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SYNTHESIS OF Mg-SiC COMPOSITES USING UNDERWATER SHOCK WAVE BY CHANGING MILLING PARAMETERS

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ABSTRACT

The weight reduction demand, in particular for aerospace and automotive applications, has renewed interest in magnesium (Mg) based materials. Though magnesium has numerous desirable properties, its elastic modulus is low in comparison with other structural materials. Incorporation of ceramic reinforcement in the form of particulates is known to improve the properties of magnesium composites. Among the various reinforcements, SiC is the most commonly used reinforcement and also it has high wettability with magnesium. In this present investigation, 70 mass% Mg- 30 mass% SiC are used for the shock compaction of the powder. This composite has high specific strength, excellent machinability, castability and good recyclability. In the fabrication of magnesium-silicon carbide composite, conventionally used process expose the composite to a high temperature for a prolonged time resulting in undesirable reaction product. Thus a fabrication technique that involves less temperature and micro second time is necessary in the manufacturing of magnesium-silicon carbide composites. Underwater shock consolidation process is a one-stage densification process, which involves a very rapid and intense deposition of shock energy on powder particle surface using transmission of shock waves in water. Here the pressure during the shock consolidation is about 10-13.2 GPa. In the shock consolidation process, the important step is the powder milling using a ball mill for the uniform distribution of the matrix (Magnesium) and the reinforcement (Silicon carbide). However, for the best realization of mechanical properties various parameters of powder mixing must be optimized. In this work, parameters such as ball to powder ratio (10:1, 20:1 mass%), milling speed (100,150 and 250 rpm) milling time (3.6, 18, 36 and 54 ks), are varied and the structural changes in the powders are observed. Several experiments on shock consolidation are conducted. Microstructural characterization using scanning electron microscope and optical microscope of the mixed powders and the recovered composites are examined.

Keywords: Milling Parameters, Shock Wave, Microstructural Characterization.

1. INTRODUCTION

In the world of modernization, light-weight magnesium alloys have recently received much more attention due to their attractive properties. With its ~ 35% lower density when compared to aluminum, it carries tremendous potential for engineering applications requiring high specific mechanical properties. Magnesium based composites due to their inherently low density and ensuring potential to exhibit high specific mechanical properties are demandable for weight-critical structural application. Increasing demand for fuel consuming and low-level emissions in the automobile industry has favorably increased the use of these materials in recent years. A recent industrial review revealed that there are 60 different types of components, from instrument panel to engine component is developed for uses. The uses of magnesium in automobile parts are increased in the world at an average rate 15% per year [1].

The properties of metal-matrix composites (MMC) depend upon the properties of the reinforcement phase of the matrix and of the interface. A strong interfacial bonding without any degradation of the reinforcing phase is one of the prime objectives in the development of MMC. One of the major limitations of magnesium and its alloys is their low elastic modulus, which limits its use in conventional and critical engineering applications as structural materials. With the advent of the metal matrix composites, it is possible to increase the stiffness and hardness of the metallic matrices by addition of stiffer and harder ceramic reinforcement. In addition, judicious selection of the type, size and volume fraction of ceramic particulates for a given metallic matrix also enhance tribological characteristics, dimensional stability, damping capacity and elevated temperature creep properties [2,3]. SiC are very easily available in the economic point of view and have high wettability with magnesium matrix [2]. A uniform distribution is essential

for fabrication of good composites. High-energy ball mill is effective to mix the reinforcement and the matrix. Ball mill can reduces the particle size with the attention of the speed, time and grinding medium. After fixing the milling condition, underwater shock wave was applied. In a microsecond of time the desired composites are obtained. The unique potential of the shock consolidation of powders results from a combination of very high pressure, high velocity and the simplicity of equipment.

The present research focused on the changing milling parameters to fix the Mg-SiC powder mixing by ball mill. Uniform distributions of the metal-matrix are desirable. After shock wave loading on the powder Mg-SiC composites are formed and microstructure of the composite is studied.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

In the present study, pure magnesium of 99% purity, with an average particle size 100 mesh was used as a base material and silicon carbide of 99% purity, with an average particle size 8000 mesh, were used as the ceramic reinforcement phase.

