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SIMULATION OF WELDING OF THIN-WALLED PIPE

SIMULACE SVAŘOVÁNÍ TENKOSTĚNNÉHO POTRUBÍ

Abstract

The presented paper deals with the residual stress after a welding operation performed by using the TIG method. It was necessary to determine whether or not tension plays a major role in the distortion of the geometry of a thin-walled pipe, or in other words, whether the drawing dimension of the ovality exceeds the specified tolerance. The result of this simulation will help to determine whether or not designers will have to find another technological solution to complete parts. The assembly consists of three parts: the weld bead, thin-walled pipe, and hoop, which are connected by welds as a final product.

Abstrakt

Předložena práce se zabývá zbytkovým napětím po svařování pomocí metody TIG. Bylo nutné určit zda–li toto napětí hraje hlavní roli v pokřivení geometrie tenkostěnného potrubí či nikoliv. Jinak řečeno, zda-li rozměry ovality překračují stanovenou výkresovou toleranci či nikoliv. Výsledek této simulace pomůže konstruktérům rozhodnout, budou-li muset najít jiné technologické řešení pro zkompletování dílců či nikoliv. Sestava tvoří tři části: svarová housenka, tenkostěnné potrubí a obruč, které jsou navzájem spojeny svary jako finální product, see Fig. 3.

1 INTRODUCTION

One of the most common applications where simulation of welding can be used is in the aircraft industry. For example the main part of an Auxiliary Power Unit (APU) is in principle the type of turbo-shaft gas turbine with an attached smaller electricity generator. The main task of the generator is to provide the aircraft with power (electric, pneumatic, or hydraulic) to start the main engine and to supply air conditioning with pressurization to the cockpit for passengers. A typical APU for transport aircraft is divided into three main sections: the turbine (power), compressor, and gearbox with accessories section. The turbine section includes a gas generator, which through the main shaft divides all types of the energy of the APU [1]. The thin-

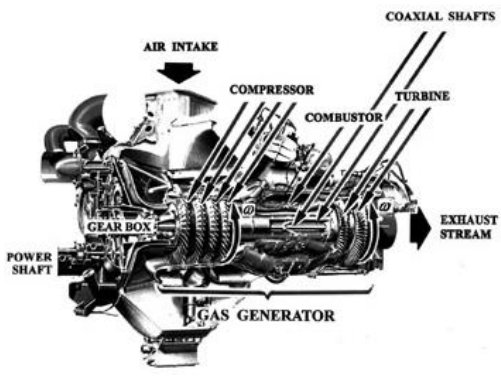

Fig. 1 Example of an APU GTCP 660-4

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walled pipe belongs to the turbine section [5] (see Fig. 1).

2 MATERIAL PROPERTIES OF AN ALLOY

The tested alloy [4] is a nickel chromium material with high strength at ambient temperature and corrosion-resistance and can be used from –253 to 704 °C. The alloy can be easily fabricated into complex parts. The other excellent property is resistance to post-weld cracking, fatigue, creep, and rupture strength. The alloy can be found in many applications, for example liquid-fuelled rockets, castings, metal parts for aircraft, mostly in gas turbine engines, steam generators, and fission and fusion reactor structures. It is also used for fasteners. The physical and mechanical properties of our tested alloy are shown in Tab. 1.

Tab. 1: Physical and mechanical properties of the alloy

	[°F]	[°C]	Poisson [–]	E [GPa]	Thermal conductivity [W/mK]	Thermal dilatation [1/°C*10E-6]
Annealed [kg/m^3]	70	21.1	0.294	200	11.4	–
8193.25	100	37.7	0.291	198.6	–	–
Annealed and aged [kg/m^3]	200	93	0.288	195.8	12.5	13.2
8220.93	300	149	0.28	193	–	–
Melting range [°C]	400	204	0.28	190.3	14.4	13.5
1260-1336	500	260	0.275	186.8	–	–
Specific heat at 20°C [J/kg °C]	600	315	0.272	184	16.2	13.9
435	700	371	0.273	180.6	–	–
Latent heat [J/kg]	800	426	0.271	177.9	17.9	14.4
227000	900	482	0.272	174.4	–	–
Yield strength [MPa]	1000	537	0.271	170.9	19.6	14.6
1193	1100	593	0.276	166.8	–	–
Ultimate strength [MPa]	1200	649	0.283	163.4	21.3	15.1
1455	1300	704	0.292	158.6	–	–
Tangent modulus [MPa]	1400	760	0.306	153.8	23.2	16
1056	1500	815	0.321	146.9	–	

3 CREATION OF THE MATHEMATICAL MODEL

The first step was necessary to implement the weld bead in the mathematic model. Its width is 5 mm. This width corresponds with the width of a real bead, which was measured. The next step was the application of a mesh with a total of approximately 100000 nodes and about 15000 elements (see Fig. 3).

