the possibility of obtaining high parameters of the tools, provide the necessary service life. The development of computer technology, equipping design bureaus and research organizations of computers allow us to introduce more modern methods of calculation of cutting tools, to make refined calculations. The main loads acting on the cupped cutters are the centrifugal forces arising during rotation. Determination of stresses and strains from centrifugal forces is the main stage of calculating the strength of cutting tools. Unevenly heating leads to thermal stresses, which can be significant, especially in non-stationary modes of operation of the tool. Evenly heated in thickness, symmetrical concerning the flat middle surface of the cupped cutter is enough to count only on the tension. For cutting tools of complex shape with a curved middle surface with uneven heating thickness or axial loads and moments during the calculation should take into account the bending.

Cupped cutters of constant thickness are rare, but the closed solutions obtained for them are necessary to control the calculations, simplified estimates and substantiate the results obtained using numerical methods [4].

In most cases, cutting tools operate under conditions of increased loading, leading to plastic deformations [5,6]. Rotary cupped cutters are undergoing an impact on high temperatures, which is associated with the appearance of creep deformations. The most common in engineering calculations is to account for plasticity and creep using appropriate deformation theories and the use of iterative procedures for the sequential solution of elastic problems. However, this does not allow us to study in detail the kinetics of the stress-strain in state of cutting tools operating during operation at different modes, with cyclically varying loads. In these cases, it is necessary to take into account the history of loading, which leads to the creation of more complex methods for calculating cutting tools in increments of deformations and forces using the theories of plastic flow and similar creep theories, taking into account the history of deformation.

The criteria for evaluating the designs of cutting tools are the stock factors for various parameters that determine their strength, deformability, bearing capacity and durability [7]. An important characteristic is the strength of the disc. The increase in work resources leads to a sharp increase in both the duration of the loads and the number of repetitions (cycles) of loads for some machines. Accumulation of long-term static and low-cycle damage in the material can lead to premature destruction of cutting tools. The strength calculation should be based on an accurate assessment of stresses and strains, consideration of stress concentration, knowledge of material properties under similar loading conditions and the use of modern concepts of damage accumulation.In practice, there are cupped cutters of considerable thickness, sometimes commensurate with the radius [8,9].

For them, calculation methods using the hypothesis of a plane stress state and a rigid normal are not suitable.

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The calculation of the spatial stress state became possible due to the development of the finite element method (FEM), which allows implementing well-developed procedures for solving the elastoplastic problem, and the introduction of CAE systems of sufficiently high efficiency. When calculating the design of cutting tools, it is also necessary to take into account the impact of the environment. For this purpose, the refined methods of calculation realized on the computer [10] are developed.

The authors have developed the design of a special multi-blade rotary friction tool. Figure 1 shows the construction of a special multi-blade rotary friction tool on both sides.

The multi-blade rotary friction tool is equipped with two cupped cutters – heating and cutting. The heating cupped cutter is made of medium-carbon structural steel of any brand, and the cutting cupped cutter is made of steel R6M5. The final formation of the treated surface and its quality is provided by the cutting cupped cutter. In this regard, the calculation of the strength of the cutting cupped cutter multi-blade rotary friction tool is an urgent task.

EXPERIMENTAL AND DISCUSSION OF THE RESULTS

Create a calculation model of the tool. We calculate the strength and stiffness of the structural units of a multi-blade rotary friction tool by numerical method.

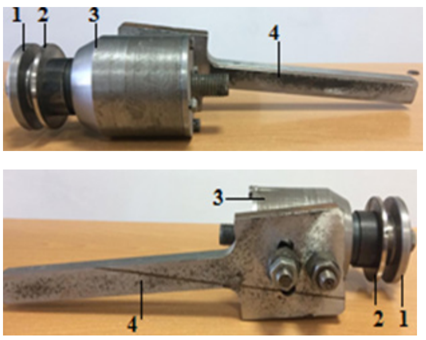


Figure 1: Multi-blade rotary friction tool: 1-heating cupped cutter; 2-cutting cupped cutter; 3-shell; 4-holder

