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Review Multi Pass Friction Stir Processing

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Abstract

The aim of this article is to provide a review of multiple passes friction stir processing technology and their effect on the microstructure refinement, improving mechanical properties furthermore enhancement of reducing distortion and defects in materials. Multi-pass FSP achieves uniform dispersion of reinforcement particles in the metal matrix composites. The present paper reviews the work done in the above mentioned areas and concludes the effect of multi-pass FSP on the mechanical properties.

Keywords: Multi; Pass; FSP.

1. Introduction

In the recent years, Metal Matrix Composites (MMCs are used to replace conventional materials for practical engineering applications such as those in the aerospace, transportation, defense and sports industries because of their superior properties. Friction stir processing (FSP) is a new solid-state technique, which uses the principles of friction stir welding for aluminum alloys [1] to process materials, furthermore fabricating surface composite.

In Friction Stir Processing (FSP) a non-consumable rotating tool with a pin probe and a shoulder is conducted to the metal surface and travel along the path to be processed. Due to interfacial friction between the rotating tool and the workpiece Localized, heating is generated. The tool probe and shoulder produces heat, which softens the material under its melting point. In FSP, the rotating tool pin has a different design according to types of processed base metal and other processing parameters.

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As the rotating tool travels along the workpiece, the material flows around the tool and is forged under the tool shoulder and causes with a new structural and mechanical condition[2,3] The mechanism of the process is schematically illustrated in Figure (1).

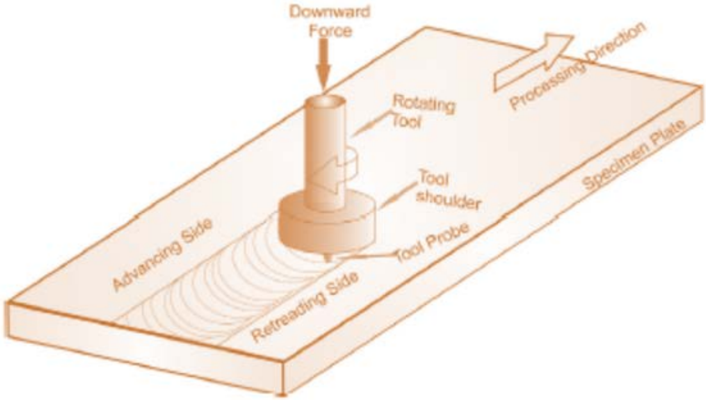

Figure 1: FSP Schematic illustration

2.1 Effect of Multi Passes FSP on Mechanical Properties

The effect of multi-pass FSP on the, microstructure, microhardness and tensile strength on the metal alloy and composites have been studied by many investigators. The importance of these additional passes is to improve the mechanical properties and obtain a fine and homogenous distribution of the reinforcement particles in the metal matrix composites.

2.1.1 Effect of Multi-Pass FSP on Tensile Strength

Multiple friction stir welding passes investigated using [4] the author noted that at the nugget center grain microstructure resultant from the first pass was appeared to be similar in all other applied passes, also the hardness have been increased after FSW but all the value were at the same range in all passes which have been performed. Tensile properties, yield strength, and elongation to fracture, all slightly decreased with increasing number of passes as shown in figure (2). The maximum strength and elongation achieved in fourth-pass FSPed composite showed increases over the as-cast condition.

multi-pass with even step (2, 4 up to 8-pass) FSP with 100% overlap has been performed by [5]on in situ fabricated Cu/SiC composite by FSP to study the effect of number of FSP passes on the mechanical properties such as, tensile, hardness and microstructure. The results concluded that multi-pass FSP were improved tensile properties of composites including UTS and ductility. The authors were reasoned this improvement because of reduced porosity contents and enhanced bonding between SiC particles and copper matrix.

the investigators [6] fabricated 4.5 vol. % CNT/2009Al by a combination of Powder Metallurgy and FSP the researcher was study the effect of multi passes FSP on the mechanical properties for resultant matrix. It was observed that as the FSP passes increased, there was good dispersion for CNT in the matrix, and the maximum tensile strength increased with increasing the passes number as shown in figure (3). Although the multi-pass FSP improve the mechanical properties as reported in the previous investigators, the multi pass has insufficient elongation.

