MICROSTRUCTURAL CHANGES OF CM186LC SINGLE CRYSTAL SUPERALLOY DURING LOW TEMPERATURE CREEP DEFORMATION

B. Dubiel[1], D. Bale[2], M. Blackler[3] and A. Czyrska-Filemonowicz[1]

[1]AGH University of Science and Technology, 30-059 Kraków, Al. Mickiewicza 30, Poland
[2]ALSTOM Power Turbo-Systems Technology Centre, Whetstone, Leicester LE8 6LH Cambridge Road, UK
[3]Howmet Ltd., Kestrel Way, Sowton Industrial Estate, Exeter EX2 7LG, UK

Continual demand for improvements in gas turbine engine power, efficiency and durability over the years has been closely related to improvements in turbine blade materials and cooling systems.
Single crystal nickel based superalloys are widely used in the aero industry; they have only fairly recently been introduced into industrial gas turbines (IGT).

CM 186LC

Second generation nickel-base single crystal superalloy <001> orientation

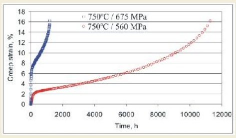
Chemical composition (wt %)

Ni - 8W - 9Co - 6Cr - 5.7Al - 3Ta - 3Re - 1.4Hf - 0.7Ti - 0.5 Mo - 0.07C - 0.015B - 0.005Zr

Heat treatment

1080°C for 4 h (vacuum) + rapid gas fan quenching in Ar
870°C for 20 h (vacuum) + rapid gas quenching in Ar

Creep tests

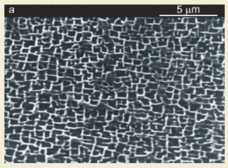


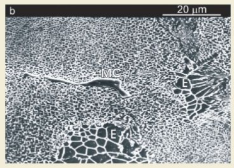
Creep curves of CM186LC
750°C / 675 MPa and 750°C / 560 MPa

number	creep test conditions		duration [h]	creep strain [%]	status [#]
	temperature [°C]	stress [MPa]			
D	750	560	75	1.2	T
E	750	560	275	2.2	T
M	750	560	7837	6.81	T
N	750	560	11440	15.3	R
A	750	675	6	8.8	T
B	750	675	25	11.6	T
C	750	675	350	12.9	T
W	750	675	1184	16.3	R

[#] T - test terminated before rupture, R - specimen ruptured

As-received CM186LC



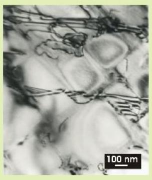


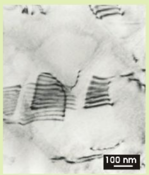
Microstructure of CM186LC superalloy, parallel to (100), SEM

750°C / 560 MPa

Primary creep

specimen D



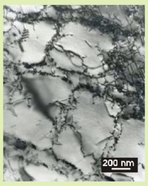


Foil plane $(0\bar{1}1)_\gamma$

Dislocations inside γ channels and dissociation of dislocations in γ' particles forming intrinsic stacking faults
Slip system {111} <112>

Secondary creep

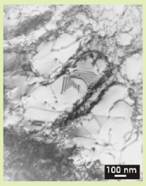
specimen M



High dislocation density in γ matrix and in γ - γ' interfaces, intrinsic stacking faults inside γ' particles

Creep rupture

specimen N

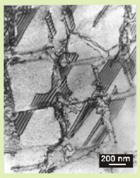


Stacking faults in two perpendicular directions as a result of activation of two {111}<112> type slip systems in γ' particles

750°C / 675 MPa

Primary creep

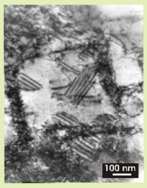
specimen A



High density of stacking faults inside γ' particles

Secondary creep

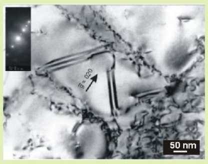
specimen C



Dislocations within γ channels and on γ-γ' interfaces as well as stacking faults in two slip systems within γ' particles

Creep rupture

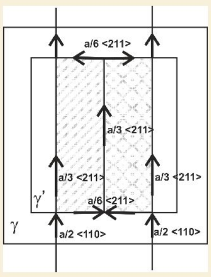
specimen W



Cutting of the γ' precipitates by two {111} <112> type slip systems in γ' particles

Foil plane $(001)_\gamma$

Deformation twins

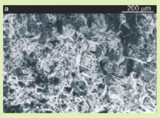


Schematic diagram of dissociation of dislocations and stacking fault formation in the γ' particle.

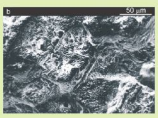
The cooperation of COST522 WP1.1 partners is gratefully acknowledged.
The authors also wish to thank Dr A Zielinska-Lipiec, Mrs K Plonska-Niznik and Mr P. Grodowski for their assistance in this study.

Fracture 750°C / 675 MPa

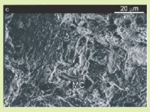
specimen W



brittle



quasi-ductile



nucleation of brittle crack inside MC carbide particle

CONCLUSIONS

1. Microstructure of CM186LC superalloy creep ruptured at 750C exhibited mixed brittle and quasi-ductile fractures facets. Creep cracks were seen to initiate at fractured primary MC carbides.

2. Primary creep stage at 750°C
lower stress: shearing of γ' precipitates by partial dislocations creating stacking faults
higher stress: higher density of stacking faults, thus easier shearing of γ' particles.

3. Secondary creep stage at 750°C
lower stress: dislocation networks inside channels and stacking faults in the γ' particles
higher stress: high dislocation density in γ matrix and in γ - γ' interfaces, stacking faults in two slip systems within γ' particles

4.Creep rupture at 750°C
lower stress: stacking faults in two operating slip systems inside γ' particles
higher stress: deformation twins cutting both γ and γ' phases