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Influence of Peening Intensity on Surface Layer Properties, Residual Stress and Hardness Performance of Al7075/10%/SiCp Metal Matrix Composite

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ABSTRACT

The surface modification is one of the most prominent phenomenon to change properties of alloys and composites as desired for typical use. Among mechanical approaches, shot peening (SP) has novelty for enhancement of mechanical properties. This has eco-friendliness, relatively low cost and minimum geometrical restrictions especially in case of metal matrix composites. This study appraises the effect of shot peening on mechanical properties of Al7075/10%/SiCp Metal Matrix Composite (MMC). This composite was successfully synthesized via stir casting route and shot peened with different peening intensities along with other parameters remains same and studied in terms of morphological and structural features, grain size, residual stresses and microhardness. The results indicated that the depth of the projectile indentations increased and the surface roughness became larger with increasing SP intensity. The compressive residual stress field was introduced after shot peening. The observation by scanning electron microscopy (SEM), the average domain size decreased, moreover the microhardness and depth of the strengthened layer increased with the increased peening intensity. This investigation can prove that the effects of SP on the Al7075/10%/SiCp metal matrix composite were distinct.

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1. Introduction

Discontinuous reinforcements in the form of whiskers, platelets and ceramic particles are used in the aluminum matrix composites, which are very familiar materials and are mostly used in the case of aerospace and structural applications. These are very useful with their increased mechanical and surface properties, compared to non-reinforced metallic matrices. This improvement obtained without increasing in weight and having higher strength to weight ratio. Moreover, surface characteristics such as microstructure, phase transformation, residual stress and microhardness are

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strived to play a vital role in raising needful responses from the surrounding biological improvement Wong *et al*., [1]. The surface modification can be done with different methods, but shot peening is one of such methods which is yielding good results with cheaper expenses. Shot peening is a cold working process, in which the surface of a component is bombarded with small spherical media called shots Gao *et al*., [2], which is used to induce residual compressive stresses in sub-surfaces of solid materials [3-5]. The instant result of bombarding high intensity shots onto a metallic substrate is the formation of a thin layer of high magnitude residual compressive stress at or near the metal surface, which is well-adjusted by a minor tensile stress in the deeper core, as shown in Figure 1. Once a distinct particles of shot media with high velocity stream, which is in contact with metal surface could produce light and rounded indents in the surface of metal, widening it radially and initiating plastic flow of surface metal at the direct contact. Moreover, leads to induction of compressive stresses and relieves tensile stresses and also improves fatigue life of the surface Kulekci *et al*., [6].

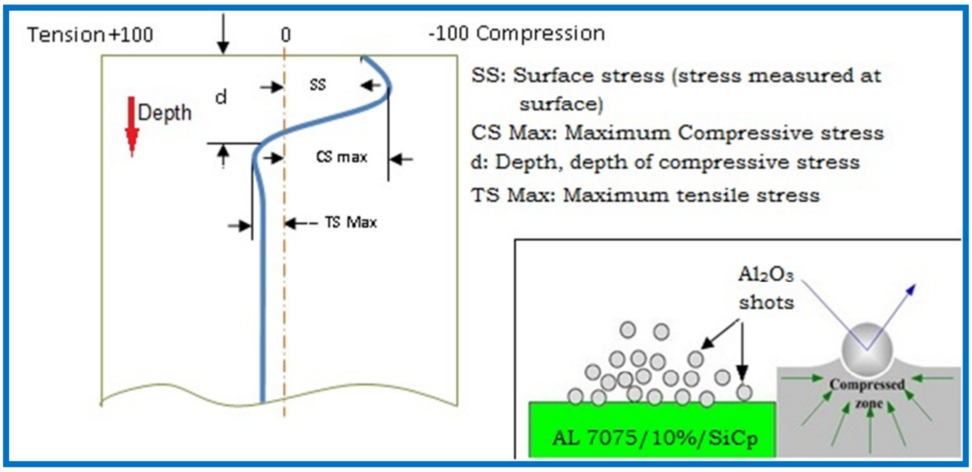

Fig. 1. Example of residual stress profile created by shot peening

Several authors reported that, the benefits of shot peening technique may not only in aluminum MMCs, and also in many other materials. For understanding, following are the literature evidences viz., the surface severe plastic deformation by shot peening of 304L and 310S steels carried out with different shot peening parameters and improved very fine nanostructure at top surfaces of both materials after peening at cryogenic temperature, results found through various characterization techniques Novelli *et al.*, [7]. Shot peening treatment has been applied on TiB2/6351 Al alloy and various factors considered and controlled to achieve better surface mechanical properties of TiB2/6351 Al alloy Luan *et al*., [8].