2.2 Proccessing

Mechanical alloying, which is usually achieved by high-energy ball milling has been utilized for producing metal or ceramic based composite powders. In this work, high-energy ball mill was used to reduce the particle size and uniformed distribution of the metal-matrix. At first 70 mass% Mg and 30 mass% SiC were taken for mixing as a weight ratio. The milling process was carried out in a planetary ball mill at room temperature using hardened still steel vial and under high purity argon atmosphere. The powder handling was done in the gloves box in the argon atmosphere. The milling medium was steel balls, 5 mm in diameter. The ball to powder weight ratio (BPR) and rotational speed were 10:1, 20:1 and 100, 150, 250 rpm, respectively [4]. The powder was milled for 3.6, 18, 36 and 54 ks respectively to achieve homogeneous distribution. XRD analysis was performed by means of X-ray diffractometer with Cu Kα radiation. The amounts and distribution of morphology of the powder were studied in the polished sections by scanning electron microscopy (SEM) and optical microscopy.

Shock consolidation is one of the techniques to produce composites from powders. By shock wave crack free material can be obtained. Good consolidation results in the case of soft powder. The very short time scale of the shock pulse during compaction is through to strongly inhibit the usual quasi-static kinetic processes that tend to have much longer time. An advantage is the capability to densify powders into near-net-shaped compacts with essentially no thermal effects, such as grain growth and crystallization of amorphous structure.

The explosive assembly (Fig. 1) fabricated using mild steel, consisted of three parts: (i) the explosive region in which high explosive was packed; (ii) the water container in which the shock transmitting medium, water

