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STUDY OF PROTECTIVE LAYERS ON NICKEL-BASE SUPERALLOYS

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ABSTRACT
Production of new generation of aircraft gas turbine engines is based on designing new constructions and materials, which make it possible to operate under still more severe conditions. The key assembly of the engine is its turbine, whose materials and design determine the tolerable gas temperature. Increased inlet gas temperatures resulted in the shortening of the service life of the blades protected with diffusion coatings.
New principles of coating deposition opened up new possibilities for purposive improvement of coating compositions and variation of their properties. Coatings protect the surface of turbine blades from damage caused by high-temperature corrosion and preserve the structural shape of blades and their mechanical properties for the required time [1 - 3].
This paper deals with compare of microstructural features of two technological processes for deposition protective coatings for rotor turbine blades of aircraft DV2. The alternative deposition plasma spray was determined because of compose the uniform thickness around the range of blade and the possibility of process automation.
Keywords: cast nickel alloy, Al-Si layer, degradation

1. INTRODUCTION
An inherence of protect layer on the surface and its non-uniformity can worsen mechanical properties of basic material. For a consideration of still performed experiments it was found that Al-Si layer made by standard method doesn´t worse mechanical properties of material at high temperatures. However, the non-uniformity of protect layer caused by hand pressure spraying is dependent on hand-mindedness of staff.
This article deals with study of protect Al-Si layers deposited onto nickel-base superalloy ZHS6K by new modern alternative technology of layer production which can ensure and extend asking life-time of rotor blades. The results were compared with the standard technology of Al-Si layer creation.

2. EXPERIMENTAL METHODS AND MATERIAL
As an experimental material were used rotor blades from 1° high-pressure turbine of aircraft engine DV2. There was applied Al-Si layer by standard technology on the surface of several rotor blades - it means pressure spraying of special Al-Si mixture with diffusion annealing at 1000 °C for 3h in

protection atmosphere. On the surface of other samples were applied mixture from Al and Si powder by deposition of plasma spraying technology. Subsequently, several samples were annealed also at 1000 °C for 3 h in protection atmosphere.
The microstructure of layers and substrate of all samples were investigated by methods of light microscopy (LM) and scanning electron microscopy (SEM) with chemical energy dispersive microanalysis (EDS). The chemical composition of basic material ZHS6K is shown in table 1 and the microstructures of Al-Si layers produced by both technologies are demonstrated in Fig. 1.

Table 1: Chemical composition of experimental material (at wt. %.).

[hm. %]	***Ni***	***C***	***Co***	***Cr***	***W***	***Mo***	***Ti***	***Al***	***Nb***	***Fe***
ZHS6K	Bal.	0,12-0,20	4,0-5,0	9,5-12,5	4,5-5,5	3,5-4,8	2,5-3,2	5,0-6,0	5,5	2,0

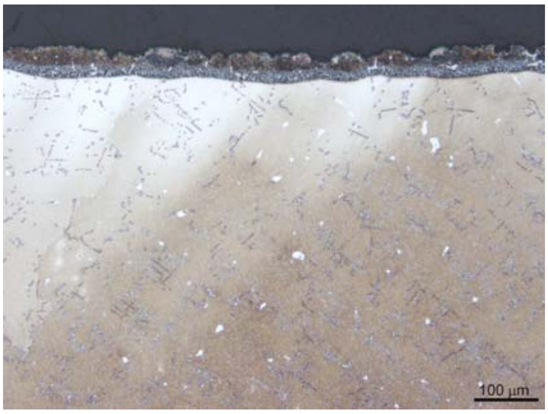


Figure 1a. Microstructure of Al-Si layer on ZhS6K (pressure spraying + diffusion annealing), LM

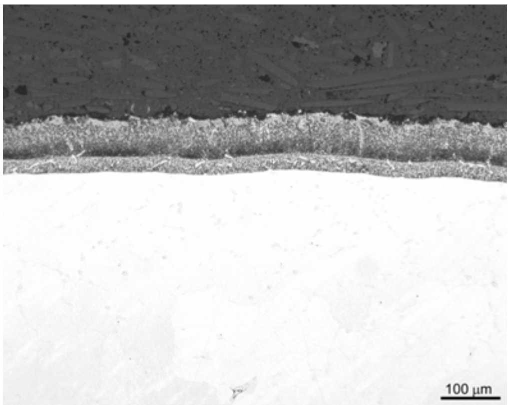


Figure 1b. Microstructure of Al-Si layer on ZhS6K (plasma spraying + diffusion annealing), LM

3. RESULTS

3.1 Al-Si layer made by pressure spraying and diffusion annealing

The old classic method of Al-Si layer production is consists of manual pressure spraying of suspension (Al and Si powder in organic compound) and diffusion annealing in protection atmosphere of argon at 1000 °C for 3 h with subsequent slow cooling in retort. The microstructure of Al-Si layer after annealing splits into several sub-layers; outer layer „coating zone“ and inner layer „inter-diffusion zone“ (Fig. 2). The average thickness of layer was 47 µm.