FSP for AA7075 alloy using multiple passes demonstrate that, the largest strain rate was obtained at single pass [7]. The influence of multi-pass FSP on the mechanical properties of Aluminum Alloy 6082 investigated by [8].The authors investigated that, increasing the number of FSP passes causes a dynamic recrystallization IN the stir zone and accumulated heat, which leading to increasing equiaxed grains size with high angle grain boundaries.

The effects of an overlapping multi-pass FSP with rapid cooling on the mechanical properties and microstructure of the AZ31 magnesium alloy has been studied [9]. The results showed that, overlap multi-pass FSP increased the grain distribution, furthermore the grain size decreased.

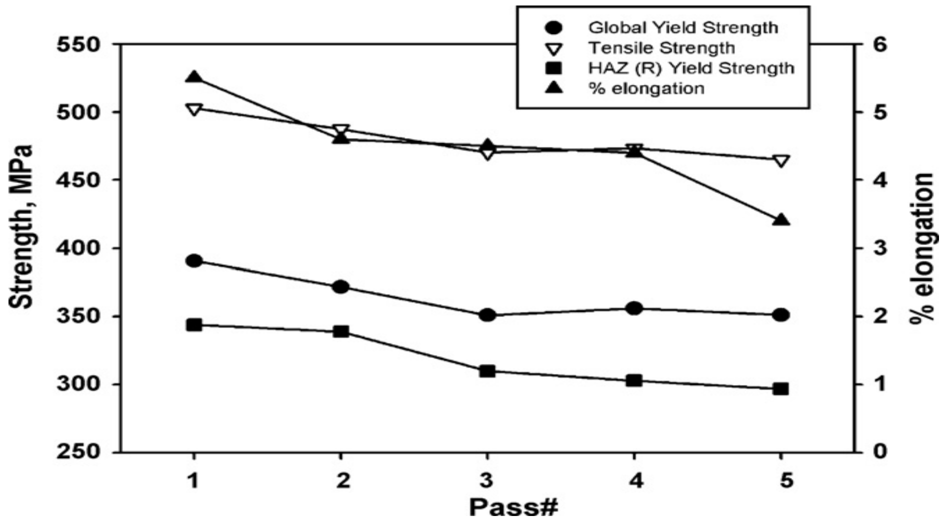

Figure 2: Tensile properties as a function of pass number.

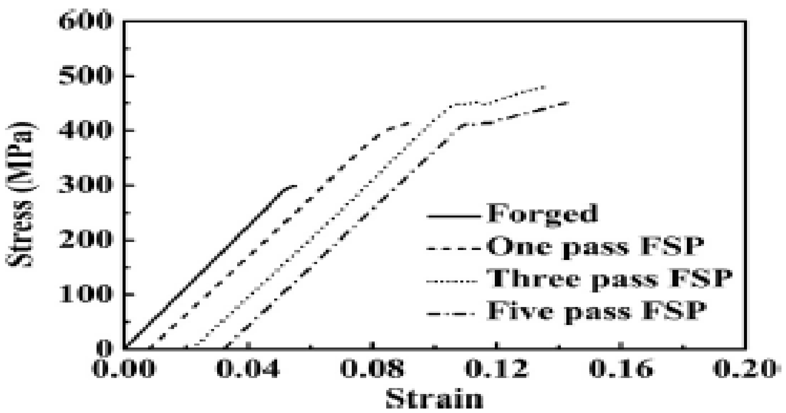

Figure 3: Tensile curves of 4.5 vol.% CNT/2009Al composites with different FSP passes.

This increased hardness ultimate tensile stress and reduced elongation more than for the overlap in one pass as shown in figure (4). The Multi-Passes Overlapping FSP of As-Cast NiAl Bronze was improved tensile properties compared to the BM, also results revealed multi-pass FSP did not effect on the elongation of the single-pass FSP samples [10].