This paper explains the use of the conventional shot peening on Al7075/10%/SiCp metal matrix composite (MMC). The study have been made to observe, the influence of shot peening in creation of residual compressive stress, micro hardness, grain refinement and surface roughness were analyzed with the help of various measuring instruments on peened specimens. The treated surface has been observed via scanning electron microscopy (SEM) for surface topography. Observed that, the shot peening has a significant role in improving mechanical properties in the Al7075/10%/SiCp metal matrix composite.

2. Experimentation

In this study, aluminum alloy (Al7075) is used as matrix metal for the fabrication of the composite, which has been reinforced with 10 wt. % of Silicon Carbide particles (SiCp) of average 53 µm size. This composite was fabricated via stir casting route, because it is the best and low cost method for producing the MMC materials Shivanand *et al.*, [9]. Figure 2(a) depicts the set up for fabrication of Composite and steel die for cast composite and 2(b) surface images of un-peened (base) and shot peened specimens.

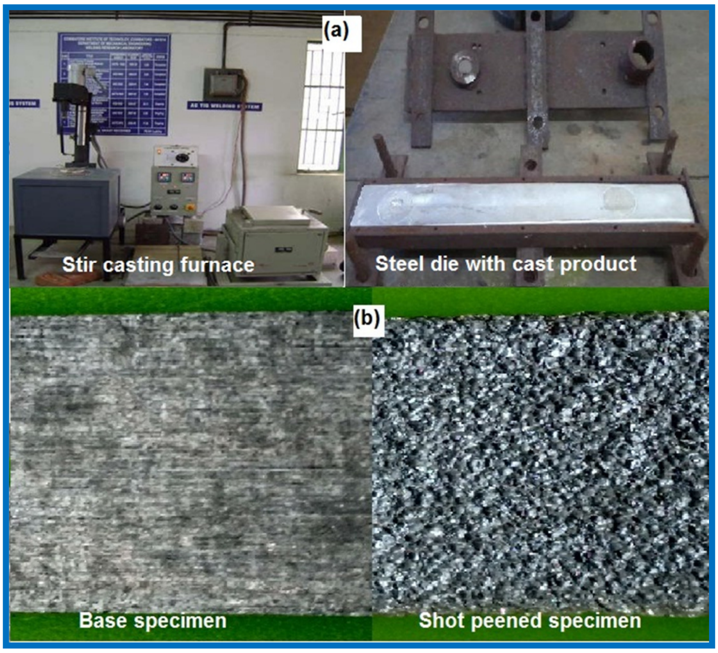

Fig. 2 (a)Schematic of MMC fabrication, (b)Base and shot peened surfaces of specimens

The specimens for shot peening were prepared by using wire electric discharge machining (WEDM), all specimens were cut with the dimensions of (50 × 10 × 5) mm for shot peening in the next stage. Shot peening was performed according to the MIL-13165 standard with peening parameters such as, peening pressure: 3.5 bar, peening intensity (mmA): 0.15, 0.3 and 0.5, type of shot: Al_2O_3 ceramic shots, diameter of shot: 0.25 mm, stand-off: 150 mm, duration of peening: 30 min. and coverage 100 %.

All these specimens were tested for various outcomes such as, hardness values were measured by using, MVD-402TS-Level-2 microhardness measuring system HNDS Kelly Instruments, china Expert. Hardness tests carried out with Diamond indenter of 500 g load for dwelling time of 15 sec. Ervina *et al*. [10] prefferred10 kgf load, which was then applied and followed by pressing of diamond pyramid into the flat surface of the specimen for a duration of 15 s. Surface roughness was calibrated by Mitutoyo Surface Roughness tester (SJ-201P). The surface topography has been observed by using scanning electron microscope (CarlZeiss model EVO MAIS at S. V. University).

3. Results and discussion

3.1 Surface Roughness

The surface roughness was measured by using Mitutoyo Surface Roughness tester (SJ-201P). The table 1 illustrates the values of surface roughness after shot peening, the surface roughness of peened specimens with three peening intensities have difference of approximately 1 μm only. Moreover, 0.5 mmA intensity created little bit higher roughness than others. The surface roughness is directly proportional to the peening intensity in three specimens. It is well known with reference, getting high surface roughness with increasing peening intensity leads to nucleation and early propagation in micro-cracks, which make damage for fatigue life of components Curtis *et al*., [11]. In the case of shot peened titanium implants, rough surfaces typically result in good clinical outcome because of good osseointegration between the bone and implant, when compared to smooth surfaced implants Ganesh *et al*. [12].

