Hot Corrosion Service Testing of Ni-based Superalloys and Correlation with Oxide Scale Calculations

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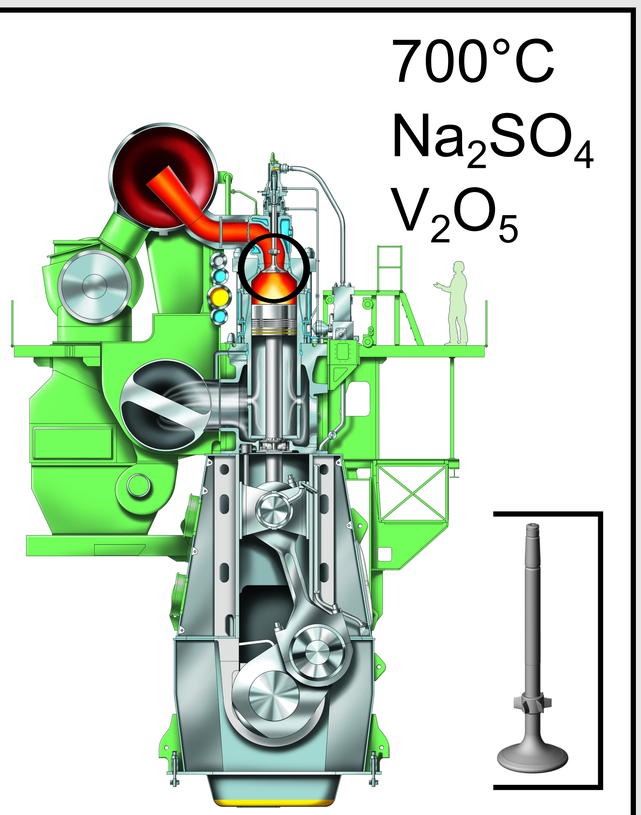
Introduction

Heavy fuel contains high amounts of S and V which combined with high temperatures causes hot corrosion of the exhaust valve spindle in large ship engines.

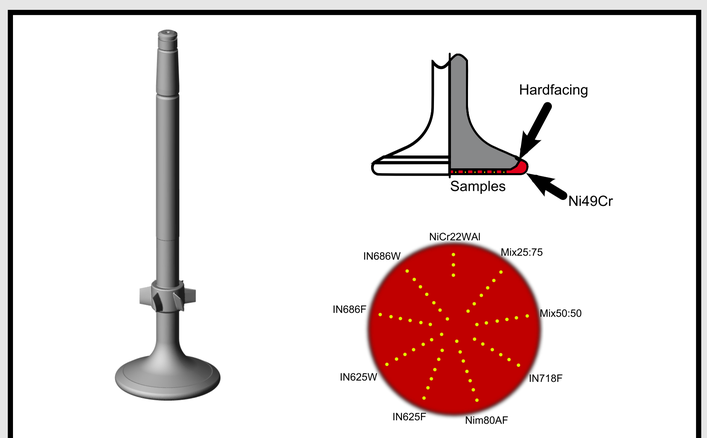
In this work the hot corrosion resistance of ten superalloys has been tested in service and the performance has been shown to be calculable with Thermo-Calc. This poster shows the results for two well known and representative alloys.



Engine cross section and the exhaust valve spindle, which is exposed to the corrosive combustion chamber environment.

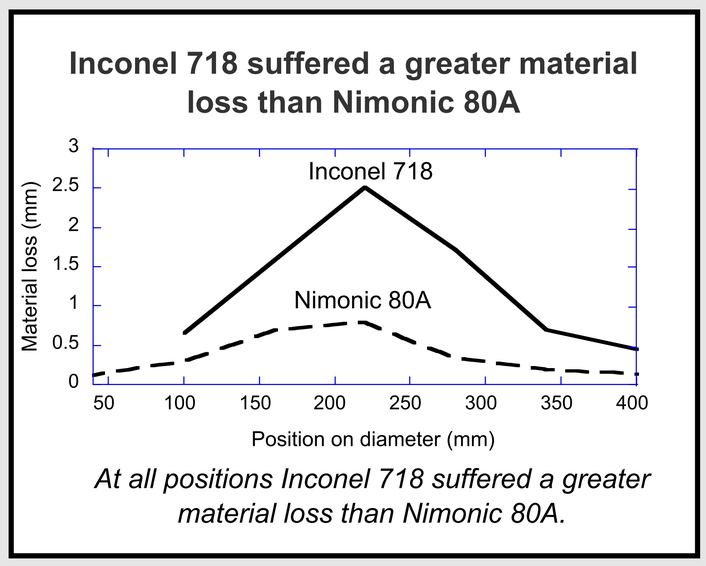
The corrosion test

A test spindle with alloy samples embedded in the bottom was produced and put into service.



The test spindle. In order to embed samples in the spindle bottom, the spindle was produced by hot isostatic pressing.

