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NUMERICAL SIMULATION THE FINITE ELEMENT METHOD (FEM) OF STRESS AND STRAIN FOR THE CHOSEN COATINGS TBCs ON TURBINE BLADES LOADED WITH LASER IMPULSES

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Abstract

This paper presents the results of laser ablation the barrier coating TBCs (Al2O3, ZrO2) generated on aircraft engine turbine blade made for nickel base alloy ŻS6K - WI.

Authors used neodymium impulse Nd: YAG laser, radiation with a wavelength of 1064 nm. In parallel with the laboratory experiment was performed numerical simulation of laser ablation. FEM simulation results were used for to choose the relevant laser parameters (impulse duration, impulse shape and course in time, power density) and to identify the temperature distribution heat fluxes and the state of stress and strain in the critical zones of the barrier coating TBCs. The simulation was carried out using the finite element method program LS-Dyna. On the basis of numerical simulation shown the influence of the impact layer TBCs as a thermal insulation and shown place the appearance of destructive deformation. Defined distributed tension as a function of time and estimated time destruction parts the barrier layer during the laser ablation micromachining.

Model 3D of the engine turbine blades DV – 2, Analyzed piece of blade, physical model, temperature maps, maps of the reduced stress are presented in the paper.

Keywords: *superalloy ŻS6K-WI, laser ablation, numerical simulation MES*

1. Object of study

The object of study was an aircraft engine turbine blade DV-2 (Fig. 1). The first stage turbine blades in this engine are made of nickel-based superalloy ŻS6K-WI. In order to increase heat resistance of turbine engine blades, they were coated with two variants barrier coating Al_2O_3 (alumina) and coating based on zirconium ZrO_2. Mechanical properties and other parameters this superalloy in different temperatures taken from the literature [1-2], the physical - chemical materials TBCs (Al_2O_3, ZrO_2 based coating) from the literature [3-4].

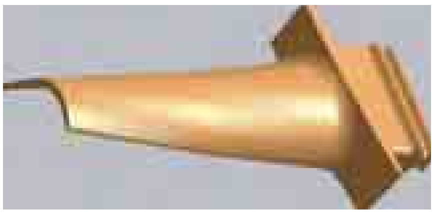

Fig. 1. Model 3D of the engine turbine blades DV - 2

2. Numerical model

Numerical analysis were selected, representative of the working surface area of the blade with radius r = 1 cm and a thickness g = 1 mm (Fig. 2). This passage was subjected for loads: single impulse laser mapped temperature (first model), the thermal load of exploitation (second model), a single laser pulse rendition pressure (third model). Based on the geometry of the shoulder, there were made two models described finite element mesh (FEM) with solid 8-node (8-hexahedron) and 6-node (pentahedron) with three degrees of freedom on each node. The elements assumed five points of the integration (Gauss). Due to the small thickness of the surface layer, developed a model made up of many former small finite elements and had about 100 thousand degrees of freedom (DOFs). Numerical calculations carried out in the LS-Dyna's Livermore Software Technology Corp., the nonlinear dynamic (explicit). As a criterion, the method of energy Huber - Mises – Henckiego was adopted.

Fig. 2. Analyzed piece of blade

3. The simulation load exploitation of turbine blade

For simulation exploitation loadings (second model), load models prepared in two variants: T = 500° C, T =1000° C (Fig. 3). In both variants the reference temperature was room temperature. In addition assume that warm is not exchanged with environment (adiabatic conditions). The boundary conditions consisted definitions of constraints. Ties the simulate samples support (vertical ties). Model charged to homogeneous temperature field T (x, y, z) = const on top surface of blade.

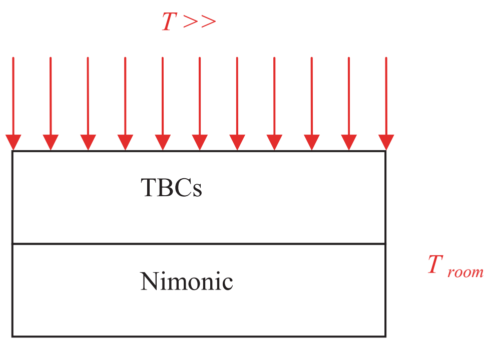

Fig. 3. Scheme of simulated phenomena (physical model)

The result numerical calculations achieved three dimensional schedules: temperature, deformation and stress as a function of time. Below shows schedules temperatures in the shoulder at t = 5 ms for the two variants of the load. Sample maps of temperature distribution are shown on

Fig. 4. Reduced stress schedules – on Fig. 5.

