CHAPTER 6

CONCLUSIONS AND SCOPE FOR FURTHER WORK
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6.0 CONCLUSIONS

In fast reactor systems, it is often required to operate with incipient cavitation because of the need to use compact and cost effective systems. The deleterious effects of cavitation are minimised by improving the hydraulic design and limiting the progress of cavitation. In addition to improving hydraulics, proper material selection and surface treatment, such as hard facing, are also important to combat damage from cavitation and reduce maintenance frequency. Increasing life of equipment and ensuring minimal maintenance is an important goal towards achieving uninterrupted plant availability.

Austenitic stainless steel is the structural material used in fast reactors. Tribological performance can be improved wherever required using hardfacing with cobalt base or nickel base alloys. The major drawback of using Cobalt base hardfacing alloys is the formation of the isotope Co\(^{60}\) from the transmutation of Co\(^{59}\) in the radioactive reactor environment. Co\(^{60}\) is a \(\gamma\) emitter (1.17MeV and 1.33MeV) with a half life of 5.3 years and therefore poses difficulties during material handling when components are removed for repair / maintenance. However, Co\(^{60}\) is known to have good wear resistance. Fluid dynamic properties also influence cavitation damage and it is known that the damage produced in sodium is much more that in water.

Hence this study was carried out to establish a facility to study cavitation erosion in flowing sodium and to evaluate cavitation damage resistance of the common structural material
in the reactor (austenitic stainless steel) and the hardfaced coatings made of Stellite6 and Colmonoy5. The following are the major conclusions:

(i) A facility was designed and commissioned for evaluation of cavitation damage in materials in liquid sodium in the temperature range of 200 - 400°C using vibratory cavitation technique.

(ii) Cavitation erosion resistance of hardfaced coatings is significantly better than that of the austenitic stainless steel 316LN. Hard carbides and borides resists deformation of the surfaces during bubble collapse and this gives the cavitation erosion resistance to hardfaced coatings. In contrast, austenitic stainless steel surface deforms easily under cavitation resulting in damage. Stellite 6 hardfaced coating is more resistant to cavitation erosion than Colmonoy 5 coatings though hardness is higher for the latter. This is attributed to higher fracture toughness and lower stacking fault energy of the former. Transformation of FCC matrix phase of Stellite 6 coating to HCP under stress is also known contribute to the improved wear resistance of the alloy. All the three alloy systems show an initial increase in cavitation erosion with temperature followed by a decrease in cavitation erosion with further increase in temperature. This is similar to the variation of cavitation erosion with temperature reported in water. This variation is attributed to variation in properties of the liquid medium that influence cavitation erosion.

(iii) It is observed that the evaluation of cavitation damage resistance on the basis of roughness measurement results in a similar ranking of various materials as that from weight loss due to cavitation damage.
6.1 SCOPE FOR FURTHER WORK

The experiments in this work were done in a static facility using vibratory cavitation. The effect of flow velocity may be studied in future work to understand the effect of flowing sodium to damage in a vibratory facility. This arrangement will be more convenient to study the effect of cavitation damage in a flowing system, when compared to the alternative system comprising a venturi, especially with respect to maintaining a leak tight sealing which is very crucial for a sodium system.

In the past attempts have been made to correlate cavitation damage resistance with macroscopic material properties (such as hardness, ultimate tensile strength, yield strength, Young’s modulus, etc.) with limited success. The results here show that microscopic properties like SFE and fracture toughness also influence damage resistance. However, values of these properties are more difficult to come by published literature, especially for alloys and hardfacing materials. Data analysis of pure metals, and alloys wherever published literature is available, to explore relationships between microscopic properties and erosion damage can provide more insight on the influence of these properties towards improving cavitation damage resistance.

Fluid dynamic properties also have a strong influence on the damage produced. It is therefore useful to study the influence of fluid properties on cavitation damage using a surrogate liquid by classifying whether the damage produced is due to inertial effects or thermal effects and modeling the relevant properties affecting damage.

Experiments to study the effect of surface treatment methods such as nitriding, hard chrome plating, laser surface modification etc. in improving cavitation damage resistance in sodium holds promise.
Another area where further work can be carried out is in the area of theoretical modeling of bubble collapse. In Chapter 3, the collapse pressure produced during collapse of a single bubble was modelled. In reality there will be a population of bubbles of varying sizes and distributed at varying distances from the specimen surface in the cavitation zone in the cavitation zone. The collapse pressure generated by the implosion of a vapor bubble will be influenced by that produced by the surrounding bubbles; moreover the energy transferred to the specimen surface will be attenuated by the neighbouring bubbles in the vapor cluster. Modelling these effects (eg. assuming a normal distribution of bubbles in space and a Monte Carlo simulation of collapse of bubbles) will provide more insight into the collapse process.