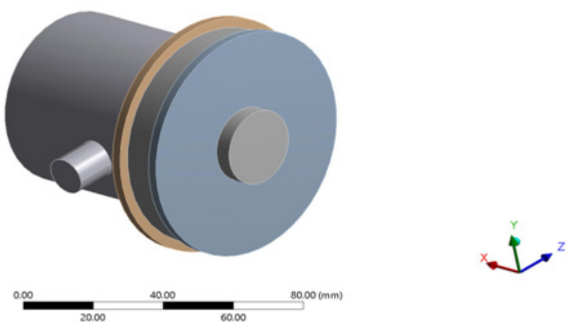


Figure 2: Three-Dimensional model of the body of a multi-blade rotary friction tool

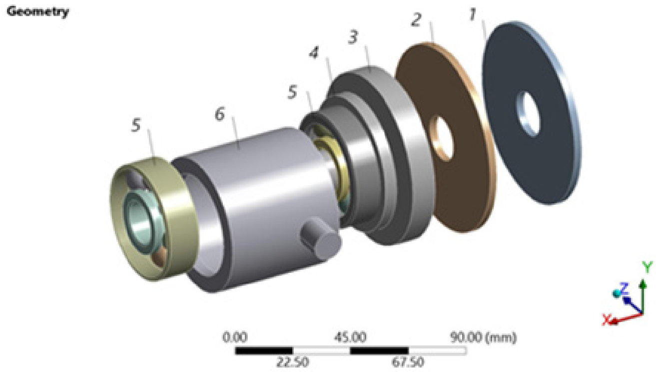


Figure 3: Nodes of multi-blade rotary friction tool: 1-heating cupped cutter, 2 - cutting cupped cutter, 3-sleeve, 4-shaft, 5-radial thrust bearing, 6-shell

Before numerical modeling, experimental studies were conducted [11,12,13,14], in which positive qualitative indicators were obtained. For this purpose, a three-dimensional model of the body of a multi-blade rotary friction tool was created in Ansys WB surrounding (figure 2).

Figure 3 shows the Assembly of a multi-blade rotary friction tool.

To create a computational model, the predicted change in the projection of the cutting force of the cutting cupped cutter on the unfavorable position of the tool was first determined, which was 15 degrees, as the contact forces during the processing of the body of rotation of the material 30HGSA. Since the processing of the material cutting force components reaches a maximum value than in the processing of materials 40HN2MA, St. 45 and St. 3c. Figure 4 shows the predicted change in the projection of the cutting force of the cupped cutter.

The calculation was made by the finite element method. The most widely known Johnson-Cook model (Johnson-Cook) is chosen as a criterion of the destruction of elements of the KE-grid. These projections of the cutting force are obtained for the following cutting mode: spindle speed-n = 1000 rpm, feed-S = 0.42 mm / Rot, cutting depth-t = 1.0 mm.

It is necessary to pay attention that owing to the discrete model, the predicted cutting force is not certain and tests some fluctuations in the course of rotary-frictional boring. The reliability of the model confirms the sensitivity of the cutting force and temperature to changes in cutting speed following modern concepts: with increasing cutting speed, the cutting force decreases and the temperature increases.

Calculation of the cutting cupped cutter and discussion of the results. To perform the strength calculation, a package of computer applications is used. Figure 5 shows the project tree of the Static Structural module.

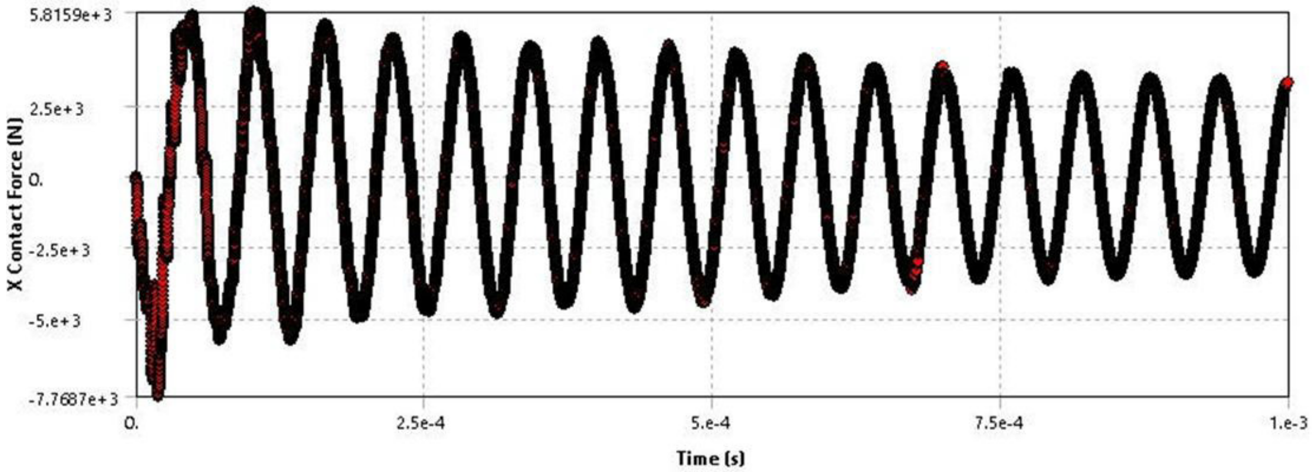
The model project tree consists of six sections: geometry, material, coordinate systems, connections, mesh and static structural.

