ABSTRACT

Generation IV nuclear energy systems are an ensemble of nuclear reactor technologies that present significant improvements in economics, safety and reliability and sustainability over currently operating reactor technologies. Proper choices of cladding and structural material are essential for the safe and reliable operation of any Generation IV system. Studies to develop optimum combination of properties for steels intended for use as wrappers indicated that 9-12Cr type ferritic steels presented superior high temperature strength at temperatures below 873 K and excellent dimensional stability at high displacement doses. The development of Ferritic-Martensitic 9-12%Cr steels with Reduced Activation (RAFM steels) for nuclear fusion was based on the excellent irradiation performance of 9-12% Cr steels in Fast Breeder Reactors. Taking into consideration the present day requirements like environment, efficiency, elasticity, experience and economy that dominate considerations of modern power station design, layout, fabrication and operation, use of 9%Cr steel is an optimum solution. Increasing the operating temperature of these steels by Oxide Dispersion Strengthening (ODS) makes them a promising candidate for advanced fast reactor core and fusion reactor blanket applications.

The present study was taken up to synthesize 9Cr-2W-Yttria dispersion strengthened (ODS) martensitic steel by Mechanical Alloying (MA) and its subsequent consolidation employing various powder compaction

methodologies. Detailed characterization of ODS alloy powders was taken up to optimize experimental synthesis and bulk production of ODS alloy powder. Characterization of the consolidated specimens was carried out to study microstructural evolution involved during compaction via various techniques. Preliminary mechanical property evaluation studies of the compacted specimens were also carried out.

Synthesis of nanocrystalline yttria used as the dispersoid was prepared through an economic, eco-friendly and efficient Sol-gel method. X-ray Diffraction (XRD) analysis of the alloy powder milled for various durations employing the above mentioned routes was carried out to confirm the formation of solid solution. Scanning Electron Microscopy (SEM) of the ODS alloy powders were recorded to evaluate the microstructural evolution during MA. The alloy powder was also characterized employing High Resolution Transmission Electron Microscopy (HRTEM) and Particle size analyzer to facilitate effective compaction of the ODS alloy powder. Energy Dispersive Analysis of X-rays of the alloy powder was carried out to study the purity of the powders produced employing different equipment.

Alloy powder characterization studies revealed the progressive nature of alloying namely, particle deformation, fracture, cold welding and agglomeration of the constituent metal precursors during mechanical milling. The optimum process parameters and the equipment for efficient experimental synthesis and bulk production of ODS alloy powder was identified.

The synthesized ODS alloy powders were compacted employing the methods listed below:

1. Cold compaction/Sintering
2. Cold compaction/Vacuum sintering
3. Hot compaction
4. Cold Isostatic Pressing/Hot Isostatic Pressing
5. Hot Isostatic Pressing

The cold compacted/sintered specimens had 82% TD while the hot compacted specimens had a density of about 96.725% TD. The density of the HIPed specimens was estimated to be about 97.75% TD. Microstructural studies of the consolidated specimens were carried out employing Optical Microscopy, SEM/EDAX, HRSEM and TEM. Heat treatment studies of the compacted samples were taken up to solutionize the two phase microstructure of the consolidated specimens and the results are reported.