CHAPTER - VII
CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

7.1 Conclusions

Under the existing experimental conditions the following conclusions may be arrived at:

i) Powder encapsulated forging is a very effective method of 'consolidation processing' as it enables attainment of dense products without employing sintering.

ii) 'Short/optimum' duration attrition is extremely useful in affecting 'mechanical alloying' efficiently. This way it is possible to do away with the limitations associated with 'long' duration attrition.

iii) In A-series of alloys containing 17% Cr, presence of 6% aluminium was found to be better than 0.3% yttria in enhancing the oxidation resistance up to 1200°C. However, at 1250°C the roles are reversed.

iv) Combined addition of 6% Al and 0.3% Y₂O₃ to 17%Cr alloy yielded the best in terms of oxidation resistance at all the reference temperatures (amongst A-series of alloys).

v) Presence of 6% aluminium greatly reduced formability, in fact A2 (Fe-17Cr-6Al) alloy could not be rolled into sheets.

vi) The formability of the Fe-17Cr-0.3Y₂O₃ alloy was better than the A2 (Fe-17Cr-6Al) and the straight Fe-17Cr alloy. However, the best in terms of formability was attained when both aluminium and yttria were present.

vii) The oxidation of the 17Cr alloys, developed through
consolidation processing, was found to be appreciably higher than the Fe-20Cr alloys developed through the conventional P/M route. This reflects favourably on the forming strategy adopted.

viii) The 22% Cr alloys containing 5.5% Al and 0.2% and 0.4% Y, while retaining the basic attributes of the A-series of alloys showed remarkably improved oxidation resistance and very useful high temperature mechanical properties.

ix) From the point of view of isothermal oxidation behaviour and high temperature mechanical properties, the B-series of alloys especially B2 and B3 are far superior to Kanthal A-1 alloy.

x) Similarly, based on high temperature tensile properties the performance of B2 and B3 alloys is comparable with that of MA 956 in the temperature range of 20-1000°C especially when both the UTS and percentage elongation values are considered together.

xi) Electrical resistivity of the alloy B2 is similar to that of Kanthal A-1 and that of B3 comparable with MA 956. Further, electrical resistivity decreased with an increase in yttria content due to an increase in the extent of densification. The low resistivity of alloy B3, inspite of its attaining an unexpectedly high hardness reflects favourably on the usefulness of the alloy and that of the processing technology.

xii) The different experimental and testing techniques employed in characterizing the alloys in totality reflect very
favourably on the consolidation processing technology developed. This is in fact the key point of the present study.

xiii) The present investigations highlights that it is possible to produce reasonably sound dense products, through the improved processing technology developed, even by employing low cost ordinary quality raw materials. The idea evidently merits further detailed exploration.

xiv) Yttria has emerged as an additive with manifold beneficial effects. Although the evidence in support of the contention is mostly indirect, it may be useful to highlight it in an abridged form.

Role of yttria as a dispersoid

This can be summarized as follows:

(a) marked improvement in isothermal oxidation resistance especially at high temperature(s),

(b) marked reduction in porosity during forging, homogenization and rolling interspersed with reheating,

(c) significant improvement in formability even in the presence of 5-6% aluminum,

(d) attainment of an improved combination of strength and elongation particularly within the temperature range of 800-1000°C (as manifested in alloys B2 and B3),

(e) reduction in electrical resistivity with an increase in concentration of yttria,

(f) enhanced homogenization of Cr during processing and

(g) large increase in hardness at room temperature (as in alloy B3).
The nomenclature 'DISPERSOID AIDED CONSOLIDATION PROCESSING' (DACP) has been coined on the basis of the aforesaid inferences relating to the overbearing beneficial effect of yttria additions.

7.2 Suggestions for future work

A detailed characterization of alloys along the lines of MA 956 can be taken up as a future developmental activity. This would include:

(i) detailed metallography including transmission electron microscopy for an indepth microstructural examination,
(ii) assessment of the creep and fatigue behaviour,
(iii) designing of alloys with increased Y up to 1% and
(iv) designing of alloys with changing Cr/Al ratio, to optimize these additions.