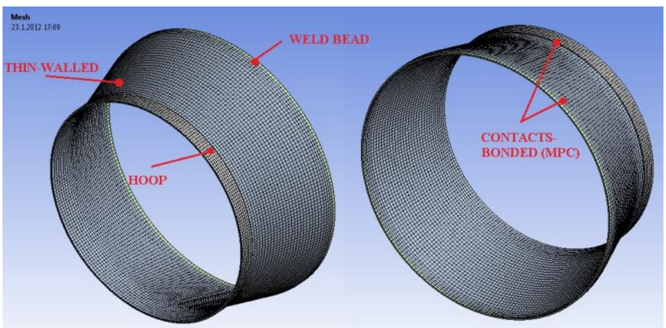

Fig. 3 Mathematic model – assembly and contacts

It is necessary to define the contact properties between each part of the finite element (FE) model. The type of contact was called Bonded in ANSYS and it was chosen for all possible locations between parts. Multipoint Constraints (MPC) formulation was chosen (see Fig. 3).

4 SIMULATION OF WELDING AND BOUNDARY CONDITIONS

The ambient temperature was set at 22 °C. First of all, it was necessary to apply heat dissipation by convection. Forced and natural convection was applied to all types of outer and inner walls at the first loading step (see Fig. 4). The left side of the figure shows natural convection and the right side, forced convection. The value is 5 W/m^2 °C for natural convection and 15 W/m^2 °C for forced convection [2].

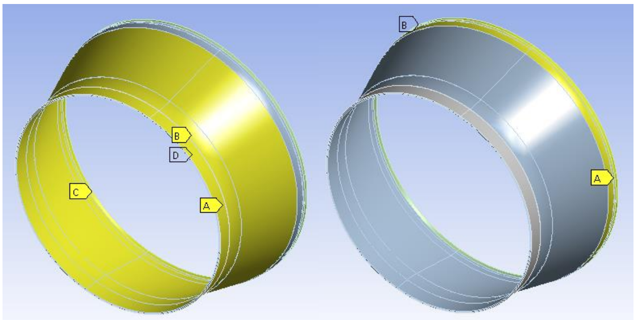

Fig. 4 Natural and forced convection at the surfaces of the assembly

In the second load step a heat flux was applied to the first surface of the weld bead. The value of the boundary condition was calculated from the technical parameters of the welding device. In the third load step a heat flux was applied to the second surface and forced convection was returned to surface number one. This cycle applied up to the 250th step around the weld bead. The cycle is shown in Fig. 5.

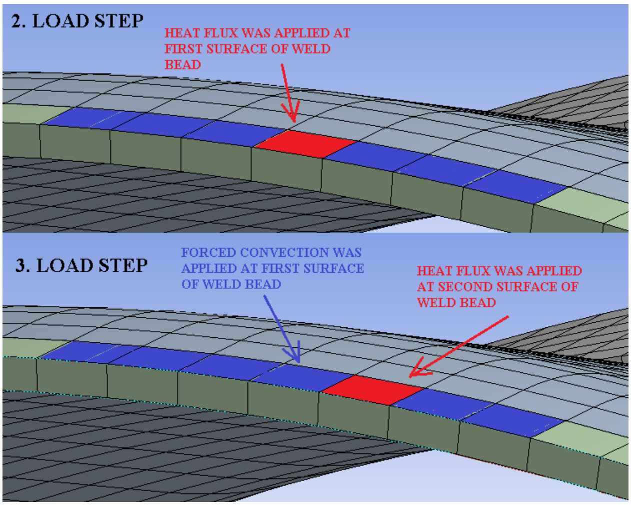

Fig. 5 Cycle of the welding simulation

From the 251st to the 500th step, the welding wire was separated at the end of simulation. A significant drop in temperature can be seen in Fig. 6. At the end of the simulation the maximum steady temperature was about 75 °C.

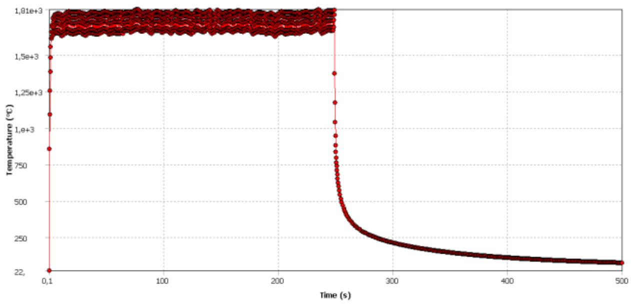

Fig. 6 Process of maximum temperature period of the welding simulation from the beginning

5 RESULTS

The end of the 250th load step of the welding is shown in Fig. 7. Also, there are a couple of probes, whose main task is to show the temperature near the hottest point in the assembly. The maximum temperature at the hottest point is about 1500 °C.