2.1.2 Effect of Multi-Pass FSP on Microstructure

Multi-pass FSP have a great effect on the refinement of grain size. The effect of overlap multi-pass FSP on hypereutectic Al–30Si alloy, they reported that Increasing FSP passes decreased corrosion rate of alloy due to the reduction of grain and silicon particle sizes as well as an increase in homogeneity of microstructure [11].

Al_2O_3 particles have been reinforced AA6061 Al alloy fabricated using friction stir processing was investigated by [12]. An array of large numbers of cylindrical holes with dimension of 1 mm in diameter, 2 mm in depth were machined in a specific area worked as a groove to hold the Al_2O_3 particles. Multi pass of Fiction Stir Processing are subjected to the alloy. Figure (5) show the typical grain structures of the base material (a), the stirred zone without Al_2O_3 particle addition, after two passes FSP (b) and the stirred zone after the four passes FSP with Al_2O_3 particle addition (c). Significant increases in mechanical properties were obtained through the addition of Al_2O_3 particle with respect to the Al matrix in the same condition.

The effect of FSP passes number on the microstructure of the fabricated matrix, distribution of SiC nanoparticles, and mechanical properties of the stir zone has been carried out by [13] . The researchers revealed that, the Increase in FSP pass number does not have a significant effect on the stir zone of the specimen FSPed without reinforcement nanoparticles while FSPed with SiC nanoparticles, it can intensely affect the distribution of nanoparticles and then microstructural evolutions and mechanical properties of the stir zone. The elongations improved using multiple passes of AA7075 Al [7]. However, the grain sizes seem to be in the same range for the various passes performed in the study.

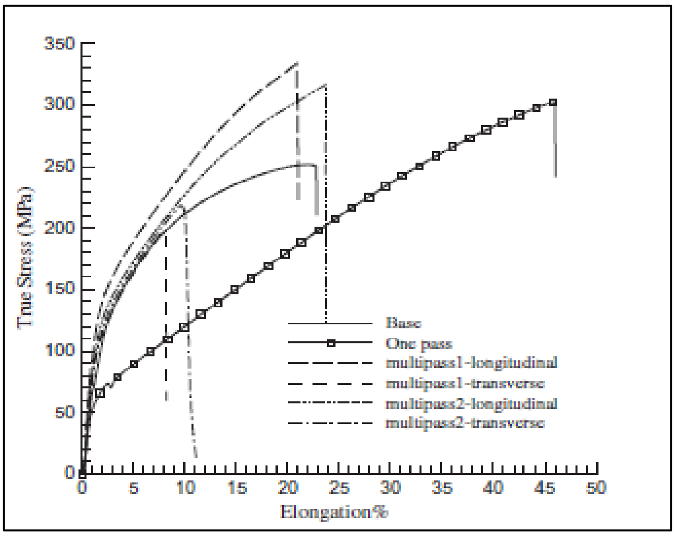

Figure 4: The stress–strain curves for multi- pass FSP for the collinear and perpendicular to the process directions

The effect of overlap multi-pass friction stir processing on the mechanical properties of Aluminum Alloy 6082 investigated by [8] . The relation between hardness and grain size is inversely in multi pass processing, where the increasing the number of passes led to an increase in the SZ-grain size also Increasing the traverse speed increases the mean hardness and UTS of the SZ as shown in figure (6).

Multi-pass friction stir processing have been carried out on commercial A356 alloy fabricated by adding inorganic salt K_2TiF_6 powder to forming 6 vol.% Al_3Ti/A356 compost. The microstructure and mechanical properties were improved as reported by [14].The authors have been concluded that Multi-pass FSP improved the distribution and dispersion of Al3Ti and Si particles, furthermore reduced their grain sizes, refinement the metal matrix grains, and eliminated cavities or porosity. Therefore, both the strength and elongation of specimens were gradually improved.

