Institute for Applied Materials
Applied Materials Physics (IAM-AWP)
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
Karlsruhe, Germany

a - Institute for Applied Materials-Applied Materials Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany
b - Departamento de Engenharia de Materiais, Escola de Engenharia de Lorena, University of Sao Paulo, Lorena-SP, Brazil

Influence of the thermomechanical treatment on the mechanical properties of 13.5Cr ODS steels

P. He[a], R. Lindau[a], A. Moeslang[a], H.R.Z. Sandim[b]

Abstract

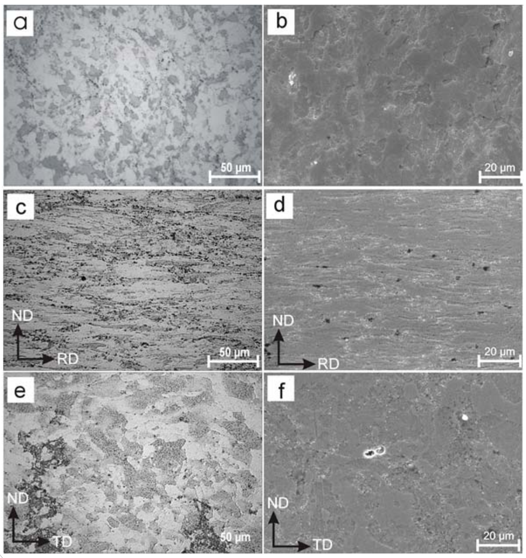
Reduced activation oxide dispersion strengthened (ODS) ferritic steels are the most promising structural materials for future fusion power plants and innovative fission nuclear reactors. The structure and mechanical properties of fine-grained 13.5% Cr ODS ferritic steels, processed by hot cross rolling to large strains of 70 % and subsequent annealing have been investigated. The microstructure after hot cross rolling is partially recrystallized. The texture of the ODS ferritic steel after rolling and annealing has a sharp rotated cube ({100} <110>) texture component. The γ-fiber component (<111> // ND) typical of recrystallized rolled ferritic steels is absent. Similar values of tensile strength are obtained for rolled samples regardless the sample orientation in comparison with hot isostatically pressed samples whereas a substantial enhancement in total elongation (22 %) is present at 500 °C. Cross-rolled ODS steels represent an increase in upper shelf energy to 2 J compared with hot isostatically pressed samples. The relatively poor toughness properties, compared to 9Cr ODS RAFM steel Eurofer-ODS, can be attributed mainly to the absence of the γ-fiber texture component, bimodal grain size distribution and high amounts of interstitial impurities (O, N).

Chemical composition and fabrication parameters of 13.5Cr ODS steels

Capsel-No.	Heat	Cr	W	Ti	Y_2O_3	Remarks
13	161/0	13.5	1.1	0.3	0.0	Ti alloyed, HIP, for comparison
1	161/1	13.5	1.1	0.3	0.3	Ti alloyed, HIP
9	**161/2**	13.5	1.1	0.3	0.3	Ti alloyed, **1 kg**, HIP + rolling
14	**161/3**	13.5	1.1	0.3	0.0	Ti alloyed, as-rec., **1kg** rect., HIP + rolling

MA: 24h (1000/4min+700/1min); H2; Ball-to-powder ratio=10:1
HIP: 1150°C, 100MPa, 2.5 hours;
TMT: Three passes cross rolling at 1100°C (thickness reduction from 22 mm to 6 mm) ; annealing at 1050 °C, 2 hours

Fig.1 Optical microscopy (a) (c) (e) and SEM micrographs (b) (d) (f) of 13.5Cr ODS steel under various processing conditions (a) (b) HIP+HT; (c) (d) RD-ND section, HIP+TMP; (e) (f) TD-ND section, HIP+TMP, respectively.



(a) (b) HIP+HT: equiaxed ferritic grains ; spherical second-phase precipitates

(c) (d) RD-ND HIP+TMP: elongated grains ‖RD with a high aspect ratio

(e) (f) TD-ND HIP+TMP: Less deformed grains, coarsen inclusions align preferable along GB

Fig.4 Kernel average misorientation (KAM) map of 13.5Cr ODS steel

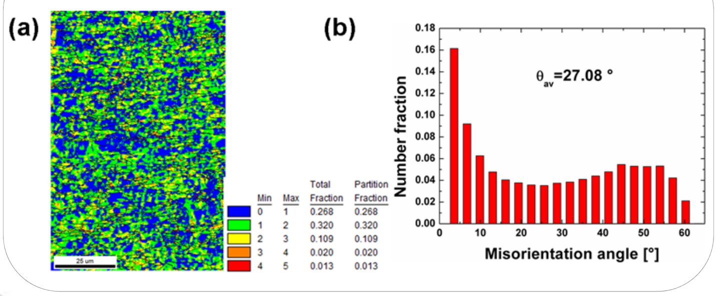
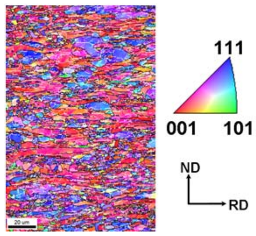
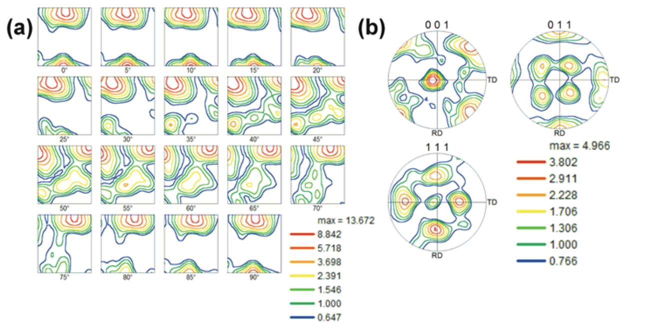


Fig.2 Orientation image map in RD-ND section and corresponding High angle boundaries (above 15°) are marked with black lines while low angle boundaries (2–15°) are marked with white lines.



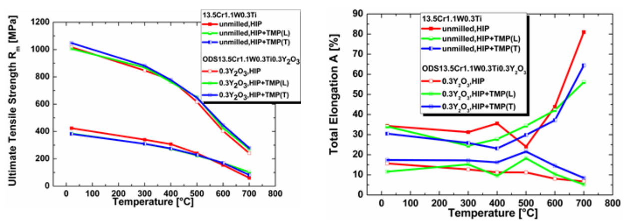
- **Elongated grains (‖RD) indicate that partial recrystallization occurs during TMP**
- **A bimodal grain size distribution is found with two maxima at about 2 µm and 8 µm**

Fig.3 (a) Orientation distribution function (ODF) plots and (b) pole figures (PF) of 13.5Cr ODS steel



The developed texture has a sharp rotated-cube {100} <100> component. The γ-fiber, usually helpful for the improvement of ductility, is not present.

Fig. 5 Tensile properties of 13.5Cr ODS and ferritic steels from RT to 700 °C (a) tensile strength and (b) total elongation



- **TMP does not influence the tensile strength markedly.**
- **Total elongation is more orientation- dependent compared with the tensile strength.**
- **Further efforts to improve toughness should be devoted to homogenize the grain structure, decrease the fraction of large inclusions and increase the intensity of γ-fiber texture component.**