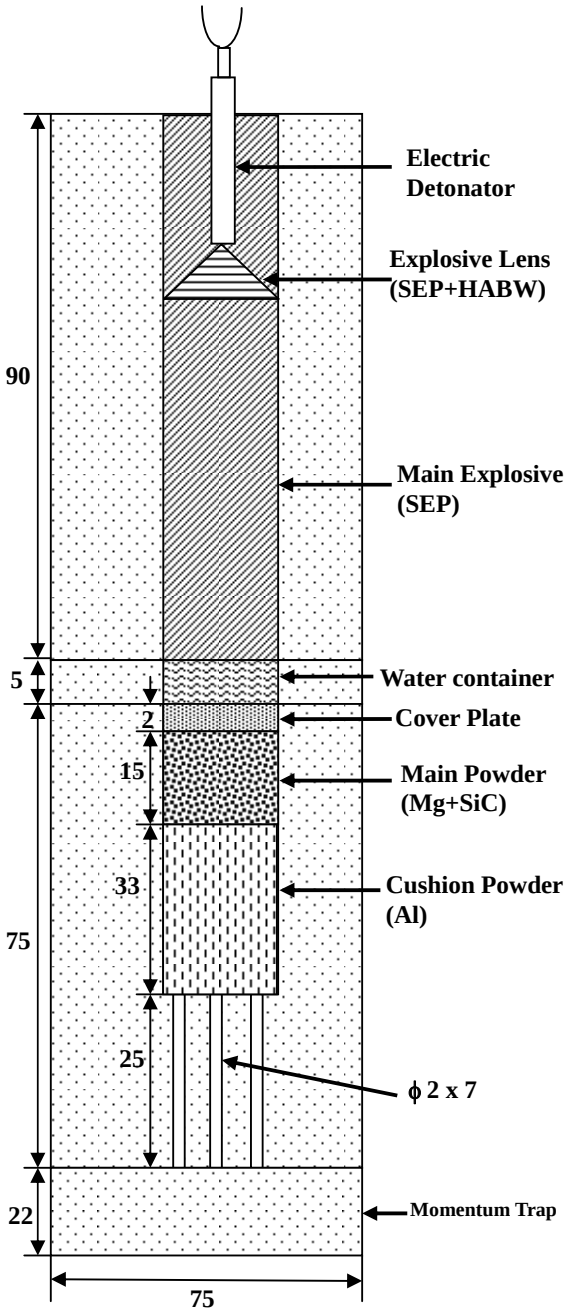


Fig 1. Schematic illustration of under water shock compaction

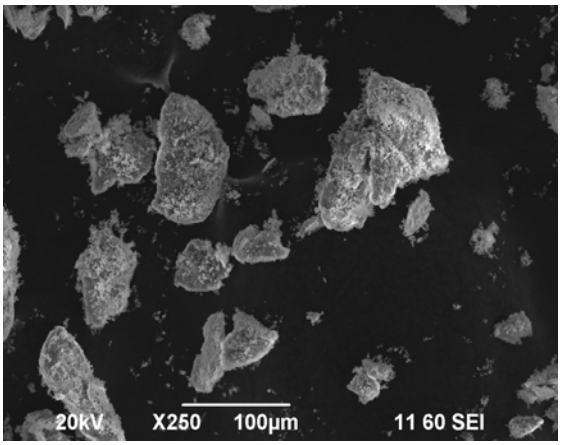
was stored;(iii) the powder mix region where the mixed powder were stacked. The detonation of an explosive by an electric detonator generates a detonation wave. The detonation wave propagates from the top to the bottom of the explosive chamber. When the detonation wave impinges on the water, an underwater shock wave is generated in the water chamber. As the underwater shock wave travels straight through the water chamber and at last it interacts with the main powder container. By adjusting the mass and the detonation velocity of the explosive shock pressure and shock duration can be controlled.

The containers are unusable following shock compaction. The shock waves generated using a planar

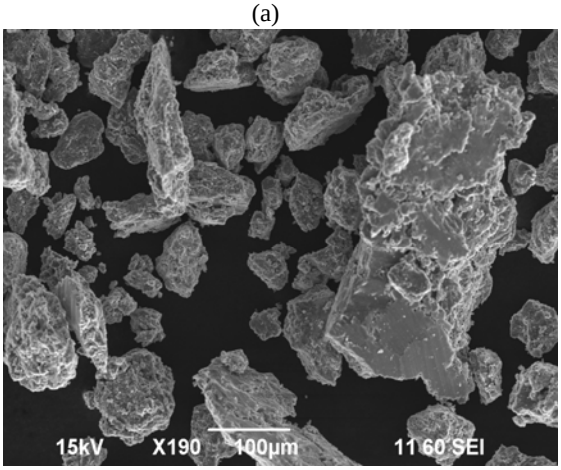
impact system by the use of an explosive lens [5], which was made, by the use of two explosive, SEP and HABW (both of Asahi-Kasei Corp., Japan; detonation velocity: 6.97 and 4.75 km/s, density: 1310 and 2200 kg/m^3. respectively) were uniform applied on the blend. Changing the water column can change the shock pulse. Three- layered stacking arrangement [6] was adopted for the easy recovery of the sample. In order to take out the compacts from the powder containers machining was done. After obtaining the specimens, some of their properties were measured and the cross-sectional areas of the samples were analyzed by scanning electron microscope (SEM) and optical microscope.

3. RESULTS AND DISCUSSION

High-energy mechanical milling was used for the uniform distribution of the magnesium and SiC powder mixing. The effect of milling time and milling speed are taken into account in the case of this experiment. In the case, when the milling speed is 100 rpm the particle size are small and homogeneous with the increase of the milling time of 36 ks and 54 ks, respectively. We used two balls to powder ratio, which are 10:1 and 20:1, respectively.



(a)



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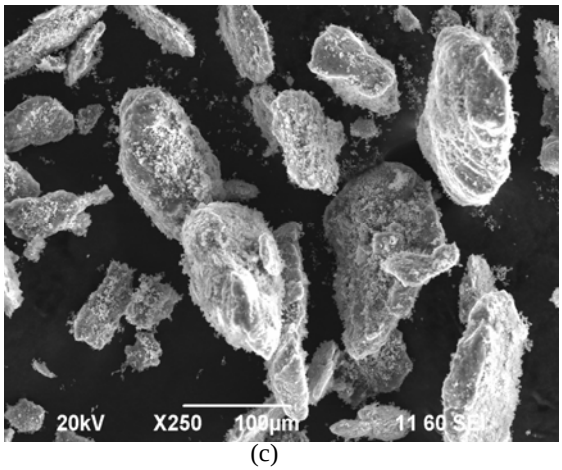

