CREEP BEHAVIOR AND STRUCTURAL CHANGES IN THE RE-CONTAINING 10% CR MARTENSITIC STEELS

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ABSTRACT. Nine to 12% Cr martensitic steels demonstrate high creep resistance and strength properties as well as a low thermal expansion at elevated temperatures that provides the application of these materials for pipes and tubes of fossil power plants, which are able to work at ultra-supercritical steam parameters (873-893 K, 20-25 MPa). The present research was devoted to revealing the reasons of different creep behavior of the Re-containing 10% Cr steels. An increase in the Cu content provides the 8-fold increment in rupture time due to the increase in duration of the primary creep stage. Precipitation of Laves phase determines the creep behavior during primary creep stage, and the additional nucleation of Laves phase on “Cu” clusters in the St0.8Cu steel provides the improvement of creep behavior.

EXPERIMENTAL PROCEDURE

MATERIAL. Two 10% Cr martensitic steels with different Cu content devoted here as St0.8Cu and St0.3Cu were investigated. The chemical compositions represented in Table were controlled via optical emission spectrometer FOUNDRY-MASTER-UVR.

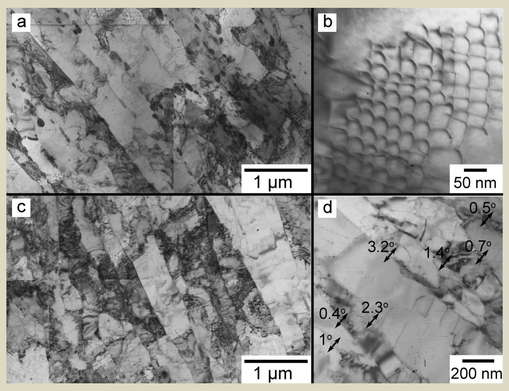
Ingot	Fe	C	N	B	Cr	Co	W	Mo	Cu	V	Nb	Re	Si	Ni	Mn
St0.8Cu	bal	0.09	0.002	0.015	9.6	2.9	2.1	0.6	0.8	0.2	0.05	0.17	0.1	0.2	0.03
St0.3Cu	Bal	0.13	0.001	0.015	9.4	3.1	2.1	0.6	0.3	0.2	0.05	0.17	0.1	0.2	0.03

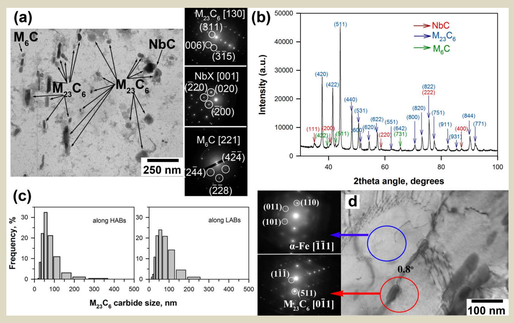
HEAT TREATMENT. Normalizing at 1323 K for 1 h, cooling in air, and subsequently tempering at 1043 K for 3 h.

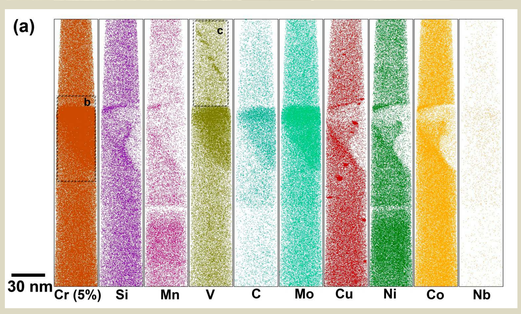
CREEP CONDITIONS. Flat specimens with a gauge length of 25 mm and a cross section of 7×3 mm^2 were crept until rupture at 923 K under the applied stress of 140 MPa.

MICROSTRUCTURAL INVESTIGATION. Transmission electron microscope JEOL–2100 (TEM) with an INCA energy dispersive X-ray spectrometer (EDS) and a Quanta 600FEG scanning electron microscope (SEM).

INITIAL STRUCTURE





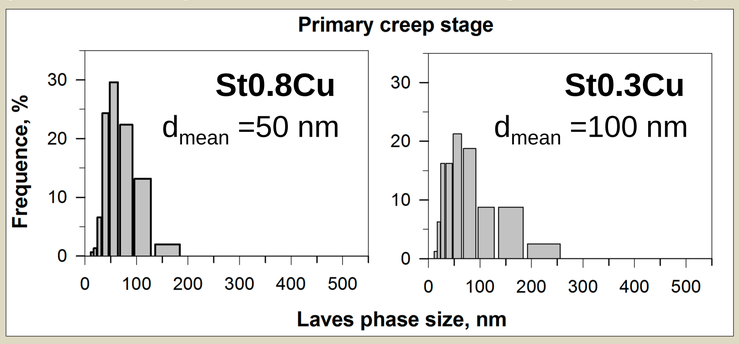


The main structural difference between the steels studied:

- ✓ Formation of “Cu”-rich clusters in the St0.8Cu:
  - mean size of 3 nm
  - volume density of 7×10^{22} m^{-3}

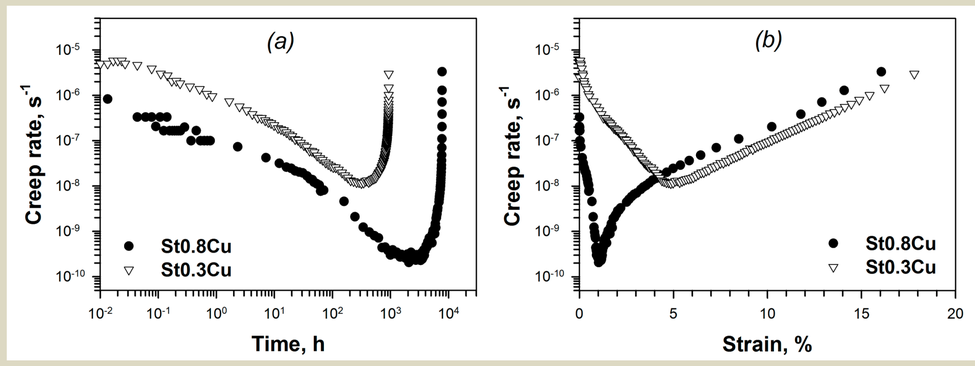
EFFECT OF CU CLUSTERS ON LAVES PHASE

The “Cu”-clusters act as the additional nucleation sites for Laves phase that provides to the change in the dispersion of this phase.



! Addition of Cu decreased the mean size of Laves phase by 2 times before coarsening

CREEP PROPERTIES 923 K/ 140 MPA

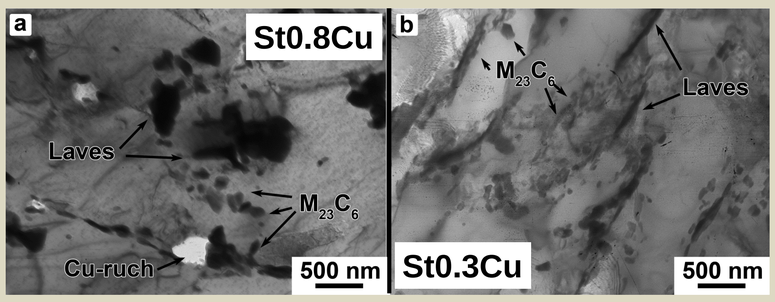


The increase in Cu content to 0.8% positively affect rupture time:

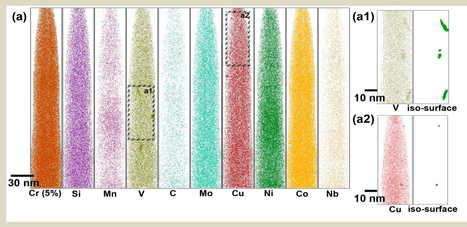
- ✓ The increment in rupture time comprised 8 times;
- ✓ The duration of primary creep stage increased by 10 times;
- ✓ The minimum creep rate reduced by two orders of magnitude;
- ✓ The rate of acceleration of tertiary creep was the same for both steels.

The significant difference in creep behavior between the steels studied was related to structural evolution during *PRIMARY CREEP STAGE*.

DEGRADATION OF STRUCTURE AFTER CREEP TEST



Dissolution of “Cu”-clusters in St0.8Cu steel provided the growth of Laves phase



Ingot	Structure		Particles					
	Lath width, nm	Dislocation density, $\times10^{14}$ m^{-2}	$M_{23}C_6$		Laves		NbX	
			Size, nm	Fraction, %	Size, nm	Fraction, %	Size, nm	Fraction, %
St0.8Cu	900±30	1.8±0.1	93±7	1.54	177±7	1.65	45±4	0.054
St0.3Cu	600±30	1.1±0.1	79±7	2.30	78±7	1.65	40±3	0.056

SUMMARY

- After tempering, tempered martensite lath structure was observed in both steels. The significant difference between the steels studied in the tempered state comprised the presence of “Cu”-clusters with mean size of 3 nm in the steel with high Cu content.
- High Cu content in the 10% Cr steels positively affects creep behavior increasing rupture time by 8 times and decreasing minimum creep rate by 2 orders of magnitude.
- Both steels demonstrate the significant structural degradation after creep test: the martensitic laths widen, dislocation density reduces, grain-boundary particles coarsen. After creep test, the constant coarsening rate of Laves phase in the St0.8Cu steel was three times higher than that in the St0.3Cu steel that could occur during tertiary creep stage.
- The change in the precipitation of Laves phase during the primary creep via an additional nucleation of this phase on “Cu” clusters could lead to an increase in duration of primary creep stage and reduction of minimum creep rate.

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