Hence, 0.15 mmA intensity is optimized for Al7075/10%/SiC_p specimens in order to obtain appropriate results. Also depths of the projectile indentation increased and the surface roughness became larger with increasing SP intensity. The surface roughness can be minimize by providing re-peening, which is accomplished with smaller and harder shots, but it is expensive. Smooth and uniform surface as the increasing the annealing temperature was reported, when done research on Annealing heat treatment of Poly(triarylamine) (PTAA) thin films deposited using spin coating by Kellie *et al*., [13].

Table 1
Surface roughness of specimens with different peening intensities in conventional shot peening

Peening intensity, mmA	0.15	0.3	0.5
Roughness, μm	1.29	2.47	3.64

3.2 Residual Stress Field

The residual stress distribution along depth direction due to different peening intensities is depicted in Fig. 3. It was very clear that, with increasing the shot peening intensity, the kinetic energy of the projectiles have been increased, and lastly the depth of compressive residual stress also increased. The values of surface residual stress is nearly remain same with constant value of about –55 MPa has shown.

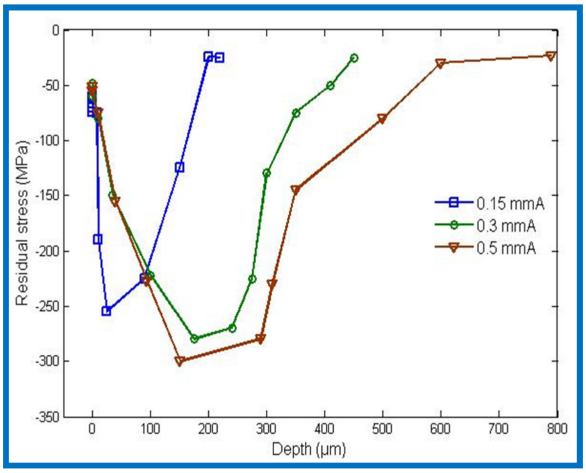

Fig. 3. Influence of three different shot peening intensities on the distribution of the CRS specimens

The maximum depth of compressive residual stress under the following conditions of 0.15 mmA, 0.3 mmA, and 0.5 mmA peing intensities, are about 230 μm, 450 μm, and 790 μm, respectively. From the experimental results, it can be identified that the shot peening intensity can improve the consistency of residual stress distribution from the surface of tested specimens. Moreover, the high shot peening intensity has predominant role in creation of great amount of residual stress in these Al7075/10%/SiC_p specimens and also induction of deeper residual compressive stress took place due to 0.5 mmA peening intensity compared to 0.3 mmA peening intensity.

During this shot peening process, the development of surface roughness occurred simultaneously as mentioned above, which is common phenomena in most of the materials, and forming crest and trough combination over the surface of specimens. Moreover, a huge quantity of kinetic energy due to high intensity converted into the plastic deformation energy of the deformed layer at the substrate. The depth of deformed layer was deeper and maximum residual stress increased as shown with 0.5 mmA line.

3.3 Microhardness

Hardness is defined as resistance of a material to localized deformation by Ahmad and Jamaluddin [14]. After shot peening, microhardness measurements reveals that there is a considerable improvement in hardness at substrate layer. Figure 4 shows the distribution of hardness along the depth direction of the peened specimens due to different peening intensities. The microhardness of specimens have been increased to the maximum value by the shot peening, which was maximum at the top surface and value was gradually decreased along depth direction from the surface.

At the top surface, the microhardness under the following conditions of 0.15 mmA, 0.3 mmA, and 0.5 mmA peeing intensities, are about 190 HV, 225 HV, and 240 HV respectively, which are approximately 50% higher than the values at 350 µm depth. Of course, it is also possible to enhance the hardness in the composite with more volume fraction of reinforcements, but it could lead to weight gain and also it takes place in the entire volume of the composite, instead of at the surface. Moreover, too much volume fraction will also result in decreasing the composite properties, finally leads to poor bonding and voids development at the interface between matrix and reinforcement.

