CHAPTER 9

SUMMARY AND FUTURE WORKS

The present investigation is an approach to develop aluminium and aluminium Al-319 alloy composites and their characterization. Two different categories of aluminium and Al-319 alloy composites and, as reinforcement, uncoated and 'SiO_2 coated ABO_w' was developed.

The chemical composition and the reinforcing whiskers content of the metal matrix composites have been determined to characterize the metal matrix composite. The major conclusion of the present study is summarized under given below.

9.1 Fabrication of composites and reinforcement.

9.2 Analysis of fabricated material.

9.1 Fabrication of composites and reinforcement

i) Uncoated alumina borate whiskers were synthesized using hydrolysis and heat treated using powder metallurgy route. Whiskers were reinforced in the aluminium metal matrix by a wet dispersion process. Thereafter powder metallurgy route was followed to prepare the samples.

ii) Coated alumina borate whiskers were synthesized by liquid sol/hydrolysis route and heat treatment by powder metallurgy route. The coating of the whiskers was done by heating the dried sol of the coating material, and finally, the preforms were calcined to obtain the oxide coating on ABO_w powder surfaces.

iii) Coated and uncoated whiskers were reinforced in Al-319 alloy using a compo casting process.

9.2 Analysis of Fabricated Material

a) XRD analysis

(i) In the case of uncoated ABO_w, XRD confirmed the presence of $Al_{18}B_4O_{33}$ phase, crystalline between 1100-1300°C. As the mass fraction of ABO_w increased, the intensity of the ABO_w peak increased, whereas the aluminium peak decreased.

(ii) In case of SiO_2 coated ABO_w reinforced in aluminium matrix composites, no other phase was formed except aluminium, ABO_w and SiO_2.

(iii) In the case of uncoated whiskers reinforced A-319 alloy except for ABO_w and Al, Al_2Cu phase was also present. SiO_2 coated ABO_w reflected beta quartz phase after increasing the calcining temperature to 500°C.

(iv) SiO_2 coated whiskers reinforced Al-319 alloy reflected SiO_2, Al_2Cu, and ABO_w phases. The tridymite structure of SiO_2 is a high temperature resistant, sheet-like crystal with high density giving scope for uniform coating of whiskers for reinforcement. For Al-319 alloy, copper diffusion is the main factor in the formation and growth of the Al_2Cu phase [151-152].

b) TEM investigation

(i) Micro rods observed in $Al_{18}B_4O_{33}$ phase were single crystals with orthorhombic structures. At 1400°C, the network formation of the whiskers has taken place, and they were not single crystals.

(ii) For coated whiskers, SiO_2 coating was uniformly deposited on the whisker surfaces and thickness 20-50 nm was observed. Zig-Zag formation of Silica was observed.

(iii) The Al-319 alloy reinforced with coated whiskers showed the formation of inter-facial product $Mg_2Al_2O_4$, a continuous product distributed at the interface between ABO_w and A-319 alloy.

c) SEM image investigations

(i) The size of whiskers increased with an increase in temperature up to 1300°C (10-15μm) but an increase in temperature further led to a decrease in aspect ratio of the crystals.

(ii) As the sintering temperature is increased to 1200°C, the particle range size has been increased (6-8 μm). Further, at a higher sintering temperature of 1300°C, particles size of whiskers of size 10–15 μm are observed, resulting in an improvement in the aspect ratio of whiskers.

(iii) In the case of coating of whiskers, SiO_2 coating is smoother and compact thickness 50 nm leaves no cavity and holes than oxide coating.

(iv) In the case of uncoated and coated fabricated composites, SEM images micrographs show almost uniform distributions of ABO_w throughout the volume of the composites. In 'SiO_2 coated ABO_w fabricated composites', uniform reinforcement distribution in the matrix materials offers excellently refined microstructures.

c) Porosity

(i) The apparent porosity of uncoated ABO_w increased with increasing sintering temperature but dropped sharply after 1300°C.

(ii) Bulk density of these samples decreased up to 1300°C and increased again at 1400°C (The density decreases due to the whisker formation).

(iii) Among all the coated whiskers, the apparent porosity of SiO_2 coated whiskers was lowest and bulk density was highest (The tetrahedral structure of SiO_2 and grain boundary growth was responsible for this).

(iv) A decrease in density of composites reinforced with uncoated whiskers was observed, with an increasing percentage of whisker content.

d) <u>Differential thermal and Thermo-gravimetric analysis</u>.

(i) Analysis revealed negligible weight loss and weight change of ABO_w whiskers.

