Microstructural characterization and hardness properties of magnesium alloy processed by high pressure torsion.

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Abstract— ***Magnesium and magnesium alloys are the lightest of all metal used for structural construction. This property of magnesium made it to be the most used material in the automobile manufacturing industries and in aerospace as well as in other industries. This research is based on the process improvement of pure commensally magnesium alloy (Mg 99.94%) using high pressure torsion (HPT) process. The investigation was based on the measurement of hardness properties and microstructural characterization of magnesium alloy processed by high pressure torsion (HPT).***

Keywords— High pressure torsion; pure magnesium; grain refinement; microstructure; micro-hardness;

I. INTRODUCTION

Magnesium is lightest material that have been discovered over two centuries it has mechanical properties that are so great in such a way that it has become the most used material in automotive and aerospace industries. In the twenty first century magnesium and magnesium based alloys have been attractive to the designers due to their great properties such as low density, and this has been a main issue in the extensive use of magnesium alloy castings and wrought products as well as other processing methods [1]. The use of magnesium has been growing over the time as the standard of technology grows. The application of magnesium and its alloys in many industries has change the standard of manufacturing process and production of engineering materials. Engineering materials are produced to used or serve a particular purpose in a structure or component. Engineering materials are produced or manufacture in such a way that are strong, lightweight, ductile or brittle, corrosion resistance and other properties that suit the required purpose of material. This report focus more the processing of magnesium alloy by high pressure torsion (HPT).

Magnesium alloy (Mg 99.94% pure commercially) is one of the engineering material that is classified as non-ferrous metal [2]. Is produced and alloyed so that it contains good damping capacity, effective for high-speed applications and dent resistant. Magnesium alloy is a light weight material with superior machinability as well as its ability to be casted easy. This property makes magnesium alloy to be good material to use for structural in high-speed and application products. But it is not good enough without high strength and toughness properties. For magnesium alloy to be strengthen several processes such as high-pressure torsion (HPT), severe plastic deformation (SPD) and equal-channel angular pressing (ECAP). High pressure torsion (HPT) is the process that will been looking at as used to process magnesium alloy (Mg 99.94%). High pressure torsion (HPT) is a modern method of severe plastic deformation (SPD) technique that is used to refine grain size of material (metals). It uses high pressure and torsion to process material. HPT has been used to evaluate mechanical properties of material alloys and their microstructural characteristics [3]. In this report HPT process will be investigated. This report is based on the effect of HPT on magnesium alloy (Mg 99.94%). This report is mainly based on the investigation of measurement of hardness properties and microstructural characterization of magnesium alloy (Mg 99.94%) processed by high pressure torsion HPT. The aim of this research work is to improve these properties and strengthen magnesium alloy (Mg 99.94%), HPT) was used to process Mg 99.94% alloy and microstructure characteristics and hardness properties was examined.

II. EXPERIMENTAL TECHNIQUES

The material used in this investigation was commercial purity magnesium 99.94 % with no extrusion. For HPT processing, a rod with diameters of about 9.6-9.8 mm is used, since the HPT facility used has two massive anvils each machined with a central depression having a diameter of 10mm and a depth of 0.25mm ,the rod is sliced into disks having thicknesses of ~1.5 - 2.0 mm, then ground carefully to give a series of HPT disk samples with smooth surface and a uniform thickness of thicknesses of 0.79-0.80 mm. the specimen were processed for 0.5 , 1, 5, 10, 20 numbers of turns under 6.0 GPa at room temperature with a rotary speed of 1 rpm.

Microstructural observations and quantitative evaluations of the samples were examined before and after processing using Digital optical microscopy (OM). For the OM the processed discs were mounted in cold resin and ground with abrasive paper. Both sides of the disk surface were polished using abrasive papers (180 to ~4000) without using cloth-polishing to give a series of HPT disk samples having final thicknesses of 0.79-0.80 mm. since some of the materials may be oxidized during polishing, ethanol is used when you polish the sample with abrasive papers of #2000-4000. An acetic-picral solution with chemical composition of 4.2 g picric acid, 70 mL ethanol, 20 mL of distilled water and 10 mL of acetic acid was used to etch and reveal the grain boundaries. The grain sizes were measured using the linear intercept method.