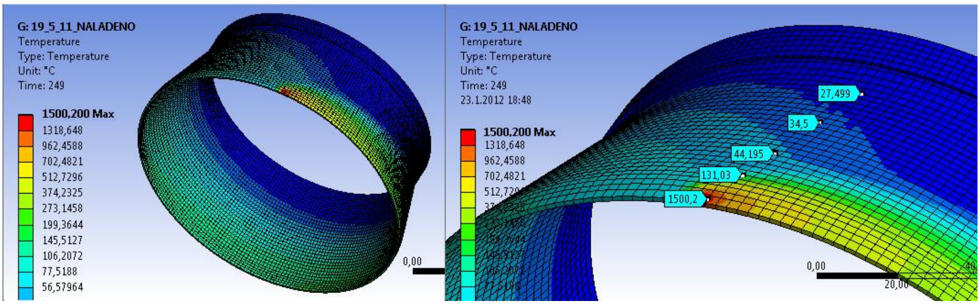

Fig. 7 Welding process at the end of simulation

The most important information can be seen in Figs. 8 and 9, where the maximum deformation and equivalent von Mises stress can be obtained. The maximum value of the directional deformation is about 0.22 mm in cylindrical coordinates and the maximum value of the equivalent von Mises stress is about 30 MPa.

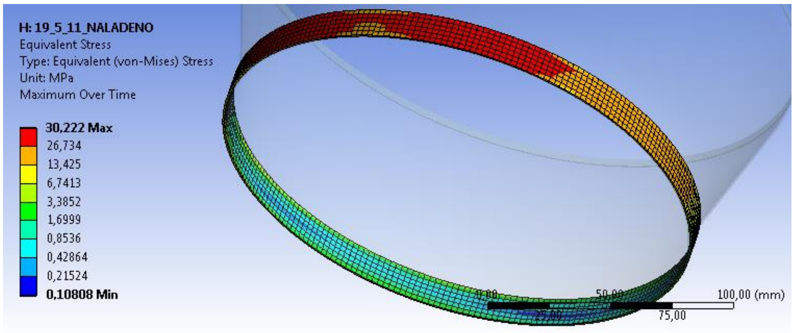

Fig. 8 Equivalent (von Mises) stress

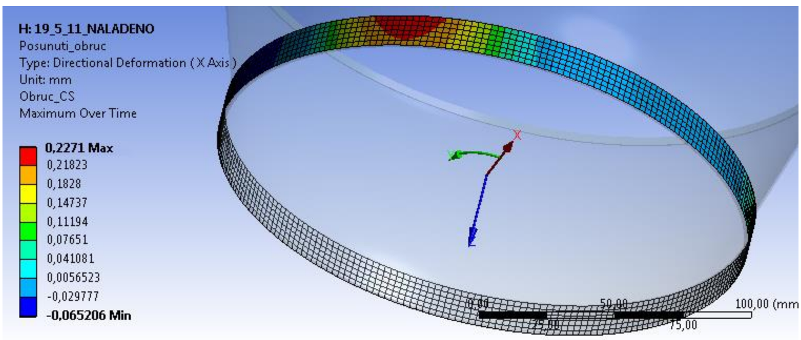

Fig. 8 Directional deformation (cylindrical coordinates)

6 CONCLUSIONS

The conclusion of this analysis is that just before the end of the simulation of welding, significant deformation and stress do not arise in the investigated area. The residual stress will not cause distortion of the drawing dimension of ovalness after the welding operation, which occurs as a result of thermal expansion when the temperature distribution has a maximum value. Because the yield stress of the tested alloy was not exceeded, deformation of the hoop and thin-walled part will go back to the starting position at which the welding operation was begun. The maximum value of the stress according to the hypothesis HMH was about 30 MPa. The alloy has a yield stress of approximately 1200 MPa at room temperature [3].

REFERENCES

[1] HANUS, M. *Turbínový motor*. Učební texty pro teoretickou přípravu techniků dopravních letadel dle předpisu JAR-66. Brno: Akademické nakladatelství CERM, s.r.o., 2004. 207 s. ISBN: 80-7204-369-2.

[2] KADLEC, Z. *Termomechanika, návody do cvičení*. 1. vyd. Ostrava: VŠB-TU, 2002. 97 s. ISBN:978-80-248-1736-1

[3] ŠESTÁK, R. *Přenos hybnosti, tepla a hmoty*. 2. vyd. Praha: Vydavatelství ČVUT, 2001. ISBN 80-01-01715-X

[4] SPECIALS METALS A PCC COMPANY. *The alloy experts*. [online] Accessed: 24 April 2010. Available from: http://www.specialmetals.com/products/index.php.

[5] BASKHARONE, E. A. *Introduction to Gas-Turbine Engines*. [online] Accessed: 24 April 2010. Available from: http://www.globalspec.com/reference/74122/203279/chapter-one-introduction-to-gas-turbine-engines