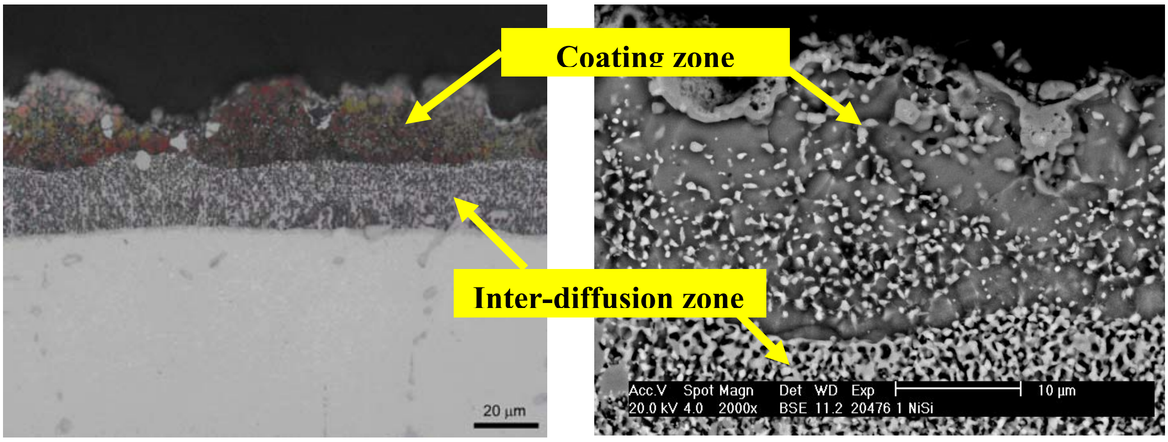


Figure 2a. Microstructure of Al-Si layer on ZhS6K (pressure spraying + diffusion annealing), LM

Figure 2b. Microstructure of Al-Si layer on ZhS6K (pressure spraying + diffusion annealing), SEM

From microstructure point of view, the outer layer mainly involves the mixture of intermetallic phases NiAl, Ni_3Al and less phases based on carbidic elements as are Cr, Mo, Si a W. The microstructure of inter-diffusion zone is also formed by Al phases and more disseminated particles based on Si and Cr, Mo a W.

Due to higher temperature and longer time of exposition the acicular and fragile phases start to create at Al-Si layer and basic material boundary. The chemical composition of these particles corresponds to Cr and Nb complex carbides.

3.2 Al-Si layer made by plasma spraying

The Al-Si layer was made by plasma spraying technology (Fig. 3) under follow conditions; velocity of rotation was 150 rev/min., distance from burner was 120 mm. Sprayed mixture was consists of Al and Si powder in ratio 50:50. The typical porosity of layer made by plasma deposition is obvious (Fig. 3a, 3b). The distribution of Al and Si was investigated by methods of scanning electron microscopy with chemical energy dispersive microanalysis – especially by "mapping" technique (Fig.3c, 3d).