(ii) Below 700 °C, no reaction takes place between B_2O_3 and Al_2O_3. Initiation of $2Al_2O_3$. B_2O_3 phase formation occurs between 700 °C–800 °C, which reacts with excess alumina above 950°C, giving $Al_{18}B_4O_{33}$ phase.

e) <u>Hardness testing</u>

(i) Hardness of ABO_w reinforced aluminium composites fabricated by conventional powder metallurgy route was increasing with an increase in whisker content in the matrix. It was obtained maximum, i.e. 40H_V for samples with 10 wt% of reinforcement.

(ii) The hardness of composite samples reinforced with SiO_2 coated ABO_w in 10 wt% was obtained maximum, i.e. 46.2 H_V. Further increase in reinforcement % led to a decrease in hardness due to agglomeration causing localized shrinkage strains.

f) <u>Mechanical properties</u>

(i) The cold and hot modulus of rupture of ABO whiskers at room temperature and at 700ºC for different sintering temperatures increased with increasing temperature upto 1300ºC, thereafter a decrease in bending strength was observed as the formation of brittle glassy phase initiates at 1400ºC.

(ii) Plastic deformation due to high thermal stresses led to a decrease in HMOR values. HMOR values were higher at 700ºC, i.e. 42 MPa. HMOR values for SiO_2 coated alumina borate samples were found maximum at 800ºC, i.e. 53 ± 2.2 MPa. It was minimum for uncoated, and ZnO coated samples at 1000ºC, i.e. 43 ± 2.2 MPa.

(iii) Flexural strength around 172 MPa, in composites reinforced with 10% ABO_w samples were obtained. Flexural strength of SiO_2 coated (ABO_w) – Al matrix composites were found to be maximum, i.e. 178 MPa in 10 wt% SiO_2 coated whisker reinforced Al composites.

(iv) It can be concluded that SiO_2 coating on whiskers provided better bending strength to whisker reinforce composites.

g) <u>Compression testing</u>

(i) Maximum compressive strength i.e. 324 MPa was obtained in composites with 10 wt% ABO_w reinforcement.

(ii) Diametral compression test (DCS) and Young's modulus test of SiO_2 coated ABO_w reinforced composites were calculated. The maximum values of DCS and Young's modulus for samples sintered with 10 wt% of whiskers were obtained i.e. 142 MPa and 89 GPa, respectively.

(iii) With the higher content of ABO_w, the proportion of the region representing the flow localization increased, and the matrix has to accommodate the deformation between the region of plasticity and non-plasticity.

(iv) The occurrence of localized plasticity signifies improvement of plastic deformation capacity.

(v) Coated ABO_w from the matrix proved to be unbreakable under the application of load, thus affecting the mechanical properties of the composites.

h) <u>UTS and δ testing</u> -The UTS and δ of the composites increased firstly and then decreased with the increasing of the coated ABO_w content. The composite with a suitable coated ABO_w content (SiO_2/7.5%ABO_w/A-319 composite) can attain the highest values of the UTS (238 MPa) and δ (6.4%).

i) <u>Dry sliding behavior</u>

(i) 7.5wt.%ABO_w/Al-319 exhibits the best dry sliding wear resistance.

(ii) Increasing the coated SiO_2 /ABO_w in the alloy may increase the hardness and oxide layer from at the surface. SiO_2 is also strongest because of its high density and low porosity.

k) <u>Wear test</u>

(i) Oxide layer developed on the surface may affect the wear resistance properties which act as a protective layer and decrease the wear rate (a reason why the SiO_2 /ABO_w /Al- 319 exhibits a fairly good wear resistance)

(ii) Uncoated worn surface of Al−10wt. % ABO_w/Al composite is much smoother and almost free from wear debris.

(iii) With 15 wt. % ABO_w, shallow surface scars with fine cracks, and subsequent delamination are observed. The whiskers are dislodged due to non-uniform dispersions forming larger quantities of debris.

9.3 Suggestions for future work

The following suggestions are made for future investigations based on the present results and analysis with regards to the phase evolution, mechanical stability, and microstructural study:-

1. Chemical corrosion behaviour of SiO_2 coated alumina boron-based refractory application for the petrochemical industry.
2. Microstructure and high-temperature mechanical properties of compo-cast SiO_2 - coated ABO_w reinforced Al-319 Composites.
3. Erosion behaviour of SiO_2 coated ABO_w reinforced aluminium alloy for automotive application.
4. Wet/Lubrication wear and corrosion behaviour of SiO_2 coated ABO_w –Al 319 composites.
5. Fatigue behaviour of coated and uncoated ABO_w reinforced Al-319 composites.