Micro-hardness tests were carried out on the surface areas of processed samples after HPT at different turns to obtain detailed information on the hardness evolution during the HPT processing. all samples were polished to a depth of about 0.1 mm from the original surface prior to the tests to achieve mirror-like surface. The Vickers micro-hardness values, Hv, were obtained at room temperature utilizing an FM-1e micro-hardness instrument equipped with a Vickers indenter. Tests were conducted under a load of 50gf with a dwell time of 10 s for each separate measurement. Also, the individual selected points were separated from each other by incremental distances of 0.3mm. A detailed description of the hardness procedure was given earlier in [29].

III. RESULTS AND DISCUSSION

Micro structure

Microstructures evolution after processing by HPT

After HPT processing under an applied pressure of 6.0 GPa through 1, 5 , 10 and 20 turns, microstructural observations were taken at the disc centres and at the edge positions of each disc.

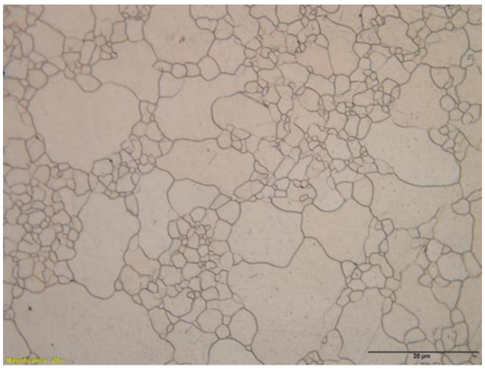
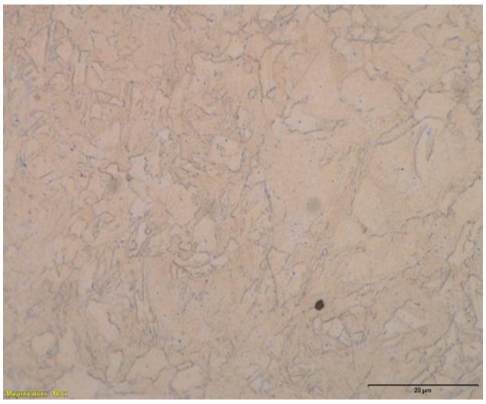
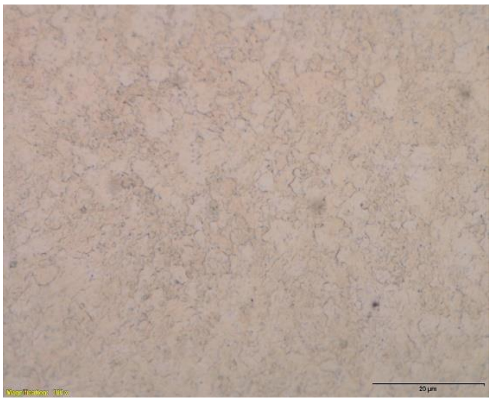


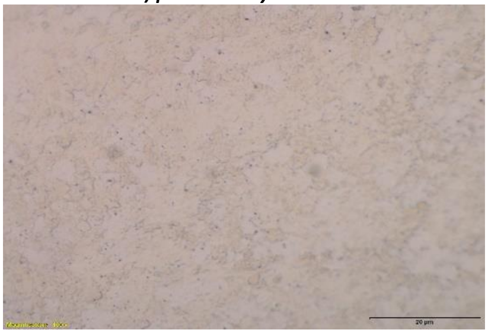
Fig.1. Shows the image of grain geometry for magnesium alloy.



Figs. 2 Shows the image of grain geometry for magnesium alloy (Mg 99, 94%) processed by HPT at N=1.



Figs. 3 ***Shows the image of grain geometry for magnesium alloy (Mg 99, 94%) processed by HPT at N=5.***

