

Mechanism of High-Temperature Corrosion of AlN-SiC Ceramics in Dry Air and Combustion Gases in Burner Rig up to 1500°C

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The mechanism of initial oxidation behavior (up to 1500°C) of ceramics containing 50 mass.% AlN and 50 mass.% SiC was studied using TG, DTA, XRD, EPMA, and SEM methods. The long-term corrosion tests (50 and 240 h) were carried out under non-isothermal conditions up to 1500°C with a heating rate of 5°/min as well as under isothermal ones at 1200 and 1300 °C in dry air (< 5 ppm H₂O) and low-velocity flow of combustion gases. These were formed in the burner rig as a result of combustion of two sorts of fuel (0.01% sulphur kerosene Jet A1; 1% sulphur industrial/marine diesel). Each fuel was burnt in the rig in the air-excess environment (air : fuel ratio = 28:1 by weight), the air being contaminated with salts derived from an aqueous solution of diluted (1:3) artificial ocean water, added simultaneously with the fuel. The main component of the resultant combustion environments was SO₂ (300 and 3 ppm from the 1% S and 0.01% S fuels, respectively) that reacted with NaCl to form Na₂SO₄. Additionally, Na₂O and NaOH were also produced. At the test temperature of 1200°C, all combustion products were gaseous. In this case for the registration of sample weight gain a sensitive Cahn thermobalance was used. In the short-term (4 h) tests, it was established that the oxidation temperature (in the range of 800-1500°C) exerts the essential influence upon not only the kinetics of oxide film initial formation but also composition of interaction products. At small times of the exposure in the air and comparatively low temperatures the β-cristobalite and aluminium oxynitride were the main oxidation products whereas at longer oxidation and higher temperatures (1350-1500°C) the formation of α-Al₂O₃ and 3Al₂O₃·2SiO₂ (mullite) was observed. Hereby under these oxidation conditions the ceramics pointed out proved to be very corrosion-resistant. Long-term oxidation of the 50% SiC - 50% AlN composite material in dry air results in the formation of a continuous crystalline surface scale, in which mullite, the preferred oxidation product for this material, is the main component (the another oxidation product is β-SiO₂ cristobalite). The rates of corrosive attack actually observed in the burner rig tests can be attributed to a combination of many factors. In the absence of Na (i.e. in the air), any silica

produced is either in the form of a highly viscous glass or is crystalline, both of which should ensure a relatively low (i.e. protective) rate of oxidation in the time that mullite is completing a continuous surface layer. When Na is present in the combustion gases, a low viscosity glass is formed which both offers little protection itself and may disrupt the formation of a mullite layer. Hereby the aluminium is contained in crystalline NaAlSiO₄ compound located in the outer parts of the scale and in Al₂O₃ particles, distributed throughout the Na-silicate glass (Na₂SiO₃). Comparatively great voids, derived from the release of CO/CO₂ and N₂ gases during the oxidation of SiC and AlN, respectively, are located both in the vicinity of the scale/composite interface, and also in the bulk of the main silicate layer. The presence of Fe additive and its rapid oxidation to Fe₂O₃ that offers no protection to the base material further inhibits protective scale formation. The net result is that growth of the low viscosity glassy Na-silicate dominates, preventing formation of a continuous mullite layer, and, consequently, the rate of scale growth can be fast enough and linear. Thus, the options to improve the corrosion behaviour of the AlN - SiC composite in the gaseous products of fuel combustion include adjusting the composition to reduce the volume fraction of SiO₂ contributing to scale formation, preoxidation of the composite in dry air before exposure to a combustion gases and also the use of AlN-SiC-TiB₂ material containing comparatively small amounts (~ 5-10 mass.%) of titanium boride additive.