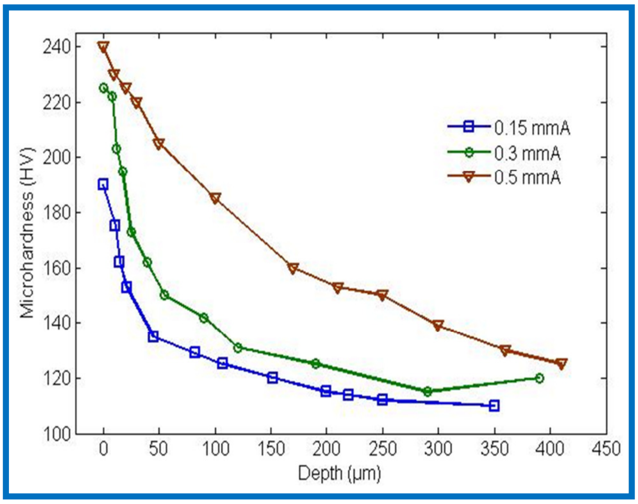

Fig. 4. Distribution of the microhardness in the surface layers after SP with different SP intensities

Shot peening is an important treatment for work-hardening, which creates refinement in domain sizes and leads to high density dislocations [15,16]. After shot peening, the high dislocation density has created at the substrate and domain sizes were refined. Moreover, in this shot peening process, the reinforcements hinder the dislocation movements, which results in the hard substrate layers of Al7075/10%/SiC_p specimens.

3.4 Gran Size

Plastic deformation caused by residual stress into the near surface layer after shot peening treatments can modify the surface microstructure Lindemann *et al.*, [17]. To investigate the microstructure variation, Figure 5 shows the scanning electron microscope image of the near surface layers of shot peened specimen without accomplishing any polishing methods. The particle size of SiCp particulate, become fine in the surface layer of peened Al7075/10%/SiC_p metal matrix composite specimen, which is caused due to large number of shots. Figure 5 also composed of partially continuous dents, which conforms that large crystalline grains have been broken down into nano-grains have been observed from the illustrated image.

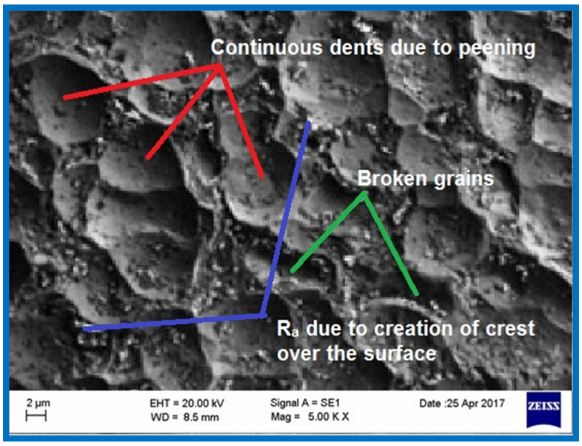

Fig. 5. Surface topography in Al7075/10%/SiC_p Metal Matrix Composite after shot peening (SEM)

4. Conclusions

The Influence of Peening intensity on surface layer properties, residual stress and hardness performance of Al7075/10%/SiC_p Metal Matrix Composite after shot peening, has been studied. The essential inventions are:

- Shot peening increases surface roughness, it is increased with increased shot peening intensity, which were exhibited as with 0.15, 0.3 and 0.5 mmA intensities the corresponding roughness were 1.29, 2.47 and 3.64 µm respectively. Moreover, here 0.15 mmA intensity has chosen for optimum surface roughness than other two intensities.
- The specimens have been induced by compressive residual stress on substrate layer of specimen after shot peening, the deeper residual compressive stresses obtained with 0.5 mmA intensity, and its value was approximately 220% higher than the value obtained by 0.15 mmA intensity, and 77% higher than the value obtained by 0.3 mmA intensity.

- Hardness in the peened specimens of Al7075/10%/SiCp metal matrix composite improved with shot peening due to change in compressive residual stress, and also due to decrease in domain size at substrate.
- The domain size of Al7075/10%/SiC_p decreased with increasing of shot peening intensity. The decreased domain size is at substrate, which further leads to improve microhardness at the top surface attains the peek values.

Shot peening has consistency in surface modification of alloys in improving several mechanical and microstructural properties since many decades. In present composite world, shot peening has its significance in altering the properties of composites. Moreover, it is treated as cost-effective, non- time consuming method with superior benefits in alloys and in composites, and its hypothesis of improving strength accepted by many researchers.

