High Temperature Resistant Exhaust Valve Spindle

Transport by ship remains the most economical and environmentally friendly mode of transport with a very low weight specific CO2 footprint. Further increase of the fuel efficiency of large ships will results in a higher internal engine temperature. To allow this without compromising the reliability of the engine, new high temperature alloys are required for a specific engine component, the exhaust valve spindle.

Two alloys are used for an exhaust valve spindle; one for the bottom of the spindle, and one for the spindle seat. Being placed in the exhaust gas stream, combustion products such as V2O5 and Na2SO4 condense on the spindle, causing hot corrosion. Current industry standards can withstand service temperatures of up to 500°C for the spindle seat and 700°C for the spindle bottom. This project was tasked with increasing these temperatures 50°C each.

Literature review as well as an in-situ corrosion test revealed that the most resistant alloy in such an environment is Alloy 657 (Ni-based, 49 wt% Cr, 1.5 wt% Nb). This alloy is suitable for the spindle bottom, but not for the spindle seat, as it is too weak.

Thermodynamic calculations suggested that it was possible to modify the chemistry of the current valve seat alloy, Alloy 718 (Ni-based, 19 wt% Cr, 18 wt% Fe, 5.1 wt% Nb, 3 wt% Mo, 1 wt% Ti and 0.6 wt% Al), and thereby to obtain a more hot corrosion resistant alloy. To validate these calculations, 16 Ni-based alloys, containing 40 wt% Cr and Nb, Ta and Ti in varying levels, were produced by experimental laser cladding. Heat treatments proved that these alloys were precipitation hardenable, and that some of them reached high levels of hardness. Based on these results, five Ni-based alloys containing 35-45 wt% Cr and 4-6 wt% Nb were ordered, to narrow down the feasible alloy compositions. During the alloy development work, extensive microstructure quantification was performed, the results of which validated the predictive thermodynamical calculations.

The heat treatment results showed that a relation exists between the solution treated microstructure and the mechanical properties. This lead to the design of the alloy Ni40Cr3.5Nb (Ni-based, 3.5 wt% Nb and 0.5 wt% Ti). This alloy is precipitation hardenable to the same level of hardness as Alloy 718, and laboratory testing suggests that it is suitable for application at service temperatures of 550°C.