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Electron microscopic study on nano sized precipitation during ageing in Alloy 617

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Introduction

Thermal power plant		
Features	**Present generation**	**AUSC**
Operation Cond.	**540 °C &170kg/cm²**	**700 ° C & 300 kg/cm²**
Thermal efficiency	**30%**	**45-47%**
CO_2 emission	**1ton/ MWe-hr.**	**20% less**

Why Alloy-617 tubes for the AUSC boiler application ?

- **Alloy-617- Solid solution strengthened Ni-Cr-Co-Mo based super alloy**
- **Excellent high temperature properties**
- **Good creep resistance- Solid solution strengthening, Carbides (MC, M_6C, $M_{23}C_6$) Nitrides(TiN), Intermetallics - γ' (Ni_3(Al, Ti))**
- **Oxidation resistance at higher temperature- Presence of Al and Cr**

Aim of study

- **Formation and evolution of the - γ' precipitates during service by ageing at different probable operation temperature regime**

Experimental

Ni	Cr	Fe	Mn	Mo	Co	Al	C	Cu	B	Si	S	Ti	N	V	Nb
Bal	21.69	0.14	0.01	9.28	12	1.19	0.05	0.01	0.004	0.02	0.002	0.45	0.004	0.01	0.01

Final solution annealed (1170 C/60min-WQ)-Tube (52 mm OD X 12 mm WT)

Aged in air @ Temperatures

700 °C/100 h | **750 °C/100 h** | **800 °C/100 h**

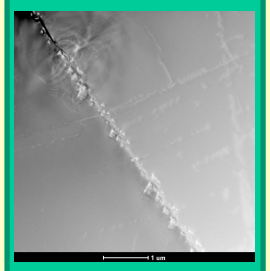
Furnace cooled

Conclusion

- **Solution annealed tube had only fine GB carbides**
- **Nano sized γ' precipitates formed in ageing and were confirmed as Ni3(Al,Ti) type and hardness increased.**
- **Fine γ' formed uniformly at 700 °C when aged for 100 h. SAED patterns identified as Ni3(Al,Ti) type γ'.**
- **γ' particles coarsened with higher ageing temperature and got enriched in Al & Ti content.**
- **Fine intragranular carbides precipitated from 750 °C. These are likely add to high creep resistance.**
- **SAED: Orientation relationship between these carbides, matrix and γ' : (110) γ' ‖ (110) C ‖ (110) M with parallel ZA <112>**

Results & Observation

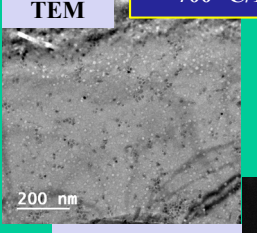
Sol Ann



Very fine carbides only along grain boundaries – observed Hardness:185 HV10

700 °C/100 h

TEM



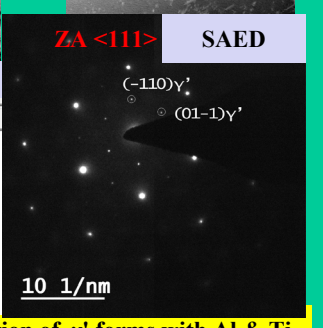
STEM-HAADF

STEM-EDS

Precipitate

Element	Weight%
C	1.73 +/- 0.30
Al	1.87 +/- 0.14
Ti	0.89 +/- 0.11
Cr	32.94 +/- 0.46
Co	8.18 +/- 0.25
Ni	43.76 +/- 0.53
Mo	10.63 +/- 0.70
Totals	100.00

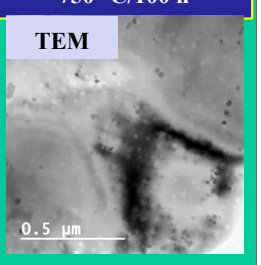
ZA <111> SAED



Fine uniform distribution of γ' forms with Al & Ti enrichment (Avg. 9 nm); 280 HV10

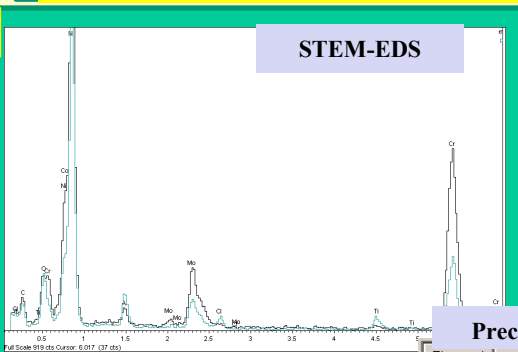
750 °C/100 h

TEM



STEM-HAADF

STEM-EDS



Precipitate

Element	Weight%
C	4.17 +/- 0.86
O	6.07 +/- 0.76
Al	3.59 +/- 0.34
Cl	1.48 +/- 0.26
Ti	1.86 +/- 0.26
Cr	14.26 +/- 0.60
Co	7.53 +/- 0.48
Ni	54.51 +/- 1.19
Mo	6.53 +/- 1.17
Totals	100.00

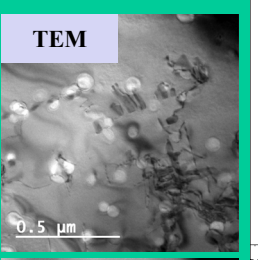
γ' –size increase s (Avg. 20 nm) And Al and Ti detection increased in EDS; Hardness: 260 HV10

Matrix

Element	Weight%
C	2.46 +/- 0.60
Al	0.82 +/- 0.20
Cr	24.61 +/- 0.66
Co	11.74 +/- 0.50
Ni	52.23 +/- 0.95
Mo	8.13 +/- 1.08
Totals	100.00

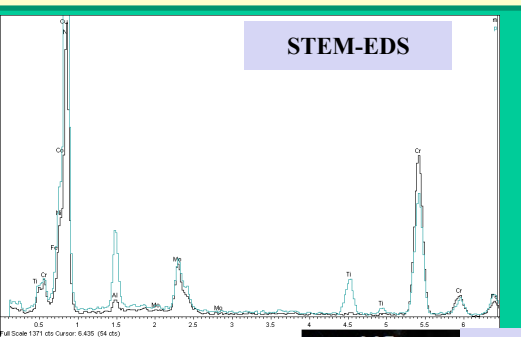
800 °C/100 h

TEM



STEM-HAADF

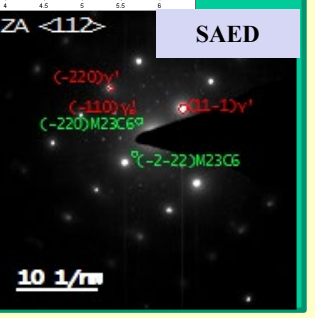
STEM-EDS



Precipitate

Element	Weight%
Al	3.92 +/- 0.20
Ti	2.95 +/- 0.17
Cr	11.41 +/- 0.29
Fe	2.13 +/- 0.16
Co	8.25 +/- 0.28
Ni	62.29 +/- 0.59
Cu	3.60 +/- 0.25
Mo	5.45 +/- 0.59
Totals	100.00

ZA <112> SAED



γ' coarsens further (Avg. 35 nm) & further enriched with Al & Ti detected; Hardness: 223 HV10