EFFECT OF Mo ADDITION ON THE OXIDATION BEHAVIOUR OF Nb-Al-Cr BASE ALLOYS IN A TEMPERATURE RANGE 1473-1673 K IN AIR

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Introduction － The current gas turbine blades for extremely high-temperature use are protected by TBC with cooling air or steam running through them for resisting high-temperature environments. However, the application of TBC needs additional cost and the cooling reduces thermal efficiency. The development of turbine blades usable without TBC nor cooling in a temperature range 1600 to 1800 K is beneficial from the view point of thermal efficiency. In a recent project a few Nb-base materials, e.g. Nb-5Mo-22Si-10HfC, possessing required mechanical strengths at such high temperatures were developed, although they are lacking in oxidation resistance. Therefore, it is necessary to develop a coating which is simpler and cheaper than the current TBC.

This study aims at developing Nb-base materials which can be applied as a protective coating for Nb-based turbine blades.

Experimental － 30Nb-40Al-(30-x)Cr-xMo(mol %), with x being 0, 7.5, 15, 22.5 or 30, ingots were produced by the following way. Powders of Nb_3Al, $NbAl_3$, Mo_3Al and Cr were mixed for making compacts of desired compositions. Then, the compacts were subjected to Ar-arc melting followed by casting into a copper mould. The main phase of all the specimens was AlNbCr with a few minor phases at grains boundaries. Coupon specimens measuring about 10 x 5 x 2 in mm were cut from the ingots. The specimen surface was polished to mirror finish with a series of SiC polishing paper and alumina powders of 0.3 μm in size. They were ultrasonically cleaned in acetone bath and dried. Metallographic examinations were performed for the specimens before and after oxidation by optical microscopy, X-ray diffractometry, SEM and EPMA. The prepared specimens were oxidised at 1473, 1573 or 1673 K for 72 ks in air. Each specimen was put in an alumina crucible, such three sets were placed on an alumina boat and the whole was placed in a horizontal furnace. In addition, two kinds of specimens were encapsulated in a silica tube and annealed at 1573 K for 72 ks in a vacuum before oxidation.

Results－The mass gains or mass losses of all the specimens are summarised in Fig. 1, where (a) means specimens subjected to the annealing.

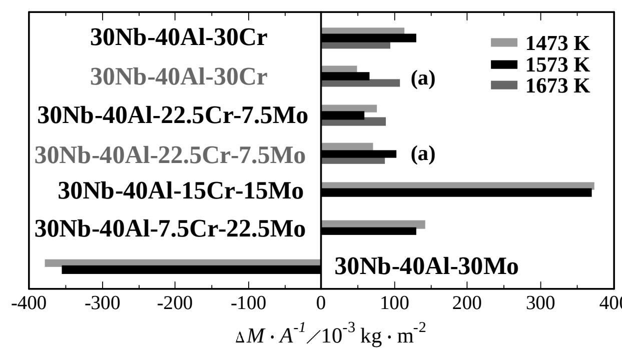

Fig.1 Mass gain of Nb-Al-Cr-Mo oxidised for 72 ks in air

The specimens of 30Cr and 7.5Mo without or with the annealing treatment formed protective scales with relatively small mass gains, while the other specimens formed poorly protective scales. In particular, 30Mo showed large mass losses mainly due to the formation of MoO_3 , major part of which vapourised during the oxidation making the scales a layered structure with partial separation between layers.

The scales on 30Cr consist of an inner Al_2O_3 layer with a thin outer layer of $AlNbO_4$ and $CrNbO_4$ or Cr-containing oxides. The scales formed at 1473 and 1573 K were partially convoluted and thus locally detached from the substrate. The annealing treatment prevented the scale convolution. The replacement of Cr with 7.5% Mo much improved the protectiveness of the scales and the scale convolution was reduced significantly. However, the scale protectiveness decreased as the Mo concentration increased. This is attributable to the increasing amount of MoO_3 formed by the oxidation. A part of MoO_3 appeared in a form of sharp needles, which seem very similar to those formed on $MoSi_2$.