Politechnika Śląska

PRACA DOKTORSKA

Technologiczne podstawy zwiększenia żaroodporności monokrystalicznego stopu Rene'N5

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Abstract

Thesis title:

Technological principles of increasing the heat resistance of single crystal Rene'N5 alloy

Abstract:

The materials for hot section components in aircraft engines must characterize brilliant heat resistance, therefore are made from nickel-base superalloys. To avoid high temperature corrosion impact, the protective coatings are applied to the substate. The most common protective coatings for turbine blades and nozzles are conventional aluminide coatings. Currently, chemical vapour deposition and out-of-pack methods are most widely used in the aviation industry. The available literature data describe influence of coatings and them properties on corrosion, sufficiently. However, there are only partial know-how about key coating process parameters, and literature experiments are focused on fundamental research in laboratory scale furnaces done on simple geometry samples. There is lack or just few of data showing correlations between laboratory and industrial scale installations, especially for real components.

The main purpose of the thesis was increasing the heat resistance of single crystal Rene'N5 alloy, current the best material for oxidation resistance applied in commercial aircraft engines. The motivation to take the topic was the evaluation of aluminide coated nozzles from GE9X low pressure turbine after exposure, which revealed that current coating is insufficient.

The research started from characterization of bare and coated material. The coating was obtained in initial process developed by Avio Polska. Cyclic oxidation tests done at 1100^{o}C in 23-hour cycles shown bare material is better than coated considering mass change criterium. Simultaneously, microstructure analysis after 10, 50 and 100 cycles exhibited frontal oxidation in area with Hf, Y and Ta segregation for bare material, while material coated in initial process shown absence of corrosion product below top layer of additive zone. Additionally, the results from isothermal oxidation at 1100^{o}C after 3000h confirmed above. Low cycle fatigue evaluation at 1093^{o}C highlighted improvement in mechanical properties for coated samples, where base material degradation was mitigated by coating presence. Frontal oxidation through tantalum carbide was eliminated leading to reduction of high-stress concentration areas.

The research focused on aluminide coating microstructure modelling in „out-of-pack", low-activity, high-temperature processes on laboratory and industrial scale installation. The technological trials allowed to determine impact of key process parameters like donor, activator, heat treatment, working zone of the furnace, quality of surface to coat and components geometry.

Based on above relationships, initial process parameters were changed. The modified process was validated on industrial scale installation obtaining modified aluminide coating rich in Al two times better then initial one, what led to increasing of oxidation resistance twice considering criterium of sample mass change to initial one. Low cycle fatigue tests result shown no detrimental impact of growth of aluminide coating thickness and Al content on mechanical properties in evaluated range.

However, the results for coatings from both initial and modified processes shown bare material characterized by better oxidation resistance in cyclic oxidation testing considering mass change criterium. Therefore, it was decided to continue the research and went outside conventional aluminide coating family.

It was the motivation to develop aluminide coating modified by platinum. To meet this goal, galvanic process and diffusion heat treatment were defined. Those operations together with modified aluminide coating process were used to coat samples. Cyclic oxidation testing shown material with aluminide coating modified by platinum was significantly better than both previous tested simple aluminide coatings and bare material considering mass change criterium. Based on that, technology demonstration was performed by coating application on nozzle airfoil.

Keywords:
Nickel based superalloys, protective coatings; nozzle guide vanes; aircraft engine.