FABRICATION AND CHARACTERISATION OF Mg/MgO METAL MATRIX COMPOSITES

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By

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CHAPTER 8
CONCLUSIONS AND SCOPE OF FUTURE STUDY

8.1 Conclusions

The present research work on the fabrication and characterisation of Mg/MgO metal matrix composites through powder metallurgy method has been undertaken by two different sintering techniques. One is rapid microwave sintering and second is the novel sintering technique. The investigations led to several salient conclusions which are presented below in two sections 8.1.1) Fabrication and characterisation of Mg/MgO MMCs by rapid microwave sintering and 8.1.2) Fabrication and characterisation of Mg/MgO MMCs by novel sintering technique.

8.1.1 Fabrication and characterisation of Mg/MgO MMCs by rapid microwave sintering

1. Pure magnesium and Mg/5 wt. % MgO composites were successfully fabricated by powder metallurgy route assisted by rapid microwave sintering at different sintering temperature of 450 °C, 500 °C and 550 °C except composite sample at 550 °C which oxidised completely in spite of several attempts. All samples were free from cracks except Mg/5 wt. % MgO composite sintered at 500 °C where very fine cracks appeared upon sintering.
2. Pure magnesium and Mg/MgO composites were nearly 97% and 96% dense, respectively. The density of pure Mg increases with increase in sintering temperature due to better diffusion between the powder particles leading to denser product. The density of composites improved due to addition of MgO

reinforcements. However, density of composite sample decreases as sintering temperature is increased.

3. The XRD results showed the presence of only Mg and MgO phases in the diffractograms and some Mg particles oxidised to form MgO at all sintering temperatures. XRD phase quantification of pure magnesium and Mg/MgO composites showed increased MgO phase formation at 550 °C and 500 °C sintering temperature, respectively.
4. MgO particles are predominantly distributed at grain boundaries as observed in microstructure. Agglomeration of MgO particles was also observed at few places at 500 °C sintering temperature. The presence of hard MgO particles at the grain boundary led to grain refinement thereby strengthening the composites.
5. The addition of hard MgO reinforcements improves the hardness of composites due to uniform distribution of MgO particles and grain refinement effect. However, there is very modest change in hardness value due to change in sintering temperature.
6. The compressive yield strength of pure Mg samples showed nominal improvement due to increase in sintering temperature because the increase in density and decline in grain size value is also very less as sintering temperature is varied. However, when 5 wt. % MgO is added in pure Mg, considerable improvement in CYS is observed due to load bearing effect, grain refinement and coefficient of thermal expansion mismatch. Ductility in pure Mg is improved as sintering temperature increases but the addition of MgO particles deteriorated the ductility in composites.

8.1.2 Fabrication and characterisation of Mg/MgO MMCs by a novel sintering technique

- The Mg/MgO composites with varying weight fraction of 0, 5, 10, and 15 % of MgO were successfully fabricated through the powder metallurgy route using a novel sintering approach. The attempt to employ carefully wrapped aluminium foil on samples to effectively prevent oxidation from the surrounding environment was successful during the entire sintering duration.
- The density increases with increase in MgO content. Composites samples were nearly 97 % and 98 % dense for 5 and 10 wt. % MgO, respectively. The highest density was achieved for Mg/10MgO sample. The structural porosity of samples decreases by 6.4 % with 5 wt. % MgO addition. It further decreases by 33.3 % when 10 wt. % MgO is added and then sharply increases in 15 wt. % MgO sample. The sharp increase in the porosity in Mg/15MgO sample is mainly due to large agglomeration and clustering of MgO particles.
- XRD results reveals the presence of only Mg and MgO phase in composites. The decreasing crystallite size with increasing MgO weight fraction shows that the composites were sintered at adequate sintering temperature. The addition of hard MgO particulates settled at grain boundary increases the micro strain at the interface. The quantitative analysis of phases showed extra MgO formation in all the samples during sintering because Mg is highly oxidative metal.
- MgO particles are mostly settled at grain boundaries and are uniformly dispersed in the Mg matrix. Clustering at few places was observed in Mg/15MgO sample. Grain size measurement showed decrease in size of grains as MgO content is increased up to Mg/10MgO thereafter it increases in Mg/15MgO. EDS elemental mapping of composites confirms the distribution of MgO at grain boundaries.

