Abstract

Traditionally, Oxide dispersion strengthened (ODS) ferritic alloys are fabricated by mixing of nano Y_2O_3 with prealloyed / individual elemental powder by high-energy ball milling followed by consolidation by extrusion/ hot isostatic press. This process has been proven as an effective technique for incorporating nano-size oxides in the steel matrix. With respect to conventional milling process, a new milling technique of dual drive concept has been implemented to produce in large scale of iron-based alloys reinforced with a fine dispersion of Y_2O_3. In the present investigations, we have fabricated a large scale dual drive planetary ball mill to employ high energy milling for mass production of ODS powder of more than 1kg batch and development of process to produce ODS ferritic alloy by mechanical milling followed by consolidation in hot isostatic press and hot rolling. A unique feature of this dual drive planetary mill is to have two drive systems, one is attached to jar and other to the gyratory shaft where both have different speed control systems. This allows to attain different transmission ratio. Due to high speed of rotation of the jars, different kind of forces (centrifugal. corolis and gravitational) acting at a time lead to a large impact energy of the balls that improves the alloying performance. The prealloyed ferritic steel powder (Fe-16Cr: 434L grade) is used as matrix material for the ODS alloy preparation. This study for the first time uses combustion synthesized Y_2O_3 nanopowders as reinforcement in ferritc steel matrix for providing dispersion strengthening. The particle size of Y_2O_3 powder is found to be in the range of 20-50nm. Data obtained from X-ray diffraction (XRD) has been analyzed by classical and modified Williamson-Hall equation to estimate the crystallite size, lattice strain, deformation stress and dislocation characters of milled ODS steel powder. It is found that 5 h of milling time and is sufficient to reduce the particle size. TEM analysis of milled ODS steel powder reveals a homogeneous distribution of nano Y_2O_3 in ferritic steel matrix after a milling time of 5h. Preliminary results demonstrate that the indigenously developed dual drive planetary ball mill is suitable for mass production of ODS powder within a short time due to different kind of forces acting at a time during MA process. Milled ODS ferritic steel powder has been consolidated by hot isostatic press and also by hot rolling technique. It is also planned to compare the different forms of Y_2O_3 (micron sized, yttrium nitrate and nano sized Y_2O_3) in the ferritic steel matrix and prepared the ODS alloy of different forms of Y_2O_3 addition. The resulted density of HIP'd and hot rolled of ODS ferritic alloy samples are found to be ~ 99% of theoretical density. Fine oxide particles are observed in the iron matrix and their chemical formulation are determined by XRD and TEM, to be monoclinic $Y_2Si_2O_7$ precipitates. Vickers bulk hardness values of HIP'd and hot rolled samples are in the range of 357-377HV and 692-712HV, respectively. Further, ODS ferritic alloy has been evaluated by creep indentation, corrosion and oxidation testing, and thermal conductivity measurement. In the creep indentation test, the first stage of the curve shows an increase in the indentation depth with time, followed by a steady-state region where the indentation depth increases linearly with time. The value of activation energy, as estimated from the slope of the plot (-Q/R), is found to be 24 kJ/mol. Corrosion resistance of the nano Y_2O_3 dispersed ferritic steel is better than that of micron Y_2O_3 and yttrium nitrate dispersed ferritic stainless steel. Oxidation resistance is also superior for the 434L ferritic steel containing uniformly distributed Y_2O_3 particles in the microstructures (0.35% Y_2O_3 with an average size of 40 nm) than that of the other investigated ODS steels. It is found that nano Y_2O_3 added ODS 434L alloy is showing higher thermal conductivity compare to that of other alloys. Thus developed process of preparation of ODS ferritic alloy can be used for making structural materials for power plants and parts of exhaust systems in automobiles.

Keywords: Dual drive planetary ball mill, ODS ferritic alloy, Mechanical milling, Creep indentation, Oxidation resistance, Hot rolling, Hot isostatic press.