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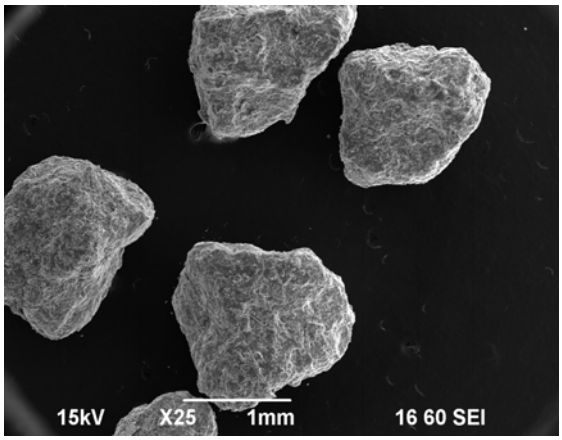
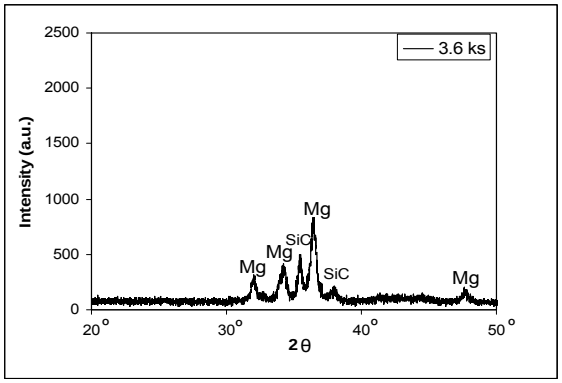


(d)

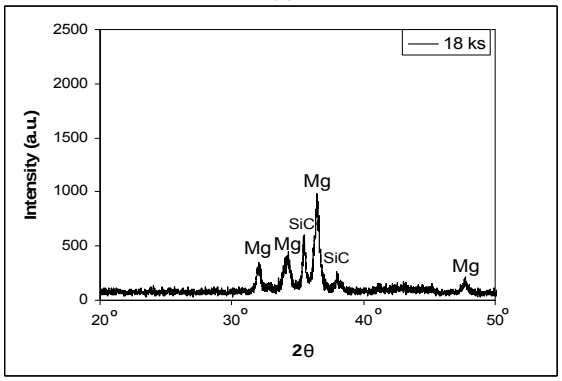
Fig 2. SEM micrographs of different particle morphologies of magnesium and silicon carbide powders in 54 ks mixing: a) 100 rpm b) 150 rpm (10:1 BPR) and c) 100 rpm d) 150 rpm (20:1 BPR).

The results of the SEM studies conducted on the Mg/SiC specimens revealed the existence of a completely recrystallised matrix. The presence of the porosity was minimal and the distribution of SiC particulate was fairly uniform. The interfacial integrity between SiC reinforcement and Mg matrix was found to be good in the case of 100 rpm specimens (Fig. 2(a), the other (Fig. 2 (c)) investigated in the present study. But in case of 150 rpm the particle size was not uniform and homogeneous. The particle become big and agglomeration were seen. The powder taken from the container of the ball mill was difficult because of powder sticking on the container. Where as, it was easy to take mixed powder in 100 rpm.

Fig. 3. shows there is no change of phase in the X-ray patterns of the mixed powder for the composite. It is known that mechanical milling reduces the particle size and creates a large surface area of the particle.



(a)



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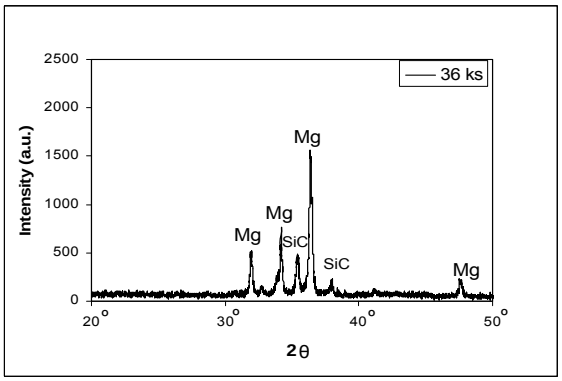

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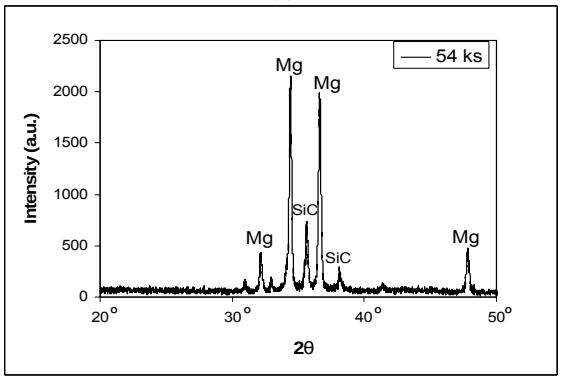

(d)

Fig 3. XRD spectra of mechanically milled 70 mass% Mg and 30 mass% SiC powders at different milling duration (a) 3.6 ks, (b) 18 ks, (c) 36 ks and (d) 54 ks (Cu-K_α).

