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Issue Article

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ANALYSIS OF THE STRAIN INTENSITY OF A PREHEATED STEEL BUSHING UNDER CONDITIONS OF PRESSING A STEEL SHAFT INTO IT TO FORM A FIT WITH A GUARANTEED INTERFERENCE

Abstract: *This article presents the results of finite element modeling of the strain of a press-fit joint bushing with guaranteed interference. The strain intensity of the bushing material was estimated by the crack growth direction, volumetric strain and the principal strain direction.*
Key words: *pressing length, bushing model, strain, vector.*
Language: *English*

Impact Factor:

ISRA (India)	= **6.317**	**SIS** (USA)	= **0.912**	**ICV** (Poland)	= **6.630**
ISI (Dubai, UAE)	= **1.582**	**РИНЦ** (Russia)	= **0.191**	**PIF** (India)	= **1.940**
GIF (Australia)	= **0.564**	**ESJI** (KZ)	= **8.100**	**IBI** (India)	= **4.260**
JIF	= **1.500**	**SJIF** (Morocco)	= **6.004**	**OAJI** (USA)	= **0.350**

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1. Introduction

The process of pressing a steel shaft into a heated bushing to form an interference fit is widely used in mechanical engineering to create fixed joints. When the bushing is heated, complex thermomechanical processes arise that require an analysis of the stress and strain state.

Preheating reduces the hardness and tensile strength of the bushing, facilitating its deformation and ensuring a tight fit to the steel shaft [1]. The intensity of strain depends on the magnitude of interference fit, pressing force and temperature distribution, which affects the yield strength of the material and the elastic and plastic transition [2-4]. Quantitative assessment typically involves the calculation of von Mises equivalent stresses, strain distributions and strain gradients using finite element modeling or analytical methods, taking into account thermal expansion, contact stresses and material flow [5-7]. This ensures that an interference fit is achieved without causing excessive residual stress or damage to components, maintaining the integrity and durability of assembled parts [8-10].

This article presents an assessment of the deformed state of the preheated steel bushing under press-fitting conditions with guaranteed interference according to several criteria, with the aim of identifying the most heavily loaded zones of the parts being joined that affect the reliability of the fit.

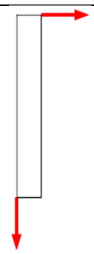
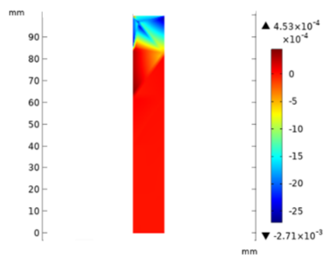
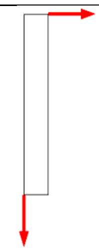
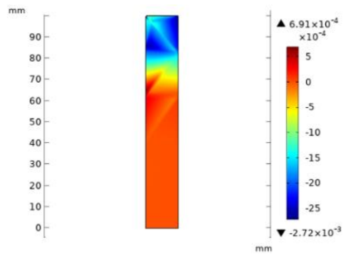
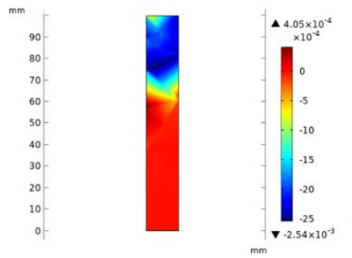
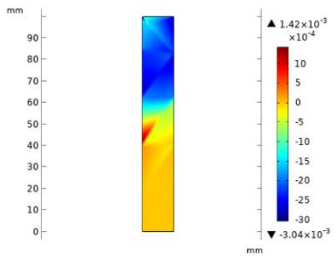
2. Materials and methods