Effect of particle Types and size distribution was studied by [15] in Al-alloy metal matrix composites it was observed that With increasing the number of FSP passes the distribution of reinforcing particles become more homogeneous than in base metal ,Also the third pass friction stir processed composite shows an improvement in hardness with 15 % compared with all processing passes . matrix composites it was observed that With increasing the number of FSP passes the distribution of reinforcing particles become more homogeneous than in base metal , also the third pass friction stir processed composite shows an improvement in hardness with 15 % compared with all processing passes . The investigator used more than three reinforcement particles and the result show that Al_2O_3 particles give finer grain and ductile fracture in the matrix composites.

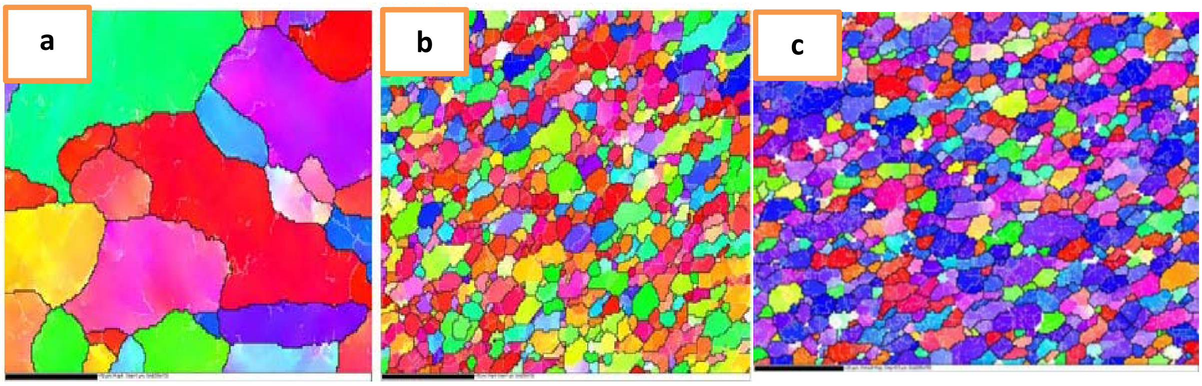

Figure 5: Typical grain structures of the stirred zone after with multi passes FSP

The influence of FSP pass number on the microstructure of the stir zone, distribution of SiC nanoparticles studied by [16], they concluded that, Increase in FSP passes number does not have significant effect on the stirring zone of FSPed specimens without nanoparticles. The samples FSPed with SiC nanoparticles were noticed affected by passes number, which increasing the passes leading to improving the distribution of nanoparticles and then microstructural evolutions and mechanical properties of the stir zone.

The advantage of Ultra fine grains (UFG) to improving mechanical properties have been carried out based on Hall-Petch relationship (grain boundary strengthening) were concerned by[17,18,19]. The approach was used to obtain ultrafine grain size without any external cooling in addition to using overlapping passes with reduced heat during successive passes by reducing the tool rotation speed. This indicated that microstructure with different level of texture and grain refinement can be obtained by controlling the processing parameters.