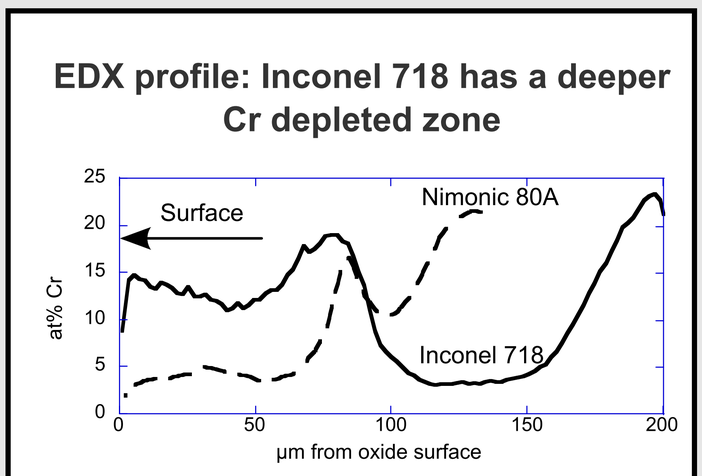
After 90 days in service, material loss of the alloy samples was readily measurable as a hole depth.



At all positions Inconel 718 suffered a greater material loss than Nimonic 80A.

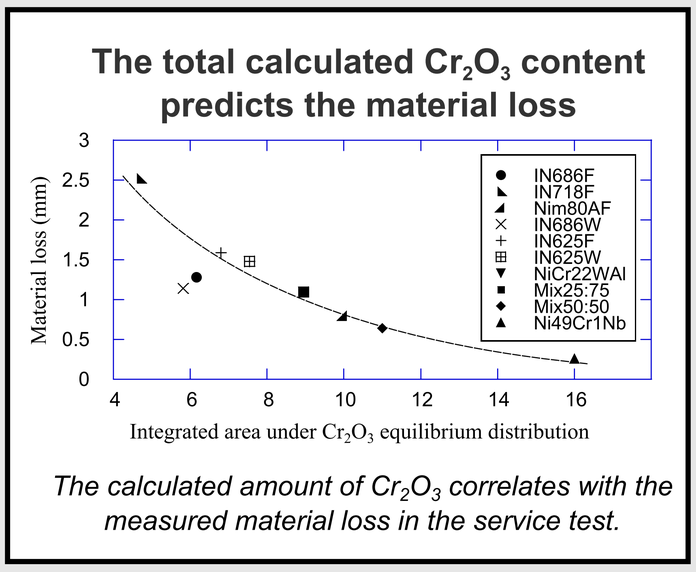
Cr depletion

EDX-analysis of the alloy samples showed that Inconel 718 suffered severe Cr depletion.



The Cr depleted zone of Inconel 718 reaches far deeper than that of Nimonic 80A.

A surprising relation was found between the calculated oxide scale and the test results.



The calculated amount of Cr_2O_3 correlates with the measured material loss in the service test.

Two superalloys

The tested alloys are commercial grades both used for the exhaust valve spindle today.

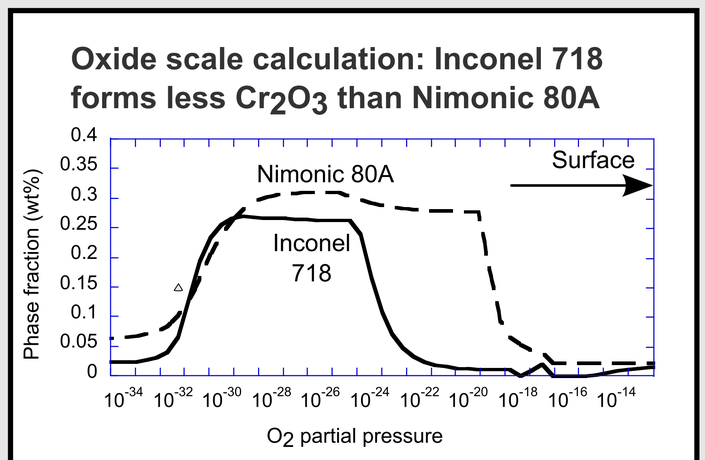
Alloy	Cr	Fe	Mo	Ti	Nb	Al	Ni
Inconel 718	18.93	17.3	3.03	0.94	5.21	0.49	Bal.
Nimonic 80A	18.91	0.22	–	2.41	–	1.7	Bal.

Chemical compositions in wt%.

A high Cr content promotes the formation of the Cr_2O_3 oxide. Cr_2O_3 is crucial for hot corrosion resistance, as it forms an efficient diffusion barrier which limits internal Cr depletion due to inwards diffusion of S, a process called sulphidation. Depending on the alloy composition, other less protective oxides can form.

Oxide scale calculations

Using Thermo-Calc, the oxide scale composition was calculated by varying PO2 to simulate the natural gradient from 0.2 atm to 0 inside the metal.



The Cr_2O_3 oxide is stable at higher PO_2 for Nimonic 80A than it is for Inconel 718.

Conclusion

The Cr depletion of Inconel 718 is deeper than that of Nimonic 80A, causing poor hot corrosion resistance.

When comparing the calculated amount of Cr_2O_3 with the measured material loss for 10 Ni based superalloys, a direct relation is found suggesting that Thermo-Calc can calculate the performance of any alloy in service.

The physical explanation for this relation is the subject of future research, as it would allow fast development of hot corrosion resistant alloys.

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