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Enhancement of High-Temperature Oxidation Resistance of Cr-Steels by Applying Surface Modification Using Shot-Peening

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Abstract – A prediction of the service life of boiler steels in aggressive atmospheres requires a full understanding of the degradation mechanisms of the material due to high temperature oxidation. In the present study the effect of shot-peening (metal particle blasting and laser shock) on the high-temperature oxidation behaviour of Cr-steels is studied. Thermogravimetric measurements were carried out by using a microbalance with a resolution of 10^{-5}g at 750℃. It could be concluded that the shot-peenin g of the steel surfaces enhances the high-temperature oxidation resistance of the steels by affecting the kinetics of Cr transport to the sample surface enabling the formation of a slow growing Cr-containing oxide(s).

The protection against corrosion of alloys operating at high temperatures is very much necessary in many industrial applications. For example, materials used in power plants at high temperature undergo severe oxidation. The tubes made of Fe-Cr-steel or Ni-based alloys are applied, e.g. to carry steam at high-temperatures and at high pressures. The inner sides of the tubes are exposed to steam and the outer surfaces of the tubes are exposed to air or combustion gas. The formation of Cr_2O_3 on the substrate surface is always beneficial for the materials corrosion resistance because Cr_2O_3 layer is protective against inward diffusion of oxygen. For the formation of a protective, continuous and adherent layer of Cr_2O_3 on the surface of an alloy, certain minimum amounts of Cr present in the alloy are required.

It has already been proven that changing the surface roughness by applying some cold work changed the oxidation behaviour of high-Cr steels. In the present study the main idea is to verify the effect of shot-peening on oxidation behaviour by applying it on steels containing Cr.

The surfaces of the steels were shot-peened by means of metal particle blasting and laser shock. Specimens of (10×10×4)mm^3 were cut from the samples for oxidation experiments. A hole of 1 mm diameter was then made (near one edge) in the sample for hanging it in the thermobalance by means of a quartz wire.

This study shows that shot-peening of the internal surface of tubes is an excellent alternative in terms of cost reduction with material cost, e.g., reduction of Cr content, as well as a way to assure more reliability to the components.

The enhancement of the oxidation resistance can be explained by the increasing on the dislocation density near to the sample surface caused by the shot-peening. This leads to an increasing on the fast diffusion paths (pipe diffusion) for Cr to the sample surface, which accelerates the formation of slow growing Cr_2O_3 scale protecting the substrate against the inward diffusion of oxygen and outwards diffusion of iron and/or other alloying elements.

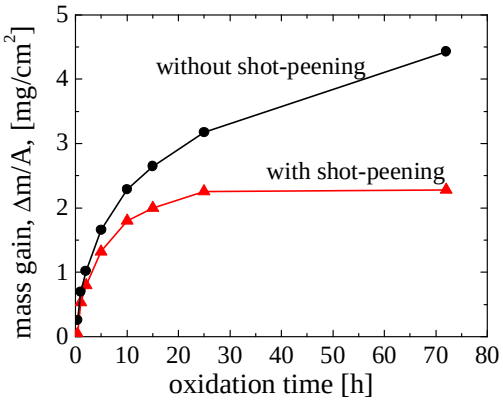

Figure 1: oxidation kinetics of a Cr-12 steel with both surface conditions at 750°C.

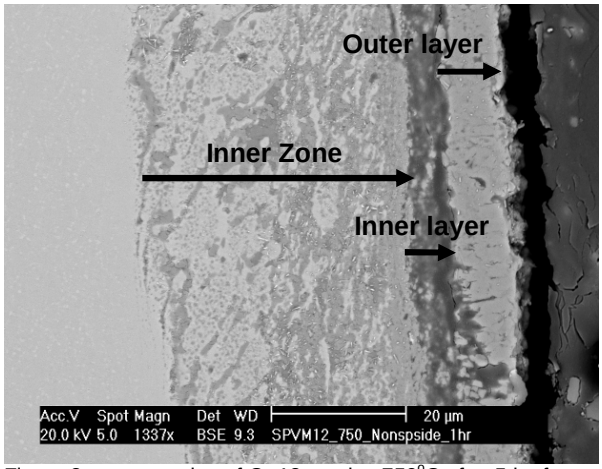

Figure 2: cross section of Cr-12 steel at 750°C after 5 h of exposure to laboratory air.