Thermal spraying of thermal barrier coatings with quasicrystalline and approximant structure

Prof.Borisov Yu.,Dr. Astakhov E.,Ph.D. Murashov A.,Prof Borisova A., Ph.D.Adeeva L.
E.O.Paton Electric Welding Institute, Kiev, Ukraine.
E-mail:borisov@paton.kiev.ua

Alloys with quasicrystalline structure possess a set of unique physical properties, including a low thermal conductivity (1-3 W/m·degree), corresponding to that of ceramic ZrO_2, combined with a thermal expansion coefficient of (14-19)·10^{-6} K^{-1}, which is typical of metals and alloys. Such characteristics determine a high potential of using coatings of these materials as thermal barriers featuring a high heat resistance.

Results of computer modelling of the process of plasma spraying of quasicrystalline coatings using the CASPSP software and investigations of phase and structural transformations in a spraying material were used as a basis for the development of the technology for thermal spraying of such coatings.

Investigations of structure and properties of such coatings deposited by plasma and detonation spraying were carried out by using powders of quasicrystalline alloy $Al_{63}Cu_{25}Fe_{12}$ and alloy $Al_{46.5}Cu_{19.1}Fe_{9.4}Ti_{15}Cr_8Si_{12}$ having a structure of cubic approximant of the ψ-phase. Thickness of the produced coatings was 400-500 μm. Their thermal-physical properties were as follows: thermal conductivity, W/m·degree – 1.81±0.10 and 1.45±0.07l; thermal expansion coefficient, 10^{-6} K^{-1} (at 100-700 ^oC) – 14.0-17.3 and 14.2-18.7 for the AlCuFe and AlCuFeTiCrSi coatings, respectively.

The efficiency of heat protection of the coatings was determined on a test bench under conditions of cyclic heating of the surface of a coating on an internal combustion engine piston with the C_3H_8-O_2 mixture combustion flame. The time of heating was 3 s, and that of cooling with compressed air was 30 s. The rate of heating the materials decreased from 25 degree/s without a coating to 9-10.3 degree/s for the AlCuFeTiCrSi and AlCuFe coatings (with thickness of 450-500 μm), respectively, whereas with the ZrO_2 coating this values was 14 degree/s.

Graded five-layer thermal barrier coatings with a variable content of ZrO_2 (0-25-50-75-100 %) (balance being alloys AlCuFe or AlCuFeTiCrSi) were produced by using the AlCuFe-base coatings having the quasicrystalline (AlCuFe) or approximant (AlCuFeTiCrSi) structure, respectively. Investigations of their heat resistance efficiency on the above test bench at a heating time of 5 s showed that it depends upon the total thickness of the sprayed layer (the range investigated – 200-1000 μm) and content of the quasicrystalline ψ-phase in the initial powder (the range investigated – 24-80 %). In the optimal case, the use of a graded thermal barrier coating with a contribution of coatings having the quasicrystalline or approximant structure allows the maximum temperature of a specimen achieved in the heating cycle to be decreased from 425 (without coatings) to 290-300 ^oC.

Therefore, the investigations conducted showed the practical efficiency of using coatings with the quasicrystalline or approximant structure as thermal barriers.