In the geometry section, a three-dimensional (one-dimensional, two-dimensional) model is loaded in which materials are assigned to each node of the structure. Also there you can change the type of material, that is, deformable or rigid.

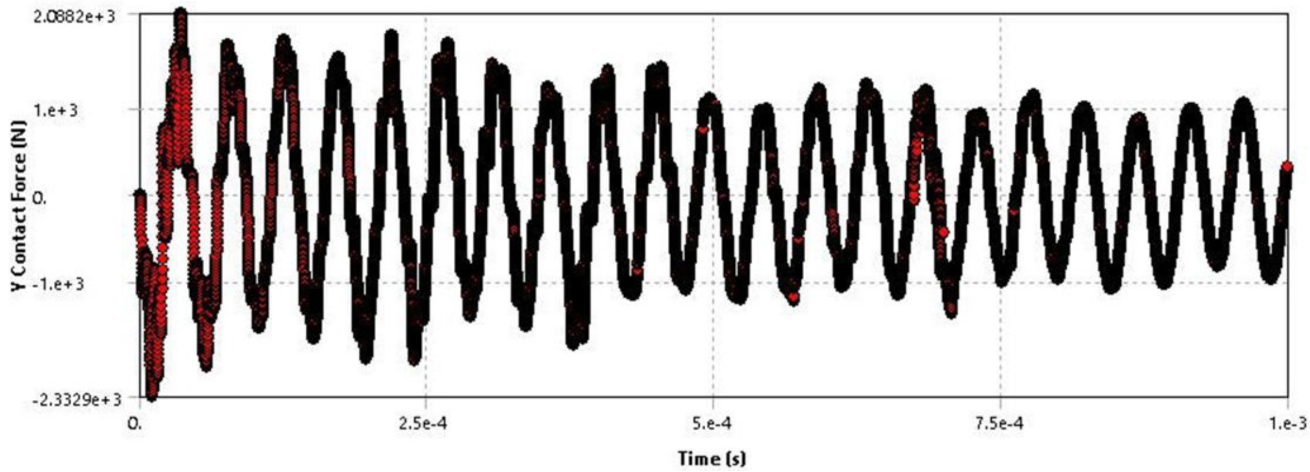
In materials, you can directly view and change the parameters of materials.

Point coordinate systems allow you to set and adjust (move, rotate) the coordinate system, switching Cartesian and cylindrical coordinate systems.

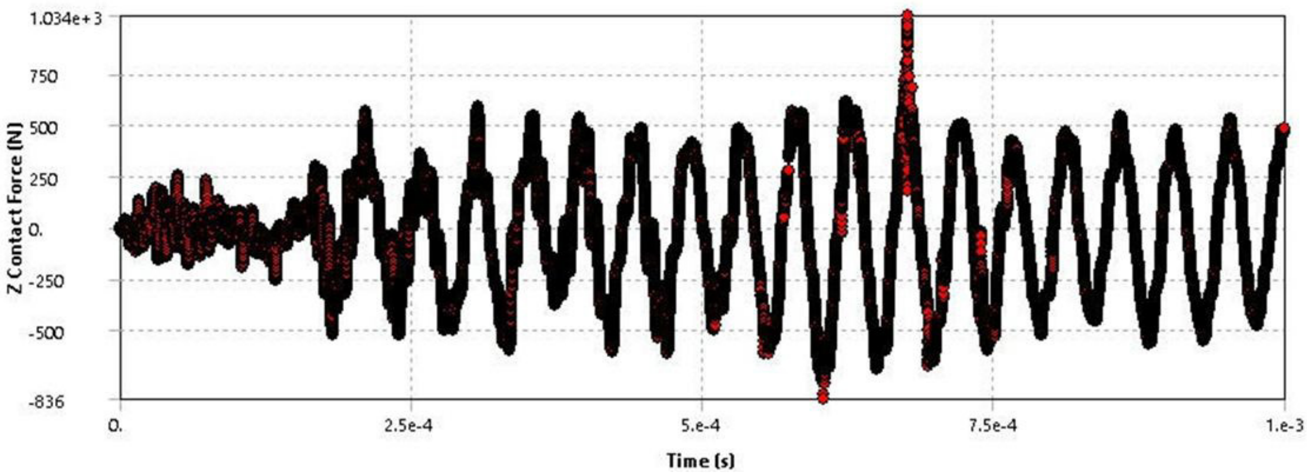
In connections, you set up contact pairs (contacts) and connection (joint). In the setting up figure the connection of bearing unit.