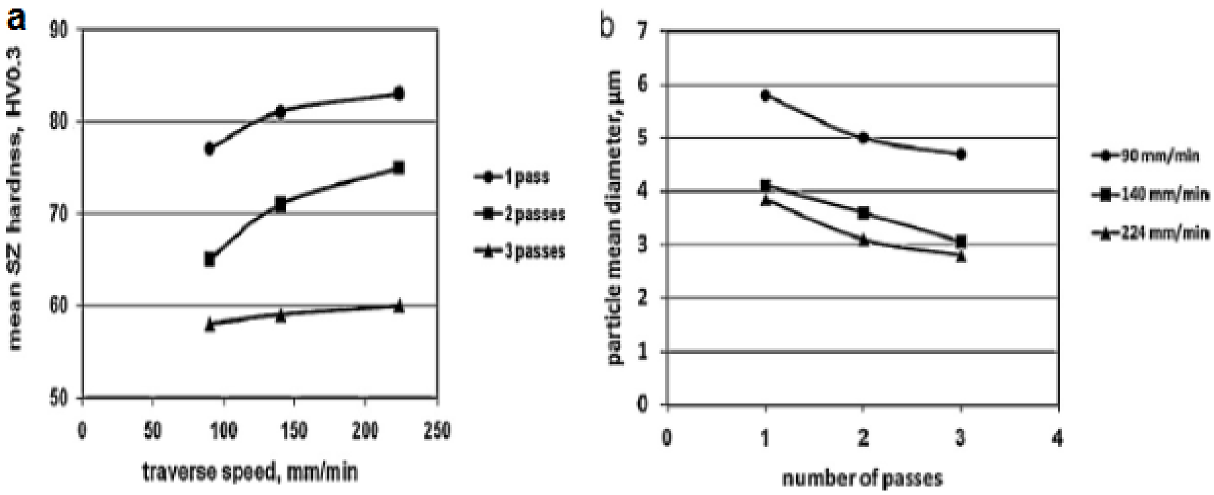

Figure 6: Influence of number of passes on (a) traverse speed with respect to hardness, and (b) particle mean diameter.

Nano sized of SiC and Al2O3 particles were conducted to as-cast AZ91 magnesium alloy fabricated by FSP [20]. The researchers reported that, increasing the FSP pass number improving the homogeneity and the particle distribution. Stirring of materials in each FSP pass dispersed the SiC particles in the metal matrix. Figure (7) shows that the mean average grain size in the samples contains SiC particles was smaller than that in the samples with Al_2O_3 particles in the same FSP pass numbers. SiC particles tended to be distributed separately in AZ91 matrix shown in the grains that are more refined.

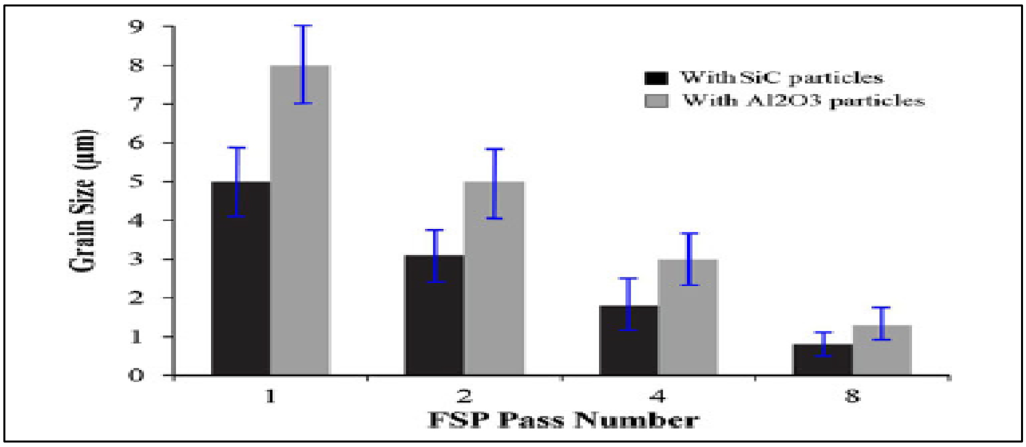

Figure 7: Average grain size in the specimens produced by several FSP passes and SiC and Al_2O_3 particles.

2.1.3. Effect of Multi-Pass FSP on hardness

Multi –passes FSP can locally eliminates casting defects and refine microstructures, thereby improving resistance to corrosion, but the hardness takes different behavior. Many researchers have been carried out multi-pass FSP on AA2219 aluminum alloy without using reinforcement particles such as [16,21,22] .They are reported that through all processing parameters, the stirred zone showed a lower hardness compared to the base metal.

