Stress Corrosion of Heat Resistant Materials under Hot Gases

A summarized report by H. Huff and F. Schreiber

Stress and cyclic stress corrosion poses a serious threat to highly stressed parts in that it reduces their endurance limit no matter how trivial the corrosive attack may often be in terms of surface area. This has made stress corrosion an important consideration. Similarly, the injurious effect of hot gas corrosion on the life of gas turbines has long since been appreciated and given close scrutiny.

Yet stress corrosion under hot gases has attracted surprisingly little attention to date. The present report describes recent experimental investigations into the concurrent effect of corrosion under hot, turbine-generated gases and mechanical stress, where the criteria were creep rupture strength, creep curves, and fatigue strength. The mechanics of hot gas corrosion are treated elsewhere. The brevity of this review restricts it to the presentation of some results relating to stress corrosion on heat resistant nickel superalloys under the action of hot gases.

The experimental set-up shown on Fig. 1 essentially consists of a gas generator, related air and fuel supply systems, and a mechanical-load machine. For a fair approximation of results in service, the gas is generated in a combustion chamber which comes from an actual small gas turbine and operates on JP4 aviation fuel. To aggravate corrosion, provision is made for spraying salt into the stream of hot gas.

Fig. 2 relates to the effect of hot gas corrosion on the creep rupture strength of a nickel-base, cast alloy material (Nimocast 713).

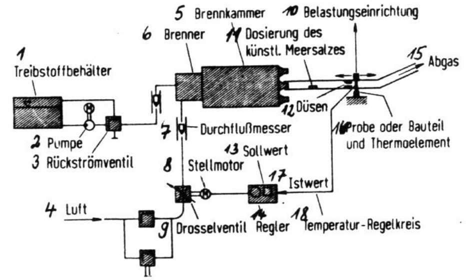


Figure 1
Schematic arrangement of hot gas corrosion test set-up.

1	FUEL TANK	10	LOADING MACHINE
2	PUMP	11	DOSAGE OF LAB SEA SALT
3	RETURN VALVE	12	NOZZLES
4	AIR	13	SPECIFIED VALUE
5	COMBUSTION CHAMBER	14	CONTROL UNIT
6	BURNER	15	EXHAUST GAS
7	FLOW METER	16	SPECIMEN OR COMPONENT AND THERMOCOUPLE
8	ACTUATOR	17	ACTUAL VALUE
9	THROTTLE VALVE	18	TEMP. CONTROL CIRCUIT

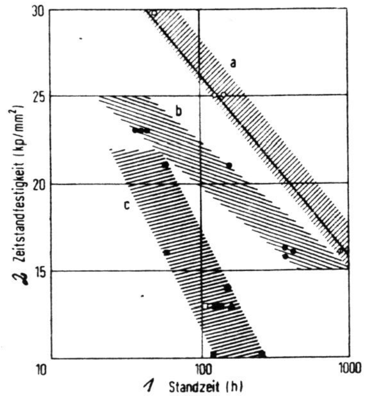


Figure 2
Effect of corrosion on creep rupture performance of nickel alloy 713V at 900°C
1) in air
2) in hot gas
3) hot gas & sea salt 36 g/48 hr

1 TIME ELAPSED (hr) 2 CREEP RUPTURE STRENGTH (kp/mm^2)

As it will become readily apparent from Fig. 3 the decline in strength is a maximum in the 800 to 900°C range, where hot gas corrosion alone accounts for a loss of fully 20% and the plunge is maximally 50% when conditions are accentuated by the admixture of sea salt.

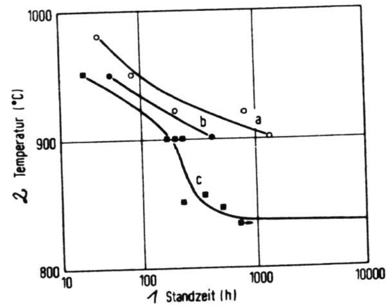


Figure 3
Creep rupture performance under corrosion Nimocast 713V at 140 N/mm^2

1 TIME ELAPSED (hr) 2 TEMPERATURE (°C)

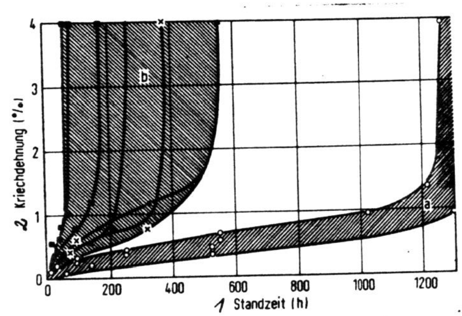


Figure 4
Effect of corrosion on percent creep of Nimocast 713V
140 N/mm^2, 900°C
a) air
b) hot gas & sea salt

1 TIME ELAPSED (hr) 2 CREEP (%)

This creep performance will convey a first rough notion of the mechanics of hot gas stress corrosion.

Creep is greatly accelerated under the added effect of corrosion (Fig. 4). This is attributed to intensified cracking which then sets in before the phase of constant creep is even entered. Whereas in a normal atmosphere cracks will be initiated not before the far end of the constant creep phase is reached.

Cracks produced by local attack through hot gas stress corrosion go much deeper than the areal attack from the same source (Fig. 5).

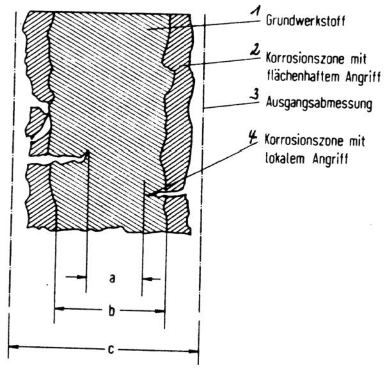
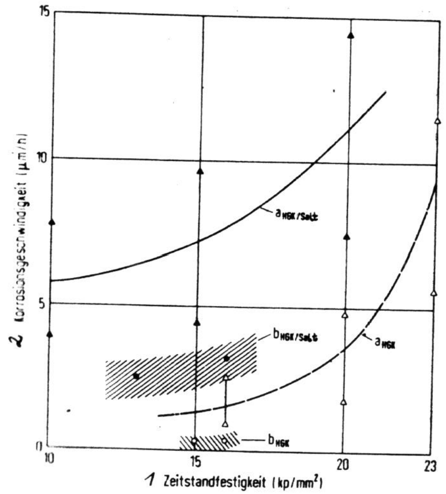


Figure 5
Rate of local and areal corrosion

1 VIRGIN MATERIAL
2 CORROSION ZONE EXHIBITING AREAL ATTACK
3 ORIGINAL SIZE
4 CORROSION ZONE EXHIBITING LOCAL ATTACK



Nimocast 713V, 900°C
a) local corrosion
b) areal corrosion

1 CREEP RUPTURE STRENGTH (kp/mm^2)
2 CORROSION RATE (µm/hr)

The impact of hot gas corrosion on fatigue strength is akin to that on creep rupture strength. A report on this aspect will be available shortly.

The substantial implications of hot gas corrosion for the creep rupture performance of heat resistant nickel materials could be demonstrated. This will be useful evidence in

- the assessment of materials for their value in designing specific service strength into engine components
- the selection, assessment and development of protective coatings
- the evolution of materials giving improved protection from corrosion.

The test conditions, as well as the related bibliography, are more fully delineated by H. Huff and F. Schreiber in "Zum Einfluß von Heißgaskorrosion auf die Haltbarkeit von Hochtemperaturwerkstoffen", Werkstoffe und Korrosion 5 (1972) S. 370-377.