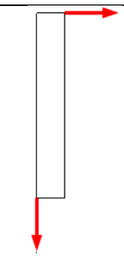
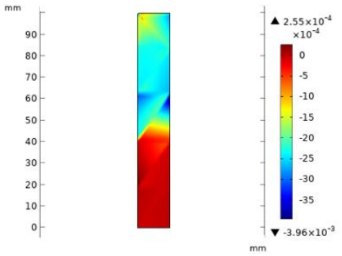
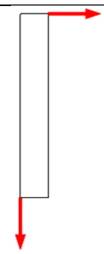
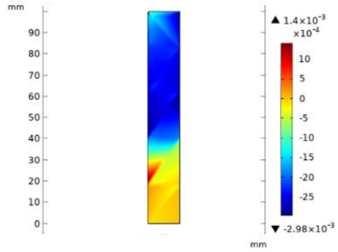
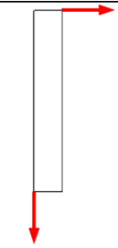
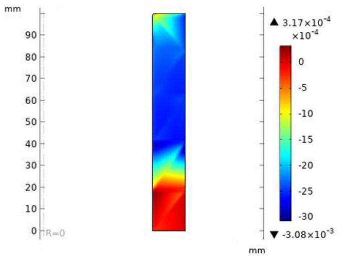
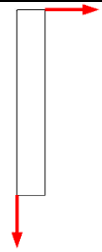
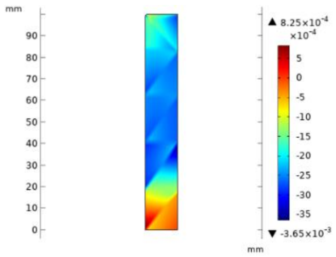
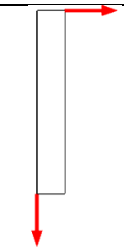
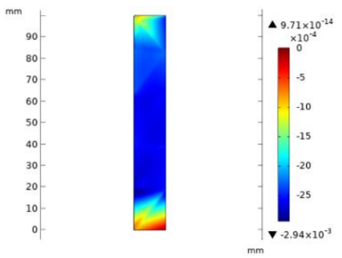
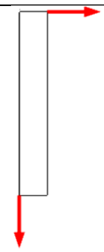
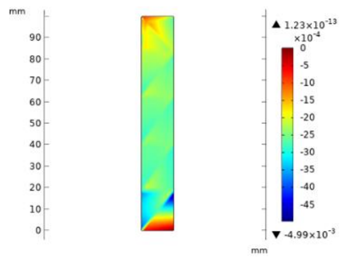
The initial and boundary conditions of finite element modeling of the process of pressing the shaft model into the bushing model are presented in [11].

3. Results and discussion

The results of finite element modeling of the deformation process of the bushing model under conditions of pressing the shaft model into it are presented in the Table 1 and the Figure 1.

Table 1. Crack growth direction and distribution of volumetric strain (contact on the model surface on the left) in the bushing model for different pressing lengths.

 Crack growth direction	 Volumetric strain	 Crack growth direction	 Volumetric strain
Pressing length is 10 mm		*Pressing length is 20 mm*	
 Crack growth direction	 Volumetric strain	 Crack growth direction	 Volumetric strain
Pressing length is 30 mm		*Pressing length is 40 mm*	

 Crack growth direction	 Volumetric strain	 Crack growth direction	 Volumetric strain
Pressing length is 50 mm		*Pressing length is 60 mm*	
 Crack growth direction	 Volumetric strain	 Crack growth direction	 Volumetric strain
Pressing length is 70 mm		*Pressing length is 80 mm*	
 Crack growth direction	 Volumetric strain	 Crack growth direction	 Volumetric strain
Pressing length is 90 mm		*Pressing length is 100 mm*	

The deformed state of the material of the bushing model is presented in the form of crack growth vectors in the axial and radial directions, the intensity of volumetric strain and the vectors of principal strain direction.

Crack growth in the material of the bushing model was calculated on the contact inner diametric and flat end surfaces of the part. Over almost the entire length of pressing, crack growth was noted in the direction of movement of the shaft model (along the inner cylindrical surface of the bushing model) and in the direction from the center line to the periphery of the bushing model (along the flat end surface of the bushing model). An exception is the multidirectional growth direction of cracks on the contact inner cylindrical surface of the bushing model over a pressing length of 30 mm.

The change in the volume of the bushing model relative to the initial volume was determined using the coefficient of volumetric strain. Positive and negative values of the coefficient of volumetric strain characterize the process of increase in volume (expansion) and decrease in volume (compression) of the material. Based on the calculated values of the coefficient, it can be concluded that the maximum compression of the volume occurs at a pressing length of 100 mm (a change in the volume of the bushing model of approximately 0.5%), and the minimum compression occurs at a pressing length of 30 mm (a change in the volume of the bushing model of approximately 0.25%). The expansion of the volume of the bushing model over the pressing length is an order of magnitude less than the compression of the volume under plastic deformation conditions. At a pressing length of over 80 mm, the expansion of the material volume is negligible.