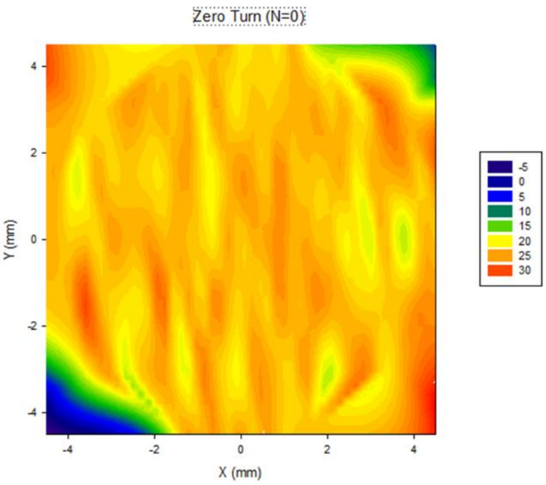


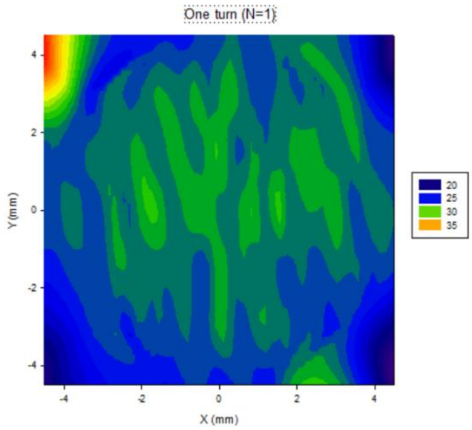
Figs. 4: Shows the image of grain geometry for magnesium alloy (Mg 99, 94%) processed by HPT at N=10.

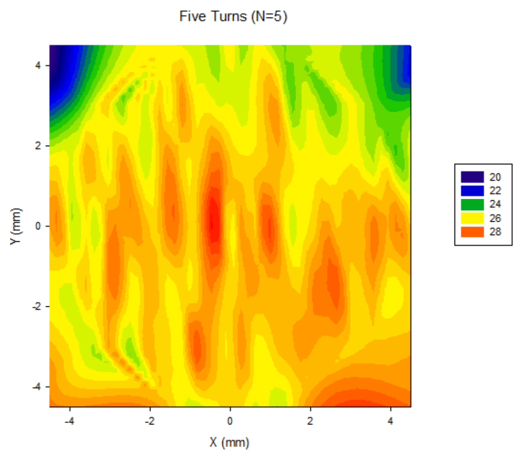
Table 1 average grain size.

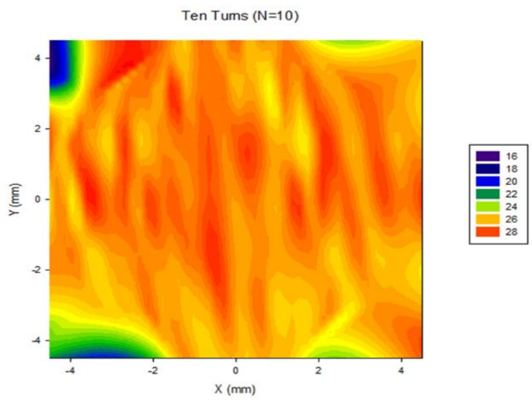
Number of Turns	Average grain size (mean) (μm)
0	149,8785
1	89,17302
5	56,2162
10	27,12055
20	17,29696

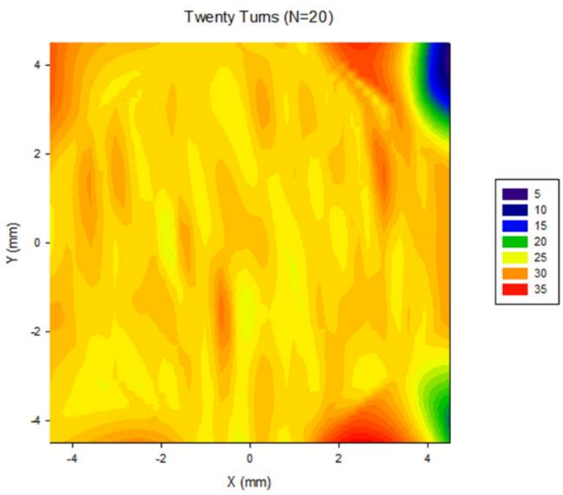
Figure 6 shows the microhardness (Hv) versus the distance from the centre of the disc for all the process of pure magensium after HPT processing under an applied pressure of 6.0 GPa through 0.5 , 1, 5 , 10 and 20 turns, the lower dashed line at Hv ~ 40 shows the initial hardness in the commercial purity magnesium material without HPT processing.











IV. CONCLUSIONS

1. A pure Mg (99.94%) was satisfactorily processed by High Pressure Torsion at room temperature under pressure of 6.0 GPa by reduced the grain size.
2. It is shown that there are variations in the grain size distributions and these observations demonstrate that the deformation is not homogeneous in the through-thickness direction during HPT.
3. Measurements of the Vickers microhardness, were recorded across the diameters of each disk and on polished surfaces, the results show the hardness distributions depend upon both the numbers of turns and It is shown from micro-hardness measurements that reasonable levels of hardness homogeneity is achieved in 99.94 % magnesium after 5 and 10 turns of HPT and slightly decrease after 20 turns.

V. ACKNOWLEDGEMENT

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