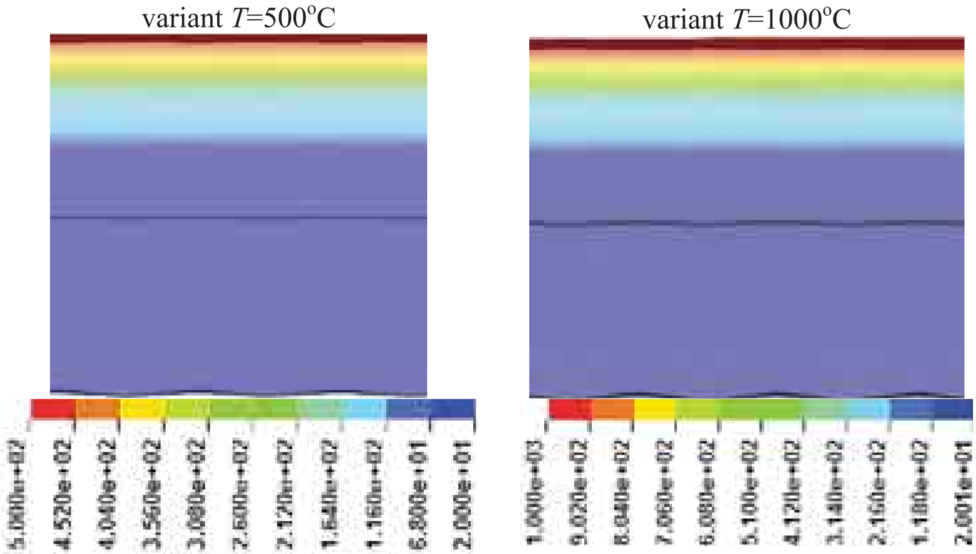

Fig. 4. Temperature maps of obtained for t = 5 ms (second model)

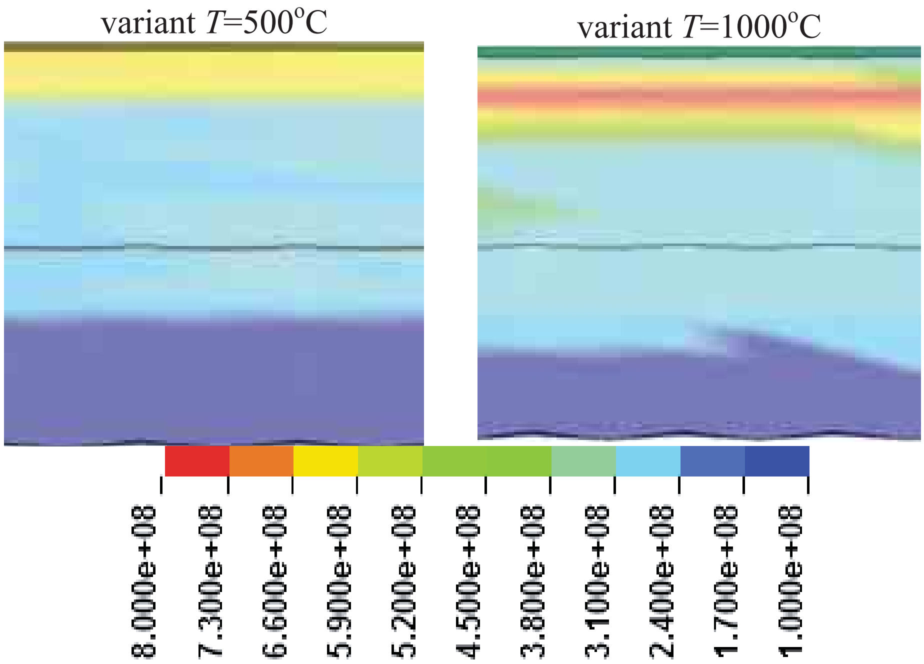

Fig. 5. Maps of the reduced stress (Pa) obtained for t = 5 ms (second model)

4. Conclusions

1. In both numerical models shown rapidly changing processes occurring in the turbine blade, not even subtler by using ultra-modern measuring equipment.
2. The distribution of stress over time can be estimated moment destruction parts of the surface layer of the barrier coating during laser processing.
3. Shown operation Layer TBCs as a heat isolator and place of the appearance of destructive deformation.
4. FEM numerical analysis requires verification of the assumptions relating to the defined loads (temperature and impulse duration).
5. Laser impulse should correspond a pressure of p = 0.7 GPa to initiate the plastic strain of the sample made from nickel-based superalloy ŻS6K-WI.

6. It is possible to use laser technology to clean the surface of the turbine blades and barrier coatings TBCs.

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