Conference Article

Computer modeling of the stress-strain state of a linear friction welded disk

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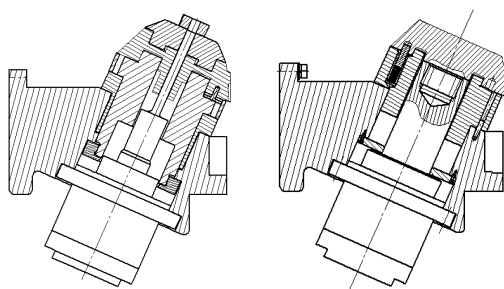
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Abstract

The paper is dedicated to design issues of tooling for linear friction welding (LFW) machine. Computer model of a LFW machine was built. As a result of computer simulation, the stress-strain state of the machine and disk module for linear friction welding of aluminum alloy blisks also was obtained. On the basis of the results of computer simulation a module with a replaceable unit and a new variant fixing of disc in the module were designed.

Keywords: linear friction welding, disk module, blisk, blades, stresses, deformations

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1. Introduction

During production of the gas turbine engine linear friction welding (LFW) is used to weld the blade disc. The disc is secured in the welding machine in a removable disk module.

When designing the disc module there are two ways that the disc can be secured into place. In the first option the object [1] is pressed against the cover disc which is attached to the hydraulic cylinder, which in turn passes through a hole in the blisk (Figure 1a). In the second case the disc is pushed by a threaded rod connecting it to the disc (1b).

a) b)
Fig. 1 – Assembly to clamp disc: a) with cover and b) without cover

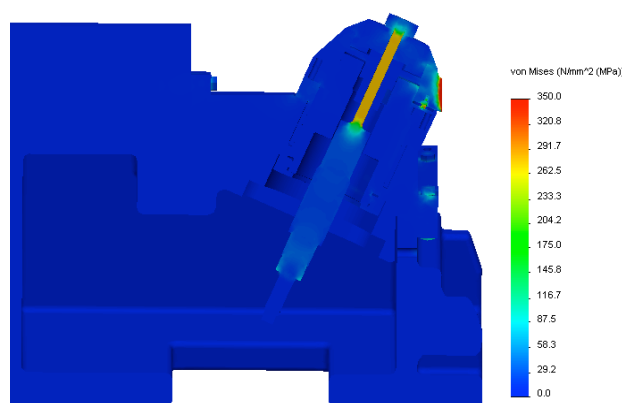## 2. Description of the computer model

In order to test for static strength and stiffness under contact pressure and welding forces the first version of the designed module SolidWorks Simulation was used. The LFW process parameters for which the analysis was performed were: oscillatory force = 100 kN; forge force = 100 kN; contact pressure = 150 kN.

The maximum size of the tetrahedral elements used in the mesh was selected to be 20mm. The material of the disc

was duralumin alloy 3.13.55 EN-AW 2024 (DIN) and its properties were taken from the library of SolidWorks Simulation 2013. The material rod and cap nuts were DIN 1.0503 C45 steel with a yield strength of 560 MPa. The material for the other parts of the unit was steel DIN 1.0301 C10. Between the two types of parts there was contact: bonded and without mutual penetration of the elements as they move relative to other parts.

3. Results and discussing

According to analysis results for the static load case (Figure 2) the highest stress on the rod hydraulic cylinders was around 280 MPa.

Fig. 2 - Equivalent von Mises stresses (MPa) due to the upward force of the oscillations

The hole in blisk with the diameter of 27 mm restricts the rod diameter and does not provide fatigue strength in threaded joint.. Therefore further changes to the design were required .

When the disk module was designed the specifications were such so as to accommodate a blisk for various stages of the turbine engine.
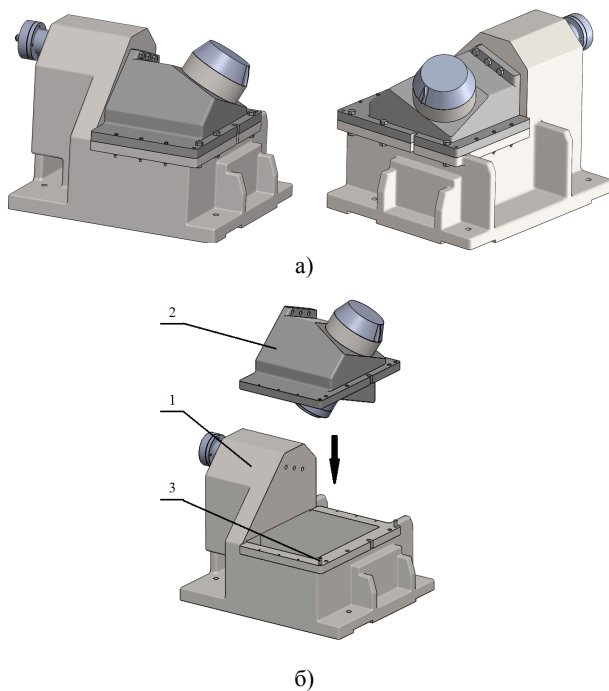
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The solution to this problem in the patent [2] is by rotating the table with a disk independently about three axes.
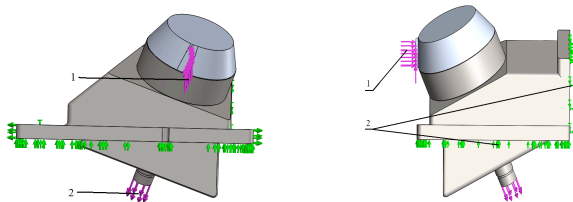
However, this arrangement of the module requires a very big suspension design and high spatial precision to position the disk, as LFW positional accuracy is hundredths of a millimeter.

