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## Relevant issues in production management for manufacturing gas turbine engine burner segments using removable models

*Production management within the aerospace sector necessitates technological advancements for manufacturing and repairing gas turbine engines (GTEs). A novel thermal protection composite material in powder form has been developed to coat gas turbine combustion chambers. Its thermotechnical properties have been defined and tested.*

Addressing the thermal protection of gas turbines from high-temperature conditions during their production has consistently been a priority in production management for companies involved in manufacturing and repairing aviation engines. The burner segments of gas turbine engines operate under extreme conditions, with temperatures ranging from 800 to 1800 °C and gas flow velocities up to 50 m/s. Such operational environments necessitate the development of materials capable of withstanding these temperatures. Ceramic composite materials (CCMs) [1–2] are particularly suited.

Consequently, a management decision was made to focus research on developing a new technology for producing CCMs. This decision was based on the need to enhance the thermal resistance of CCMs for extended operational life (10,000 hours) at temperatures between 800 and 1800 °C in the manufacturing of core components.

Production management involves organizing business processes that include: engineering design, laboratory research, and testing, among others. Preliminary testing was conducted on ceramic composite materials based on oxide-oxide systems, which produce spinels with thermal resistance superior to that of pure oxides, as well as carbide-oxide systems, where oxides enhance the thermal stability of the carbides.

The thermal resistance of the coatings was evaluated by measuring the weight change of the sample after exposure to a temperature of 1000 °C for 5 hours. This cycle was repeated three times.

It was determined that mechanical mixing of the components of ceramic composite materials did not achieve uniform distribution within the mixture or coating. More promising were sol-gel technologies, where the starting components were metal oxides. These metals, when dissolved, precipitate as oxides onto powders of carbides or borides through redox reactions.

By integrating production and operational management methods with previous scientific advancements and the expertise of specialists in the field, a technology was developed in the plasma technology laboratory for producing ceramic composite materials (CCM) capable of sustained operation (10,000 hours) at temperatures between 800 and 1800 °C.

The following technological operations (business processes) were involved:

– preparation of new powder compositions from refractory materials;
– manufacturing of removable models of components;
– plasma spraying of powder materials onto the removable models;
– removal of models from the sprayed components;
– sintering of the resulting CCM components;
– mechanical assembly of CCM components for use.

For the production of the core component based on the model, a composite ceramic powder of $Al_2O_3$ + 10% $Cr_2O_3$ was selected. This powder was sprayed onto a pre-fabricated model using standard plasma installation operating modes. The applied current was 392-395 A, voltage 70-72 V, with plasma-forming gas flows of nitrogen/argon at 15/15 L/min and a powder feed rate of 50 g/min, achieving an efficiency of 91%.

Models for spraying were manufactured from steel, aluminum, and ceramics. The laboratory tested two types of models:

1. Steel models (Fig. 1);
2. Models made from aluminum alloy. (Fig. 2).

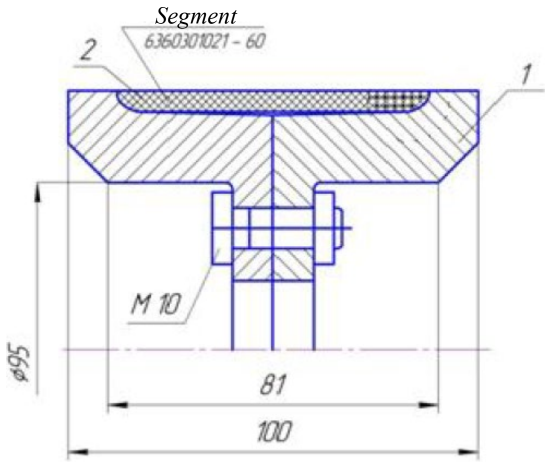


Fig.1. General view of the model of the steel for the cortical parts by spraying 1 - model 2-sprayed coating.

Model Fabrication:

1. First Option: The model was made as a removable fixture. After achieving the desired coating thickness (4.5-5.0 mm), the model was removed, leaving behind the core component.

2. Second Option: The model was constructed as a solid piece from an aluminum alloy. After spraying, the aluminum was etched away to reveal the core

component, which was then subjected to further mechanical processing, including grinding.

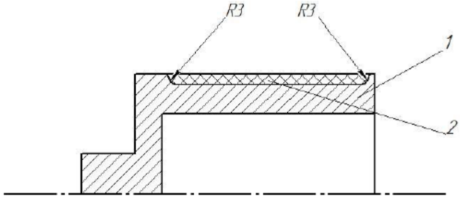


Fig.2. General view of the model from aluminum alloy (1) with the deposited layer (2)

The second option is preferred because it allows for complete spraying of the side surfaces with radius R3, eliminating the formation of voids.

Properties of the ceramic composite material (CCM) $Al_2O_3$ + 10% $Cr_2O_3$:

The properties of the ceramic composite material (CCM) $Al_2O_3$ + 10% $Cr_2O_3$ are detailed in Table 1. The material's strength was evaluated through compression tests, and its thermal stability was assessed under heating conditions ranging from 800 to 1800 °C.

*Table 1*

The properties of the ceramic composite plasma coatings

| Composition of the Coating | Compressive strength, kgf/mm² | | Thermal stability, 1800 - 800°C (cycles) | |
|---|---|---|---|---|
| | Before annealing | After annealing | | Before annealing |
| $Al_2O_3$+10%$Cr_2O_3$ | 12,1 | 131,1 | 2550 | 11200 |

The analysis of the data in the table indicates that both the compressive strength and thermal stability of the ceramic composite material (CCM) significantly improve after annealing.

The general appearance of the plasma-sprayed blank of $Al_2O_3$ + 10% $Cr_2O_3$ CCM, with a wall thickness of 4.5 mm, before mechanical processing is shown in Figure 3.

Thus, a pressing issue in production management has been resolved: the feasibility of manufacturing a core component using an aluminum alloy model with the developed ceramic composite material (CCM) $Al_2O_3$ + 10% $Cr_2O_3$ has been demonstrated.

Scientific Novelty: The primary scientific contribution of this work is the development of a new thermal protection composite material for coating the combustion chambers of gas turbine engines. This was achieved through the application of organizational methods of production management within aerospace manufacturing. The thermal and technical properties of the new CCM have been defined.

Fig. 3. General view of the cortical parts on the aluminum model

Practical Significance: The newly developed CCM has been employed in the formation of core components via plasma spraying during the manufacture of gas turbine engine burner segments. These components are undergoing industrial testing at Motor Sich JSC, demonstrating the importance of applying organizational production management methods.

The composition of the ceramic composite material for thermal protection has been determined based on maximum heat resistance requirements, and a plasma spraying technology for application onto a metallic model to produce the core component has been developed. As a result, the problem of thermal protection for gas turbines during their manufacture has been effectively addressed, benefiting companies involved in the production and repair of aviation engines.

**References**

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