References

[1] Wong, Joyce Y., Jennie B. Leach, and Xin Q. Brown. "Balance of chemistry, topography, and mechanics at the cell–biomaterial interface: issues and challenges for assessing the role of substrate mechanics on cell response." *Surface Science* 570, no. 1 (2004): 119-133.

[2] Gao, Yu-Kui, Mei Yao, and Jin-kui Li. "An analysis of residual stress fields caused by shot peening." *Metallurgical and Materials Transactions A* 33, no. 6 (2002): 1775-1778.

[3] Kawagoishi, N., T. Nagano, M. Moriyama, and E. Kondo. "Improvement of fatigue strength of maraging steel by shot peening." *Materials and Manufacturing Processes* 24, no. 12 (2009): 1431-1435.

[4] Harada, Yasunori, and Kenzo Fukaura. "Influence of shot peening on surface characteristics of high-speed steels." *International Journal of Modern Physics B* 22, no. 31n32 (2008): 6094-6099.

[5] Khun, N. W., P. Q. Trung, and D. L. Butler. "Mechanical and Tribological Properties of Shot-Peened SAE 1070 Steel." *Tribology Transactions* 59, no. 5 (2016): 932-943.

[6] Kulekci, Mustafa Kemal, and Ugur Esme. "Critical analysis of processes and apparatus for industrial surface peening technologies." *The International Journal of Advanced Manufacturing Technology* 74, no. 9-12 (2014): 1551-1565.

[7] Novelli, Marc, Jean-Jacques Fundenberger, Philippe Bocher, and Thierry Grosdidier. "On the effectiveness of surface severe plastic deformation by shot peening at cryogenic temperature." *Applied Surface Science* 389 (2016): 1169-1174.

[8] Luan, Weizhi, Chuanhai Jiang, Haowei Wang, Julien Panardie, and Dong Chen. "XRD investigation of thermostability of TiB 2/Al deformation layer introduced by shot peening." *Materials Science and Engineering: A* 480, no. 1 (2008): 1-4.

[9] Shivanand, H. K., Mahagundappa M. Benal, S. C. Sharma, and N. Govindraju. "Comparative studies on mechanical properties of aluminium based hybrid composites cast by liquid melt technique and P/M route." *Materials Processing for Properties and Performance* 3 (2004): 57-60.

[10] Efzan, MN Ervina, S. Kesahvanveraragu, and J. Emerson. "Microstructural Characterization and Hardness Properties of A333 Grade 6 Low Carbon Steel in Offshore Platform Pipelines." *system* 2, no. 11 (2014): 15.

[11] Curtis, S., E. R. De los Rios, C. A. Rodopoulos, and A. Levers. "Analysis of the effects of controlled shot peening on fatigue damage of high strength aluminium alloys." *International journal of fatigue* 25, no. 1 (2003): 59-66.

[12] Ganesh, B. K. C., N. Ramanaih, and PV Chandrasekhar Rao. "Dry sliding wear behavior of Ti–6Al–4V implant alloy subjected to various surface treatments." *Transactions of the Indian Institute of Metals* 65, no. 5 (2012): 425-434.

[13] Kellie Miandal, Khairul Anuar Mohamad, Afishah Alias. "Annealing heat treatment of Poly (triarylamine) (PTAA) thin films deposited using spin coating." *Journal of Advanced Research in Materials Science* 26, no. 1 (2016): 7-12.

[14] Ahmad Fuad Ab Ghani, Jamaluddin Mahmud. "A description on deformation and failure of hybrid composite under static loading." *Journal of Advanced Research in Materials Science* 36, no. 1 (2017): 21-27.

[15] Luan, Weizhi, Chuanhai Jiang, Vincent Ji, Yanhua Chen, and Haowei Wang. "Investigation for warm peening of TiB 2/Al composite using X-ray diffraction." *Materials Science and Engineering: A* 497, no. 1 (2008): 374-377.

[16] Luan, Weizhi, Chuanhai Jiang, Haowei Wang, Julien Panardie, and Dong Chen. "XRD investigation of thermostability of TiB 2/Al deformation layer introduced by shot peening." *Materials Science and Engineering: A* 480, no. 1 (2008): 1-4.

[17] Lindemann, Janny, Cesar Buque, and Fritz Appel. "Effect of shot peening on fatigue performance of a lamellar titanium aluminide alloy." *Acta Materialia* 54, no. 4 (2006): 1155-1164.