

Conference Article

## Computer Modeling of Localised Heat Treatment of Girth Welds

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### Abstract

The local heat treatment of girth welds can be optimized by the criterion of minimum temperature drop using computer modeling

Keywords: heat treatment, welded joint.

### 1. Introduction

In order to manufacture welded components with ring joints heat treatment is usually required to improve the microstructure and mechanical properties of the weld.

Localized heat treatment of such welds (shown in Fig. 1) can be effected by local heating instead of prolonged heat treatment of the whole of the part in a furnace. Computer modeling of the heating process significantly reduces the development cost of local thermal treatment.

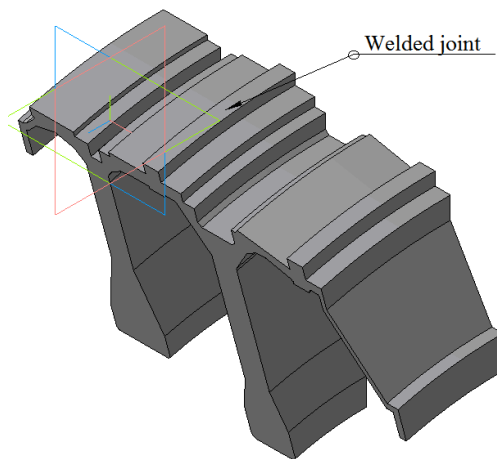


Fig. 1. Ring joint segment

Modeling the heat treatment was carried out for the following conditions: speed of heat source was 0.5 m / s, the power of the heat source  $P$  varied from 1800 to 3600 watt, diameter of the heating spot  $d_h$  was chosen to be either 16 mm or 24 mm.

The size of the weld after removing the top and bottom edges was equal to 5 mm. According to [1] the maximum temperature at the upper boundary of the weld at point T1 was assumed to be 920 ° C.

### 2. Description of the numerical model

The aim of modeling local heat treatment was to obtain the minimum difference between the temperature at point T1 and point T2 at the lower boundary of the weld. Modeling of heat treatment was performed in the software package ANSYS / Multiphysics ver. 14 based on the differential nonlinear heat equation:

$$\rho \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left( \lambda_x \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( \lambda_y \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( \lambda_z \frac{\partial T}{\partial z} \right) \quad (1)$$

The temperature dependence of thermal properties of the alloy Ti6Al4V was based on those provided by the software package Deform 3D as shown in Fig. 2.

The model assumed that heat lost from the weld is symmetrical, so that the temperature field can be determined for one single part of the ring joint. To accelerate the computation model has been presented in a reduced form shown in Fig.3.

Heating of the upper surface of the welded joint was set to a circularly distributed heat power source and was calculated in the cylindrical coordinate system according to the equation :

$$q(r, \varphi, z) = \frac{k}{\pi} q e^{(-k((z-r \cos \varphi)^2 + (y-r \sin \varphi)^2 + x^2))}, \quad (2)$$

The diameter of the heating area and the coefficient of heat concentration are connected through :

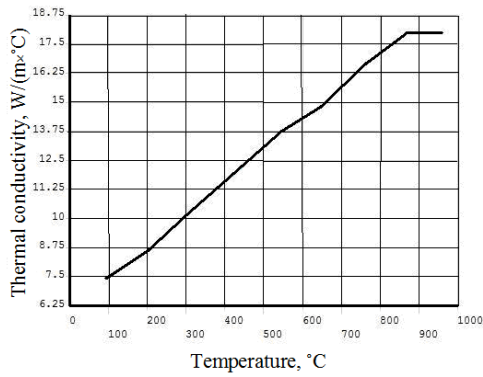
$$d_h = \frac{3,46}{\sqrt{k}}, \quad (3)$$

The model takes into account the heat radiation losses from all surfaces of the disk, with the exception of the plane of symmetry of the weld. The heat radiation was calculated [2]:

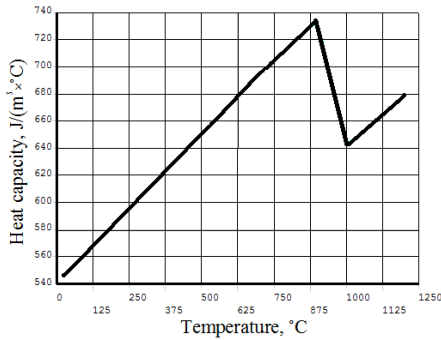
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$$q_{2r} = \epsilon C_0 (T^4 - T_c^4),$$

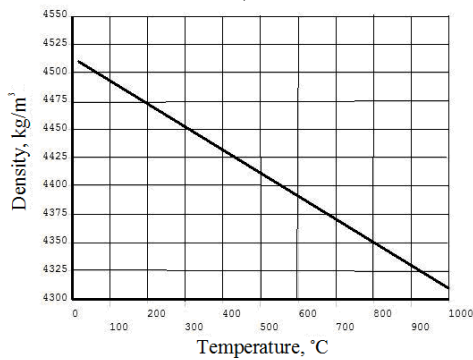
- (4) temperature and strongly affects the temperature difference  $\Delta T$  in the weld zone:  $\Delta T = 11^\circ\text{C}$  at a  $d_h = 24\text{ mm}$ ,  $\Delta T = 33^\circ\text{C}$  at  $d_h = 16\text{ mm}$ .



a)



b)



c)

Fig. 2. Temperature dependence of thermal conductivity, heat capacity and density for Ti6Al4V (a) to (c) respectively

The initial temperature of the disk was set to  $20^\circ\text{C}$ . The value of the integral coefficient of radiation  $\epsilon$  is dependent on temperature for titanium alloys [2]. Figures 4 and 5 shows the results of numerical modeling the heating zone of the welded joint with allowances for welding and machining of the rotor disks.

The calculation results shows that in spite of the local heat input to the disk its rotation provides uniform heating of the weld around the entire circumference. The inner part of the disk is heated to a temperature of about 100 degrees so the heat transfer into the axle of jig can be neglected. The heating process in Fig. 4 shows that the predetermined temperature of the weld is achieved in the range of 300-350 seconds, followed by overheating. Clarification of the heating time was achieved with additional calculations in this period of time.

Figures 5,6,7 show the temperature field in the heat treatment zone in the welded joint.

When heating is intense at 3600 watt the spot diameter does affect the heating time to reach the predetermined

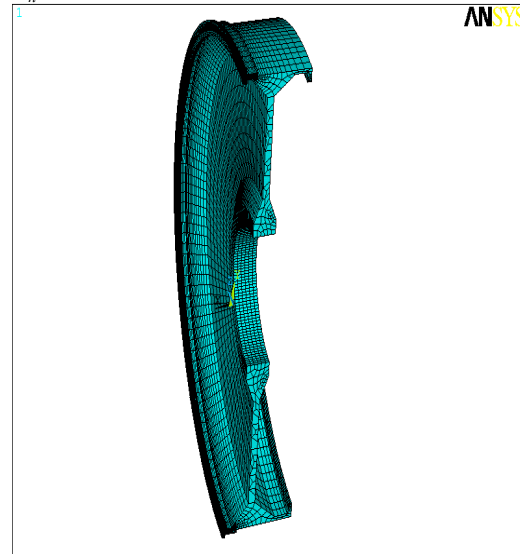
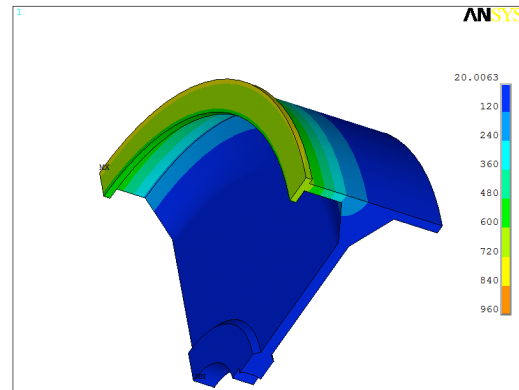
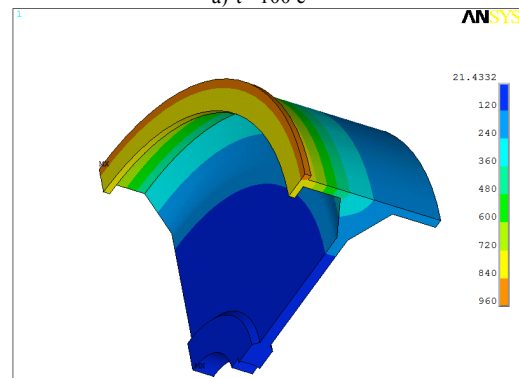