Multi-pass friction stir processed aluminum alloy 6063 [3] has been investigated by [23], the study concluded that, a considerable reduction in the microhardness of FSPed samples (40–60 Hv), as compared to the BM sample as shown in figure (8). On the other hand, the hardness results were improved by 20% with multiple passes performed on ADC12 aluminum die casting [24].the authors were explaining the reason for improving the mechanical properties due to elimination of the casting defects and uniform dispersion of the finer Si particles, furthermore grain refinement of aluminum matrix.

Reinforced the metal alloy with ceramic particles are concerned by a number of researchers. They deal with fabricating metal matrix composites by multi-pass FSP. Multi-pass with 100% overlap was carried out using in situ fabricated Cu/SiC composite by FSP [5].The results were revealed that, the hardness results of 1Pass, 4Pass and 8Pass are increased about 30%, 50% and 58% with respect to the base metal, respectively as shown in figure (9). As it was discussed before, increase in FSP passes leads to refine the course grain, better dispersion of SiC particles.

Fabrication of wrought Mg–Al–Zn alloys using multi-pass FSP followed by higher cooling rate of liquid N2 developed by [25]. Due to the type of cooling and the number of FSP, new intermetallic components was produced. Increasing the FSP passes will enhance the HV values and reduce the variation of HV inside the stirred zone as shown in figure (10). With liquid N2 cooling, a slightly greater hardness than the same alloy system without liquid N2 achieved.

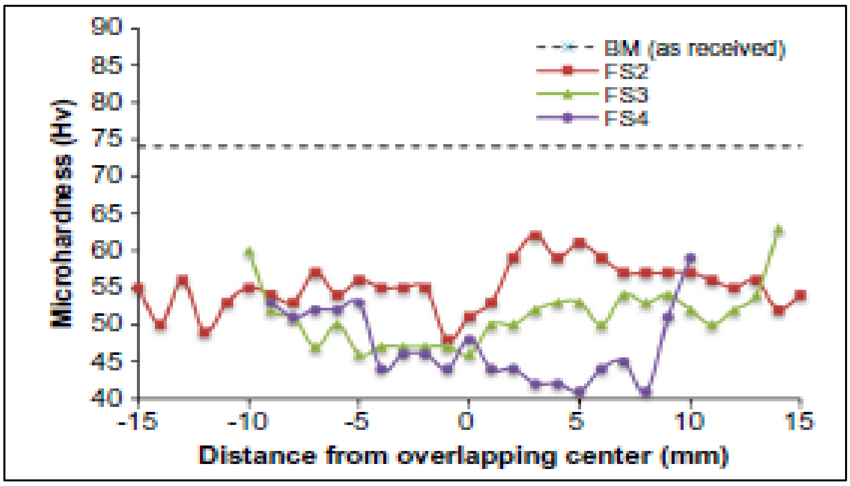

Figure 8: Microhardness profile of multiple-pass samples with different overlapping percentages