- EDS line scanning samples from periphery towards centre confirms that the O element profile does not show rising trend when line scanning is done from outer surface towards core. This confirms that the samples did not get oxidised at the outer surface.
- The composites showed an increasing trend in hardness value with an increase in MgO volume fraction. There is an increase of 9 %, 13 % and 29 % hardness value with respect to pure Mg in Mg/5MgO, Mg/10MgO, and Mg/15MgO samples, respectively.
- The distribution of MgO particles in the Mg matrix improves the compressive behaviour of composites. The increase in CYS is nearly 6 % for Mg/5MgO and 23 % for Mg/10MgO compared to pure magnesium. Further MgO incorporation in Mg/15MgO sample resulted in decrease in CYS value. The UCS value improves in Mg/5MgO sample compared to pure Mg. Further improvement is observed in Mg/10MgO sample but in Mg/15MgO sample, UCS value drops sharply. The ductility of the sample decreases gradually as MgO content is increased in composites.
- The addition of hard MgO particles in the Mg matrix improves the wear resistance of composites. At 0.6 m/s sliding velocity, Mg/15MgO has best wear resistance at 5 N and 10 N load among all samples. However, at 15 N load Mg/10MgO shows the best result. At 0.9 m/s sliding velocity, Mg/10MgO has best wear resistance at 5 N and 10 N load and at 15 N load, Mg/5MgO has highest wear resistance. At 1.2 m/s sliding velocity, Mg/5MgO shows the best results at 5N and 15N. Therefore, it is concluded that an optimum MgO content gives the best wear resistance at different combination of load and sliding velocity.

- The wear rate of all samples increases with increase in load as well as sliding velocity except Mg/0MgO and Mg/5MgO samples at 15N load.
- It is also concluded that wear in different compositions of Mg/MgO composites does not occur by a single wear mechanism. In fact, multiple mode of wear mechanisms work simultaneously. There is no clear boundary for wear mechanism operating in the present study though one of the wear mode becomes dominant at particular load and sliding velocity. In unreinforced composite (Mg/0MgO), wear due to abrasion was dominant at low load followed by plastic deformation at higher loads. In composite samples, wear due to oxidation and delamination were dominant. Adhesive wear was dominant at high load and high sliding velocity conditions.
- The coefficient of friction was lowest for pure Mg samples at all loads as compared to the composite samples owing to soft nature of Mg and absence of MgO particles. The COF value generally increases as load is increased because at higher load, asperities interlocking also increases. There is very minimal variation in COF value with respect to change in MgO weight fraction in composite samples.

8.2 Scope of future study

In the present study, Mg/MgO MMCs have been successfully fabricated by powder metallurgy technique employing rapid microwave and a novel sintering technique. The composites have been characterised for physical, mechanical and tribological properties. However, there are many possibilities to explore the novel sintering technique as well Mg/MgO composites for different applications. Thus, following investigations can be carried out in future related to present work.

1. Investigations on fabrication of other reinforcement's composition in Mg MMCs as well as Mg alloys to explore effectiveness of the novel sintering technique and a comparative study with respect to other prevailing fabrication methods.
2. Tribological behaviour of Mg/MgO composites can be studied by incorporation of solid lubricants and study of synergistic wear behaviour in dry as well as in wet conditions.
3. Mg/MgO composites can also be studied for its use as biomaterial as both Mg and MgO have good biocompatibility with human body.
4. The Mg/MgO composites can also be studied for corrosion behaviour in different mediums.