a)



b)



c)

Figure 4: Predicted change in the projection of the cutting force of the cutting Cupped cutter: (a) X-axis; (b) Y-axis; (c) Z-axis

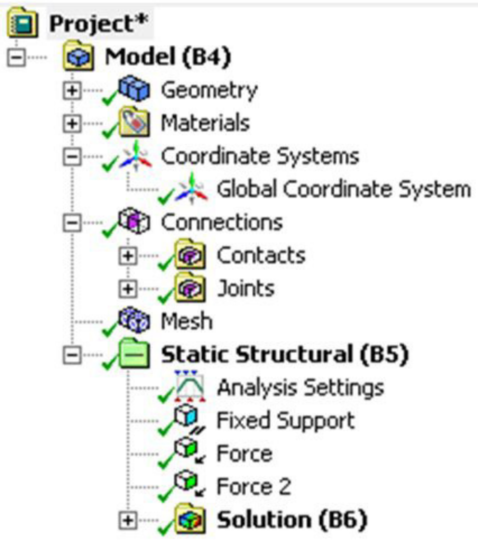


Figure 5: The project tree of the Static Structural module

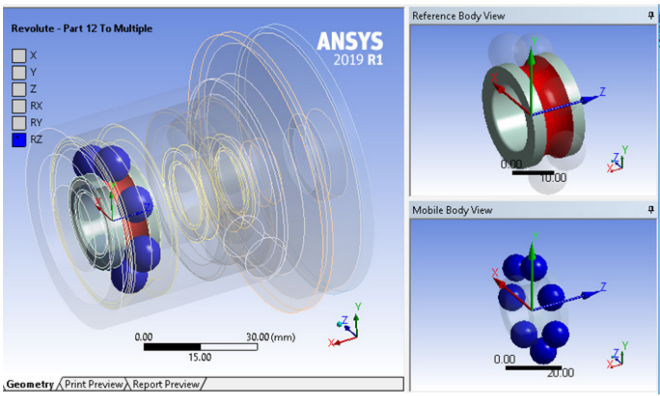


Figure 6: Setting up the bearing unit connection

In a Mesh surrounding partitioning into finite elements occurs. This section requires additional settings. Figures 7 and 8 show the FE model and boundary conditions of a multi-blade rotary friction tool.

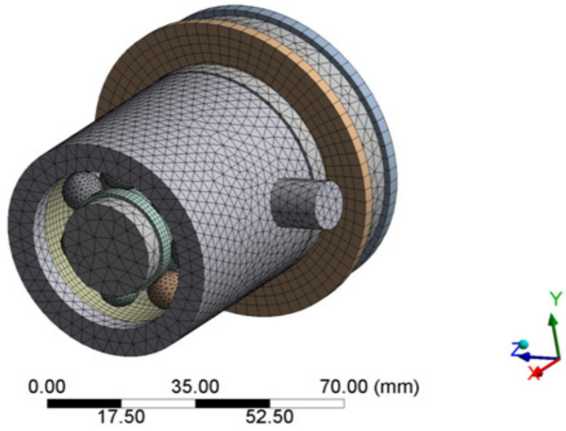


Figure 7: FE model for multi-blade rotary friction tool

The static structural clause specifies the boundary conditions.

The strength of the cutting cupped cutter is ensured. This is due to the frequent change of the cutting area due to the transition of the friction force to the rolling force.