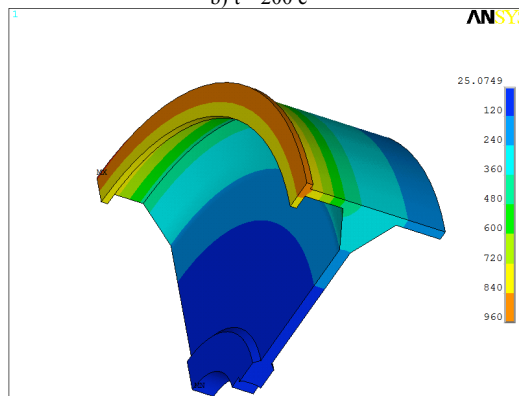
Fig.3. Model for calculations of temperature field



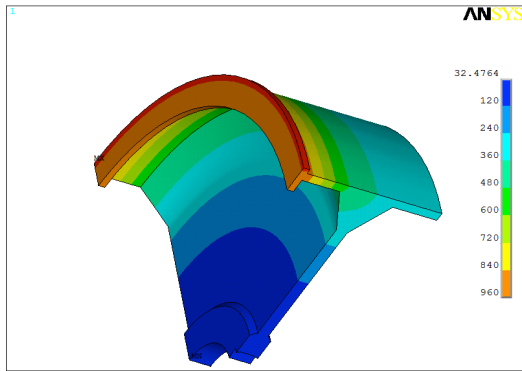
a) t = 100 c



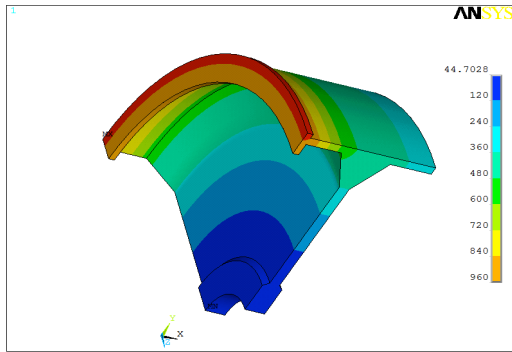
b) t = 200 c



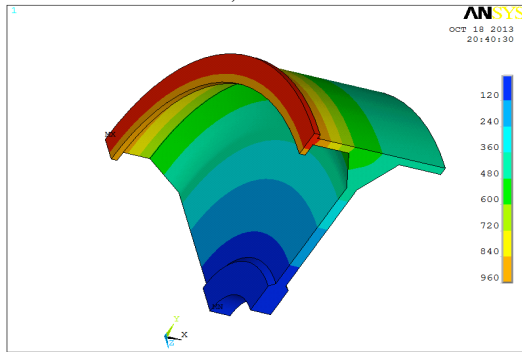
c) t = 250 c



d)  $t = 300 \text{ c}$

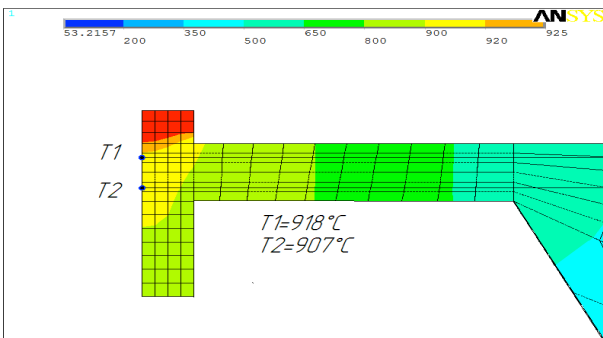


e)  $t = 350 \text{ c}$

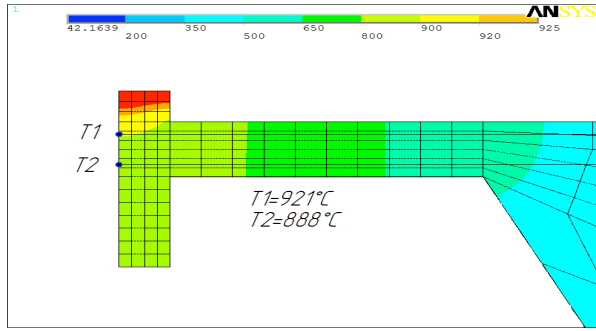


f)  $t = 400 \text{ c}$

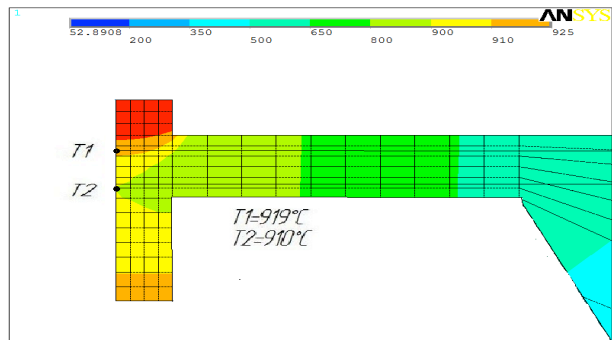
**Fig.4.** Dynamics of heating the disk during heat treatment of the welded joint with parameters:  $d_h=16 \text{ mm}$ ,  $t=338 \text{ s}$ ,  $P=3600 \text{ watt}$



**Fig. 5.** Temperature field of the welded joint of disk when  $\Delta T=11^\circ\text{C}$ ,  $d_h=24 \text{ mm}$ ,  $t=376 \text{ s}$ ,  $P=3600 \text{ watt}$



**Fig. 6.** The temperature field of the welded joint of disk with parameters:  $\Delta T=33^\circ\text{C}$ ,  $d_h=16 \text{ mm}$ ,  $t=338 \text{ s}$ ,  $P=3600 \text{ watt}$



**Fig. 7.