For joining several blisks without reinstalling the entire module disk a replaceable unit has been designed (Figure 3). The frame of the housing disc in the first position is made of cast steel billets. A replaceable unit is installed individually for each blisk in a frame along the guide pins on the supporting surface, and then the plug-in unit is bolted to the frame.

The disk module with the removable unit dimensions to fit the specified loads of LFW were calculated with SolidWorks . The mesh size and the types of contact , the materials of disk and disk module were the same as in first simulation.

a)

б)

Fig. 3 -Module disc, complete with an additional removable unit for welding of aluminum alloy blisks: a - in the assembly; b – parts of it
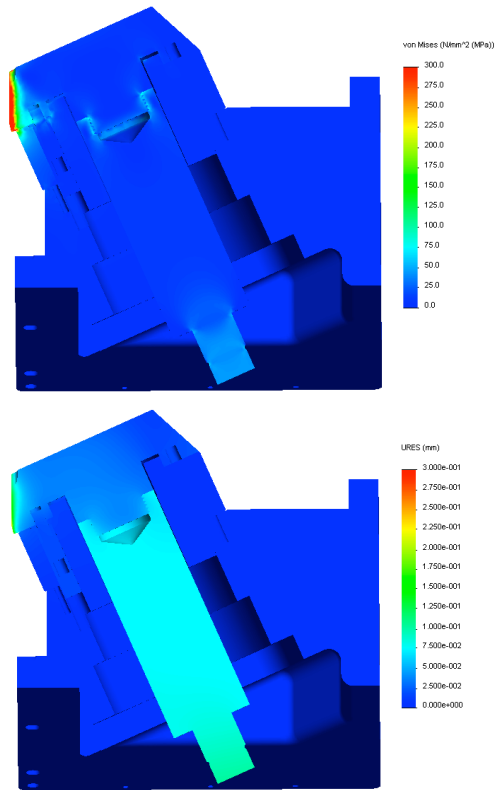

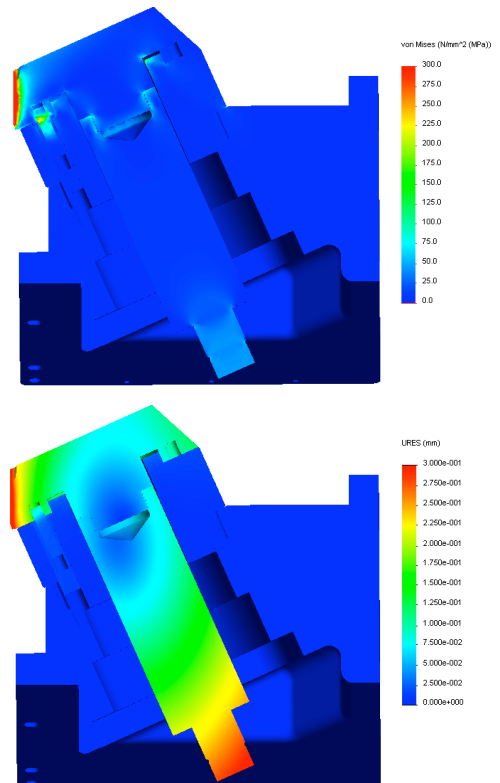**Fig. 4** - Module disk drive assembled to use in LFW machine

It was found that when estimating deformations the model can only include the interchangeable disk unit because it coincides with the calculation disk module only by an error of less than 0.01 mm.

The estimated model with a removable disk unit for LFW is shown in Fig. 4 and the model calculations in Fig.5…Fig.9.

According to the results of the analysis (Figure 5 and 6), the design of the disk module proceeded to have the necessary strength and during LFW the maximum deformation of the surface of the module plug-in unit, which
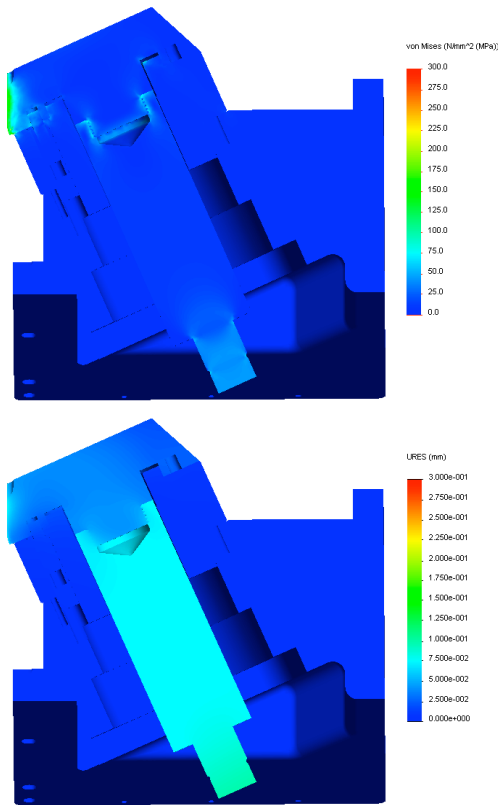