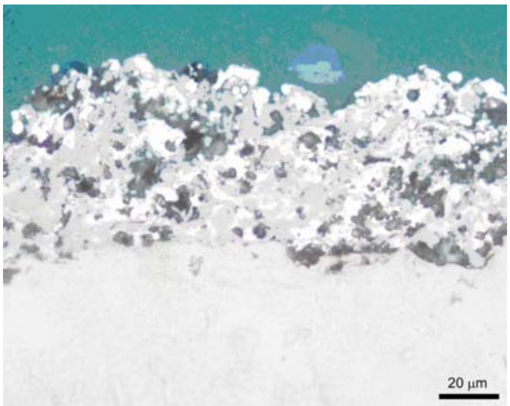


Figure 3a. Microstructure of Al-Si layer on ZhS6K (plasma spraying), LM

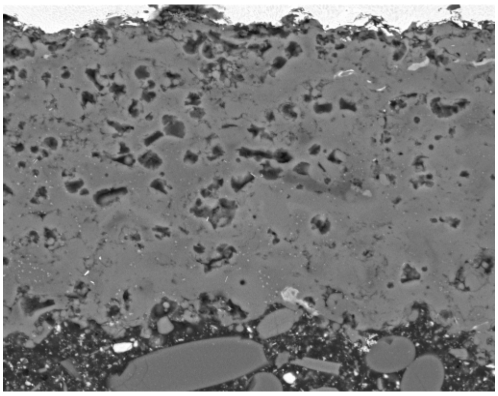


Figure 3b. Microstructure of Al-Si layer on ZhS6K (plasma spraying), SEM

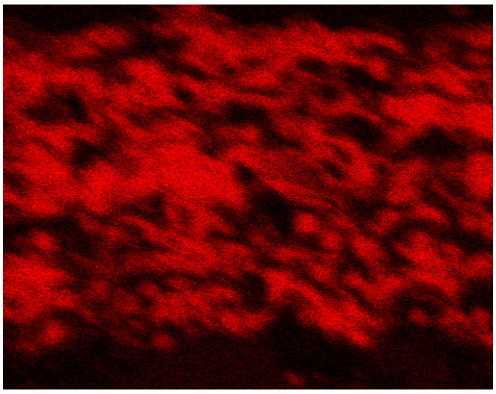


Figure 3c. Area distribution of Al particles on ZhS6K (plasma spraying), SEM-EDS

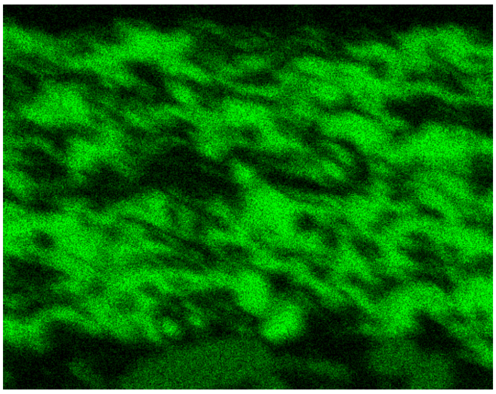
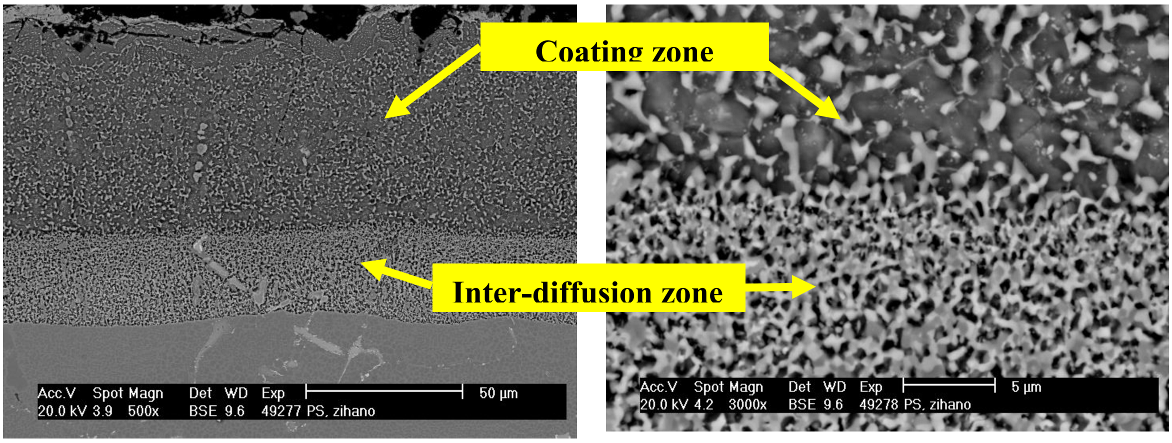


Figure 3d. Area distribution of Si particles on ZhS6K (plasma spraying), SEM-EDS

3.3 Al-Si layer made by plasma spraying and diffusion annealing

After plasma spraying of Al and Si powder into blades surface were applied the heat treatment, especially diffusion annealing on temperature 1000 °C for 3 h. The average thickness of layer was 45 or 100 μm. The microstructure of Al-Si layer is shown on Fig.4.



Fiure 4a. Microstructure of Al-Si layer on ZhS6K (plasma spraying + diffusion annealing),SEM

Figure 4b. Microstructure of Al-Si layer on ZhS6K (plasma spraying + diffusion annealing),SEM

The microstructure of outer sub-layer (coating zone) is consists of NiAl alloyed by silicon and by uniform distributed particles of carbides based on Si, Cr, Al, Mo, Ti and W. The inner inter-diffusion zone is created by Ni_3Al and higher part of carbides. According to the planar chemical EDS microanalyses from scanning electron microscopy, a weight content of chromium is higher in outer sub-layer and aluminum content is bigger in inner sub-layer.

4. CONCLUSION

The main aim of this research were review and evaluate the microstructure of layers made by alternative technology - plasma deposition of Al and Si powder onto surface of rotor blades which were made out of nickel-base superalloy ZHS6K. The main results can be summarized as follows:

1. The new alternative technology of Al-Si layers production hasn´t worked strong changes in microstructure of these layers as compared to classic method of pressure spraying.
2. The difference in microstructure of Al-Si layer between both technologies is in percentage area distribution of carbides. Technology of plasma spraying and annealing caused that outer sub-layer has bigger representation of carbidic phases. The influence of these phases to appropriate change of heat-resistance and creep-resistance of basic material is necessary to check-up by next experiments.
3. We expect the higher uniformity of layer and simpler application on surface of shape-complicated components after specification of particular parameters for using of plasma spraying technology.
4. Pursuant to still carried experiments is possible to state the technology of plasma spraying is suitable method supplying hand-made pressure spraying in light of microstructure of Al-Si layers.

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5. REFERENCES

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