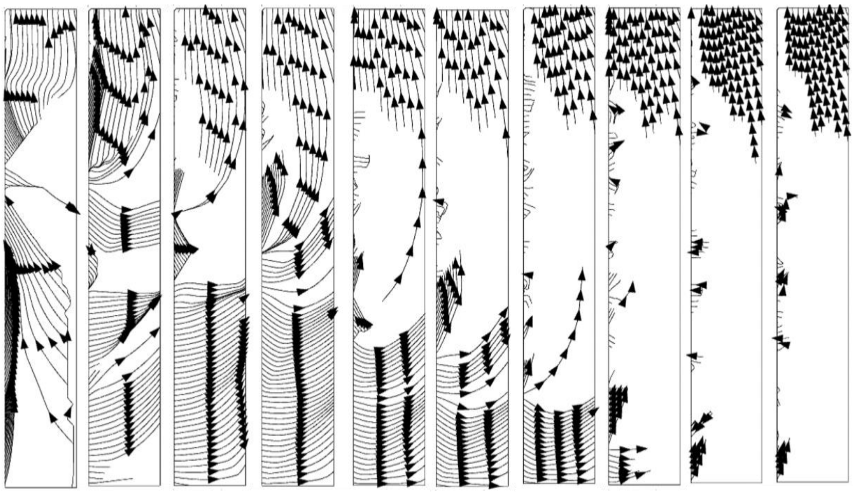


Figure 1. The vectors of principal strain direction in the wall of the bushing model along the pressing length (contact on the surface of the model on the left): ***A*** **– 10 mm,** ***B*** **– 20 mm,** ***C*** **– 30 mm,** ***D*** **– 40 mm,** ***E*** **– 50 mm,** ***F*** **– 60 mm,** ***G*** **– 70 mm,** ***H*** **– 80 mm,** ***I*** **– 90 mm and** ***J*** **– 100 mm.**

The vectors of principal strain direction of the material of the bushing model demonstrate the directions of tensile strain without taking into account shears. Cracks form in the material perpendicular to the calculated vectors. At extreme strains, partial destruction of the material of the bushing model may occur. It is noted that the stretching of wall of the bushing model is concentrated in the upper part, which can lead to the formation of cracks in the radial direction.

4. Conclusion

Strain of the steel bushing under conditions of pressing the steel shaft into it is represented by the following regularities:

1. Crack growth in the bushing material occurs in the axial (in the direction of movement of the pressed shaft) and radial (in the direction from the center line to the periphery) directions. An exception is the crack growth in the axial direction in opposite directions over a pressing length of 30 mm.

2. During the pressing process, the bushing material is subjected to elastic and plastic deformations of compression and tensile. Pressing the shaft into the bushing along its entire length is characterized by maximum compression of the bushing material with a loss of approximately 0.5% of its original volume due to cutting off a layer of material from the contact surfaces of parts.

3. The vectors of tensile direction of the bushing material volume at different stages of pressing were obtained. In the deformed sections of the bushing, the strain of material is directed in the opposite direction to the shaft movement. Pressing the shaft to its full length is characterized by localized low-intensity tensile in the upper part of the bushing material, which indicates the formation of potential cracks in this area in the radial direction.

References:

1. Bekher, S. A., et al. (2024). Inspection of Press Joints Based on the Analysis of Their Deformation Patterns under Local Thermal Loading. *Russ J Nondestruct Test, 60*, 54-62.
2. Ramamoorthy, B., & Radhakrishnan, V. (1994). A study of the surface deformations in press and shrink fitted assemblies. *Wear, Volume 173, Issues 1-2*, 75-83.
3. Chemezov, D. A. (2015). Deformations of the contact surfaces of the parts when pressing-in. *ISJ Theoretical & Applied Science, 02 (22)*, 1-7.
4. Rozhkova, E. A., & Chetverikov, S. V. (2018). The method of conducting experimental studies of the stress-strain state of profile joints with tension, *Vestn. RUDN, vol. 19, no. 1*, 46-58.
5. Lewis, R., & Marshall, M. B. (2005). Measurement of Interface Pressure in Interference Fits. *Proceedings of the Institution of Mechanical Engineers – Part C: Journal of Mechanical Engineering Science, Vol. 219, No. 2*, 127-139.
6. Kuliyev, S. A., & Mammadov, A. F. (2019). Determination of stresses in the connection hub

with tension during loading. *Vestn. Mashinostr., no. 7*, 27-30.

7. Mammadov, A. F. (2019). Calculation of the connection with tension to the shock load. *Probl. Mashinostr. Avtom., no. 4*, 85-87.
8. Bedlaoui, A., & Boutoutaou, H. (2023). Effect of interference and form defect on the cohesion of the shrink fit assembly. *Int. J. Adv. Manuf. Technol., vol. 128*.
9. Santus, C. (2019). Initial orientation of the fretting fatigue cracks in shrink-fit connection specimens. *Frattura Integr. Strutt., vol. 13 (48)*, 442-450.
10. Elmekawy, A., Badr, T., & Elgamal, H. (2023). Interference Fit Contact Finite Element Modelling and Optimization for Modal Analysis and Friction Instability. *AIAA SCITECH 2023 Forum*.
11. Chemezov, D., et al. (2026). Analysis of the stress intensity of a preheated steel bushing under conditions of pressing a steel shaft into it to form a fit with a guaranteed interference. *ISJ Theoretical & Applied Science, 03 (155).*