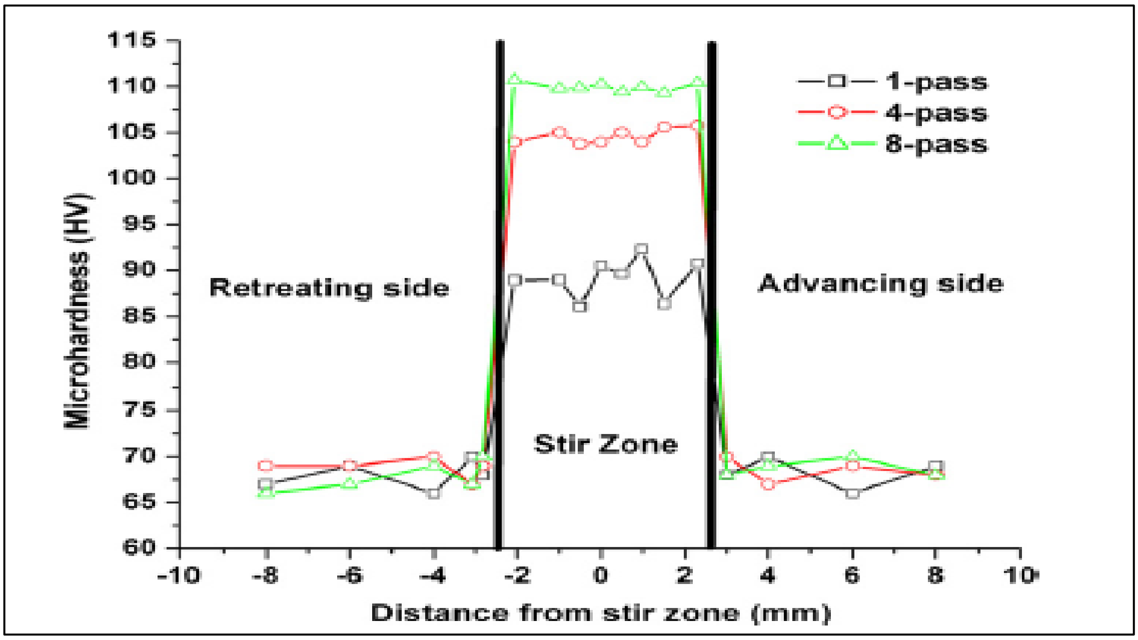

Figure 9: Microhardness values of 1Pass, 4Pass and 8Pass.

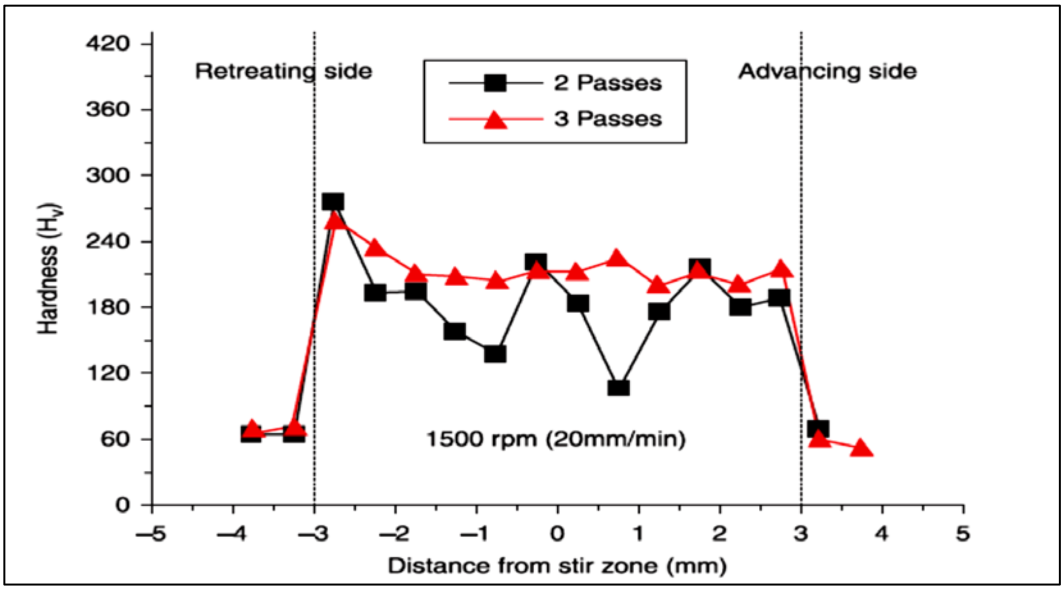

Figure 10: The variation of HV along the transverse cross sectional plane of the $Mg_{60}Al_{20}Zn_{20}$

3. Conclusions

Multi-pass FSP can be used to improve the mechanical properties of metallic alloys in the selected regions. Depending on the design of the tool used and processing parameters, multi-pass FSP can produce refine and homogenize microstructures.

In case of surface composite process, multi-pass FSP play very important role in the distribution and dispersion of the reinforcement particles in the composite matrix.

Tensile strength slightly enhanced after performing a number of passes during the fabrication of MMCs.Cavities, defects were eliminated, and the Hardness is significantly improved by using multiple passes.

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