The accuracy and quality of the treated surface is characterized by the magnitude of the deviation in the axial and radial direction. Figure 10 shows the results of the stiffness calculation of the cutting cupped cutter.

The results of the deformation pictures show a radial displacement of 19.4 microns and an axial displacement of 48 microns which is insignificant.

Thus, for this cutting mode, used for processing steel 30HGSA, the strength and stiffness of the cutting cupped cutter is sufficient.

CONCLUSIONS

Projected change in the projection of the cutting force and the cutting temperature are sensitive to changes in the cutting speed following modern concepts: with increasing cutting speed, the cutting force decreases and the temperature increases.

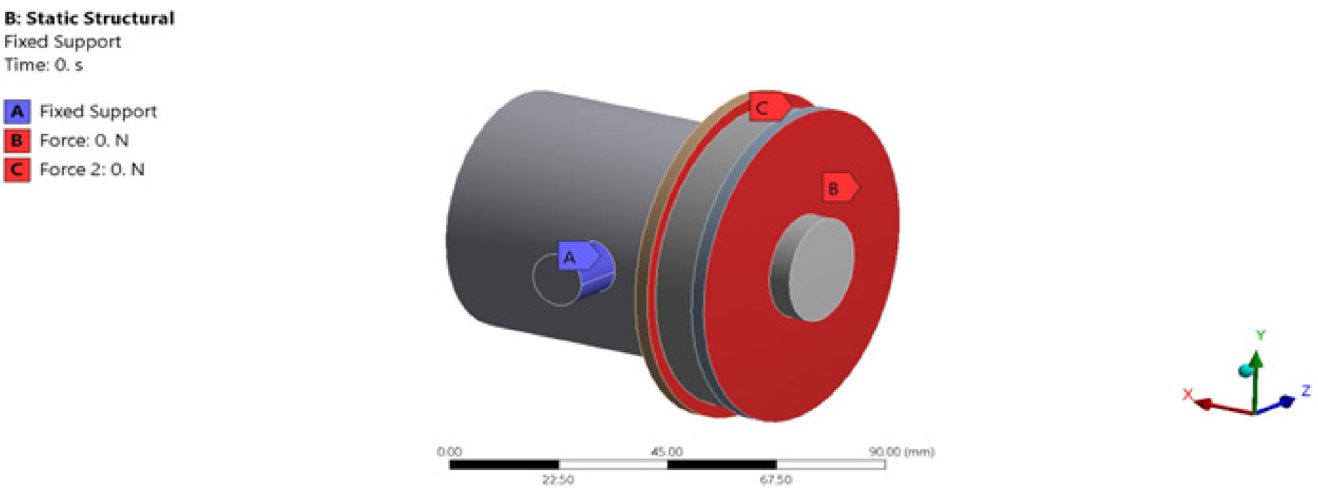


Figure 8: Boundary conditions of a multi-blade rotary friction tool