Fig. 5 - Equivalent von Mises stress (MPa) and total displacement (mm) with friction pressure when the oscillation force is directed down
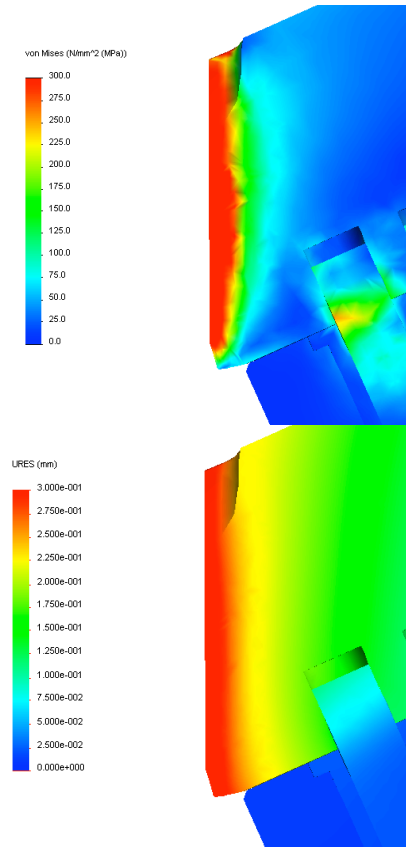

Fig. 6 - Equivalent von Mises stress (MPa) and total displacement (mm) with friction pressure when the oscillation force is directed upwards
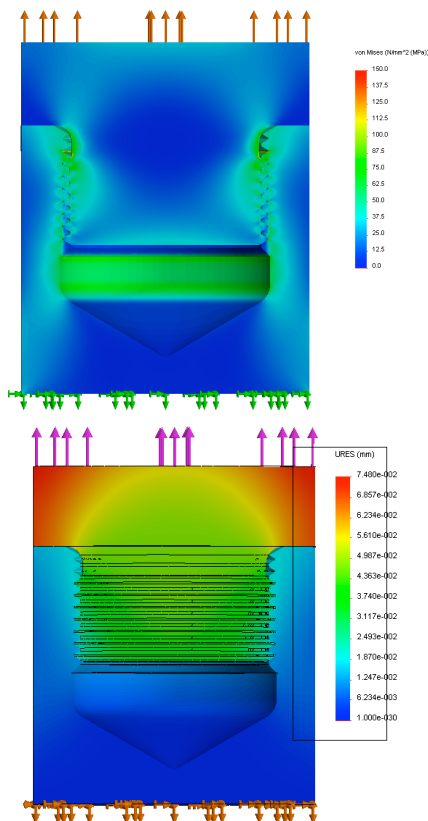
drive is under 0.05 mm. The numerical modeling has shown that the largest stresses and deformations occur during the application of the upward force of the oscillatory movement

Fig. 7 - Equivalent von Mises stress (MPa) and total displacement (mm) with forge force friction pressure without the oscillation force

Fig. 9 - Equivalent von Mises stress (MPa) and total displacement (mm) with friction pressure when the oscillation force is directed upwards in welding area

For the design with the threaded connection with the rod blank disc another model was developed with the maximum size of tetrahedral elements used in the mesh set to 2 mm under a force of 225 kN which is 1.5 the design load of pressing the disk. All other parameters and conditions were chosen to be the same as in the modeling of the entire module disk. The results of the analysis are shown (Figure 8)

After the termination of the oscillatory movement these deformations are reduced and do not exceed 0.02 mm (Fig.7).

Fig.9 shows that maximum stresses in the disc in the welding zone at the start of the process do not exceed the yield strength of the disc material and the maximum of elastic deformation of the lower edge of the disk do not exceed 0.2 mm. This is sufficient for the implementation of LFW process.

Thus, the results of numerical modeling of the stress-strain state have been applied successfully in the LFW of blisks of aluminum alloy.

4. Conclusions

The numerical modeling of the stress-strain state of the fixture module for the linear friction welding of blisks assisted in the design of a new module for welding aluminum alloy blisks with a replaceable unit and a new variant of the fixing disk.

Fig. 8 - Equivalent von Mises stress (MPa) and total displacement (mm) with friction pressure when the oscillation force is directed upwards in threaded joint

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References

[1] *Linear Friction Welding - Machine Design //* URL: http: //www.cyrilbath.com/linear-ficton-welding/lfw-machine-design.html (Date of treatment: 14/04/2015)
[2] Searle J.G., US Patent 5,148, 957 (1992)
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