In the case of 100 rpm in 20:1 BPR it has been observed that the particle size has been reducing and creates large surface area with the increase of milling duration. From the observation of the XRD the picks are increase with increase of the milling hours. That is a clear evidence of reduction of the particle size. There was no intermetallic compound formation.

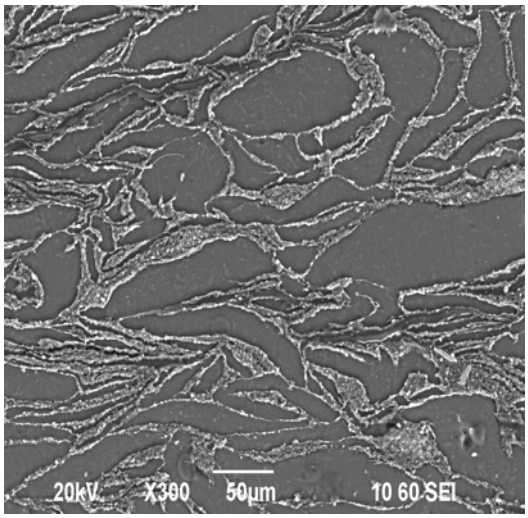

Fig 4. SEM micrographs of the magnesium and silicon carbide composites after compaction.

After shock wave deployed to the mixed powder with pressure the plastic flow of magnesium particles in the extrusion direction is disrupted by the interaction with SiC, which showed from the Fig. 4. As magnesium is softer than the ceramic, magnesium particle have to flow around the particles, changing the initial orientation. For highly elongated particles, it can be observed that the flow lines deviate from the original orientation near the particles.

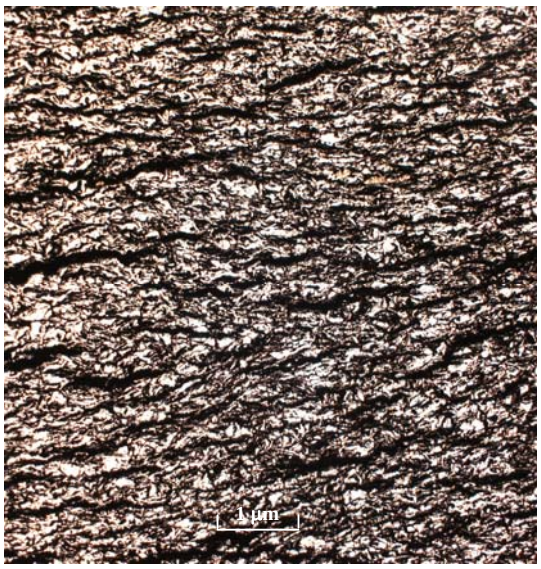

Fig 5. Optical micrograph of the recovered sample.

The experiment on 20:1, 100 rpm and 10:1, 100 rpm was recovered and the other experiment was not recovered. The microstructure of the recovered sample is shown in Fig. 5. In general, a homogeneous distribution of the particles was observed.

4. CONCLUSION

By using high-energy ball milling of the mixture of powders, SiC particle reinforced 70 mass% Mg- 30 mass% SiC composite powder can be obtained. From the microstructure characterization, it has been observed that with the increase of the milling speed Mg powder become very reactive. In this respect, 100 rpm is the best milling speed than all other milling speed. The particle become very sticky to the container and recovery process were very difficult in the case of 150 and 250 rpm. Uniform distribution of the Mg and SiC reinforcement can be obtained with 100 rpm milling speed. From the XRD we found that there were no intermetallic compound formation and with the increase of milling hours in the case of 100 rpm particle size become reduced. So, we were chosen the best condition 100 rpm, 54 ks, 20:1 BPR and 70 mass% Mg- 30 mass% SiC for shock compaction. With this milled powder, composites were made in a microsecond with under water shock wave methods.

5. REFERENCES

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6. NOMENCLATURE

Symbol	Meaning	Unit
rpm	Revolution Per Minute	(r/min)
BPR	Ball to Powder Ratio	(mg/mg)

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