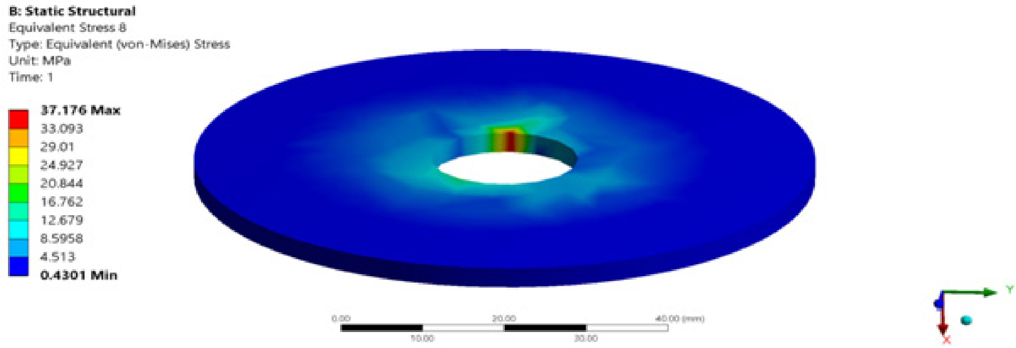
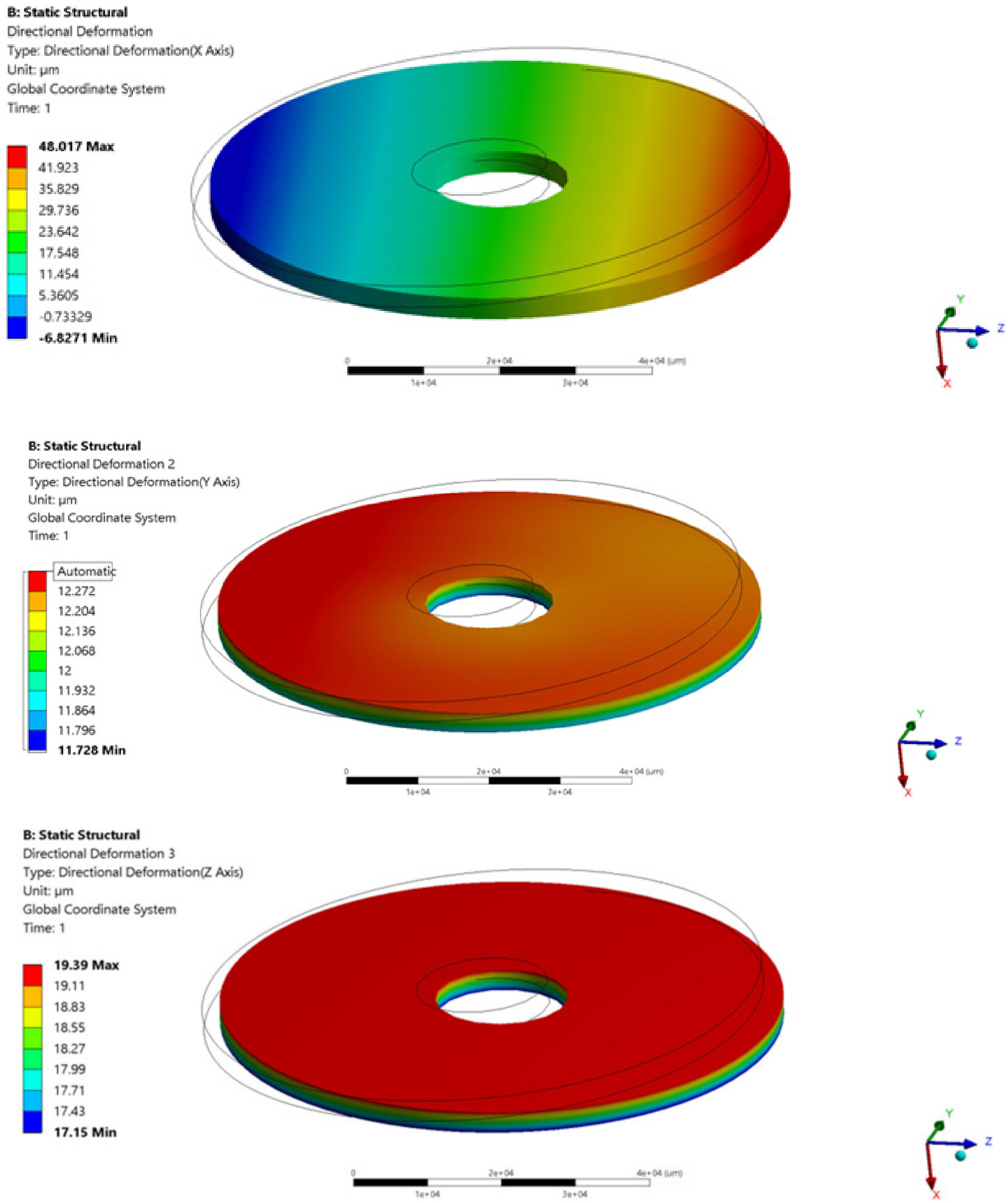


Figure 9: Stress state of the cutting cupped cutter



a)

b)

c)

Figure 10: The deformation picture in directions:a) along the X-axis;b) along the Y-axis;c) along the Z-axis

It is established that when processing steels 30HGSA cutting force components reach the maximum value than when processing materials 40HN2MA, St. 45 and St. 3sp.

It is established that the strength and stiffness of the cutting Cupped cutter is sufficient for processing optimal cutting conditions: *nsp* = 1000 rpm; S = 0.42 mm/rev; t = 1.0 mm.

Modern methods used in scientific and industrial practice for modeling processing processes, created on the basis of computer and analytical studies should be accompanied by additional experimental researches.

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