** The temperature field of the welded joint of disk with parameters:  $\Delta T=9^\circ\text{C}$ ,  $d_h=16 \text{ mm}$ ,  $t_1+t_2= \text{s}$ ,  $t_1=415 \text{ s}$ ,  $P=3600 \text{ watt}$ ,  $t_2=75 \text{ s}$ ,  $P=2160 \text{ watt}$

However, for the two-stage heating case with intensive heating at  $P = 3600 \text{ watt}$  for 338 seconds, and maintaining heat at  $P = 2160 \text{ watt}$ , the temperature field in the welded joint becomes even with the reduced diameter of heating spot 16 mm, to reach a value of  $\Delta T = 9^\circ\text{C}$  on the second stage of heating with a duration of 75 seconds or more.

Therefore, localized heat treatment of welds in the rotor can be successfully performed with a reduced diameter of the heating spot when using of the two-stage technique of heating.

### 3. Conclusions

Modeling of local heat treatment welded joints of rotor by local heating showed the ability to create a temperature field on the borders of the girth weld with a minimum temperature difference in the weld.

### References

- [1] V.S.Lyasotskaya. *Heat treatment of the welded joints of titanium alloys*. Moskow.: Ecomet, 2003. [in Russian]
- [2] *Radiative properties of solid materials. Reference book*. Under the total. Ed. A.E.Sheyndlina. Moskow.: Energia, 1974. [in Russian]