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Investigating the Effect of Hybrid Process: MPF/SPIF on the Microstructure and Mechanical Properties of Brass (65-35) Sheet

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ABSTRACT

Metal forming process is one of the most important manufacturing processes that translate the sheet and bulk metal to the final product with simple punch and. Single point incremental forming (SPIF) process is considered as a modern flexible manufacturing techniques that is use a simple tool and non-specific fixture die to complete the forming, this method is used in prototype manufacturing system due to the time consuming during the forming. The advantage of this process is low cost and simple equipment. However, some limitation was founded including poor geometric accuracy, non- uniform thickness distribution, dimple and high forming time. Multi-point forming (MPF) is another modern forming method that is used in industrial applications due to its advantage such as uniform thickness distribution with low forming time consuming. This method used matrix of simple tools to deform the sheet metal to the desired shape. Wrinkle and dimple due to small contact area between tool and blank under high forming force are considered the main limitation of using MPF process. To take the advantages of this processes with reduced the limitations a hybrid forming (HF) process of both MPF and SPIF are used. The experimental work was applied to produce a hemi-spherical product of brass blank using the SPIF, MPF, and HF processes. Satisfactory results are obtained using a hybrid forming process with free of defects products and reduction in production as compared to the SPIF. A high improve in microstructure including refinements in grain size with twins effects. The sample produced with SPIF process showed a high microhardness as compared to the sample produced using MPF process, however, the hybrid MPF and SPIF forming process showed slightly improving in microhardness as comparing to the as received materials, reflecting the microstructure development of the processed samples.

Keywords: mechanical properties, microstructure, sheet metal forming, single point incremental forming process, multi point forming process, hybrid forming process

INTRODUCTION

Sheet metal forming process has been widely used in industrial applications including automotive, aerospace, renewable energy and medical. In traditional process the products performed to the desired shapes and dimensions using suitable punch and dies, which is appropriate for mass production. However, the use of conventional process for manufacturing of small batch with high value results in high tooling costs long with lead time and high energy consumption. To overcome these limitations a flexible sheet metal forming with advantage of reduction in tool costs, Furthermore, unlike the conventional processes production of dissimilar shape products using flexible forming process do not require the use of different dies which required long time to manufacture the needed tools. [1,2].

Multi-point forming (MPE) process replace the conventional punch and die with two opposed matrices consists of many movable tools [3]. which is constructed in the way that is independent of one to another, this can be easily change with respect to the forming shape. Consequently, the controlling of the height of the forming tool resulted in continuous operating of the forming surface and three-dimensional surfaces can be obtained. The curved surface of the die is generated by large number of forming tools in the MPF process [4], Figure 1 illustrate the schematic design of the (MPF) process.

Single point incremental forming (SPIF) process and Multi-point forming (MPF) process are two typical flexible sheet forming concepts. SPIF process is a flexible, very simple and alternative of reduce cost design as compared to the traditional forming processes, however the production rate is considered low [6-8]. This method does not need to dedicated costly equipment, with sheet metal is held at the simple blank holder which is fixed on CNC milling machine table. The programmable moving tool with respect to blank holder slide on the sheet to achieve the forming of the desired shape. The process has some limitation including coarse surface finish, poor geometrical accuracy and long processing time. In order to avoid these limitations, a number of variations of the single point incremental forming process must be made to explore [9].

A hybrid process which consists of two or more technique may offer the solution of some sheet metal forming process limitation. For instance, Araghi *et al.*[10] applied a new hybrid process consists of combination of Asymmetric incremental sheet forming (AISF) and stretch forming as the pre-forming process. The results showed a good reduction in production time with uniform thickness distribution as compared to AISF process. Lu *et al.* [11] employed a simulation method using finite element model to investigate Hybrid Flexible Sheet Forming of two steps forming process of multi-point forming to obtain the initial shape followed by incremental sheet forming process to achieve final part geometry with uniform thickness distribution. The results demonstrates that the possibility and effectiveness of the developed forming process with uniform thickness distribution and elimination the defects. In a more recent work Boudhaouia *et al.* [12] Experimentally conducted a combine of two common manufacturing methods, multipoint forming (MPF) and incremental sheet forming (ISF) processes. The results demonstrate that the new technique is effective approach to produce a multitude of parts with different shapes with low equipment cost

The aim of this work is to apply the adopted method that used the MPF process as a primary step of SPIF process to elimination the defects that result from used the MPF and SPIF processes, a spherical cap geometry is selected to perform the forming with different forming depth to reach the desired shape and compered them with SPIF process product. Further analyses were performed including microstructure, strain hardening and thickness distribution.

EXPERIMENTAL WORK

In this work, four samples of 0.71 mm thickness of brass (Cu-65/Zn 35) sheet were used, Table 1 present measured and standard chemical composition of the blank brass (Cu-65/Zn 35) sheet, the chemical analysis performed using Energy dispersion spectrograph (EDS).

The experimental conducted using three-axis model C-tek CNC machine (KM- 80D) with oil lubricant. The process parameters of peak feed rate and rotation speed was kept constant at 10 m/min and 6000 rpm, respectively. The CNC part program was achieved using NX-program to perform the forming toolpath

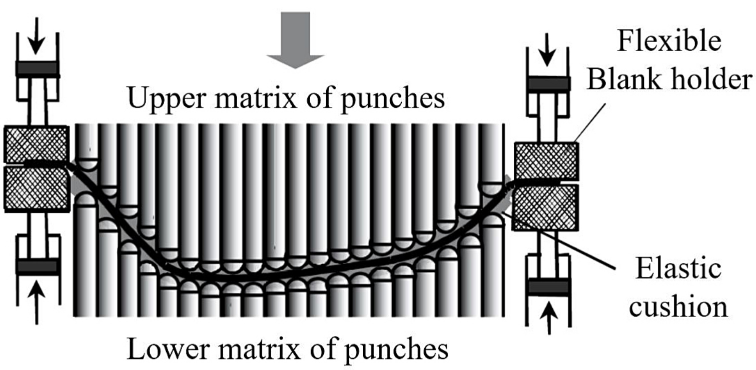


Fig. 1. Schematic design of (MPF) process [5]

Table 1. Brass (65-35) chemical composition (ISO workpiece – Cu Zn 65-35 426/1)

Elements %		Zn	Pb	Sn	P	Fe	Ni	Si	Al	Cu
Brass	Experimental	35.23	0.007	0.001	0.007	0.021	0.001	0.001	0.002	64.7
	Standard	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0

[13], which is used to manufacture the CAD model that used in SPIF process to manufacturing the forming part and used the same program to produce the lower die. Figure 2 illustrate the hemi-spherical forming part geometry, the toolpath and MPF die used in this work. Microstructure analyses was performed using optical microscope and scanning electron microscopy SEM model (VEGA3 TESCAN) with 20 kV and spot size 4.

The hybrid technique that is used in this work consists of sequence of MPF process as a pre-forming process and SPIF process with different forming depth to find the effect of using this method on the final product and compered them on the SPIF process product. A square blank holder that used to fixed the blank during both forming process with rubber thickness (4mm) and forming speed (2mm/min), Figure 3 presents the MPF die and SPIF die.

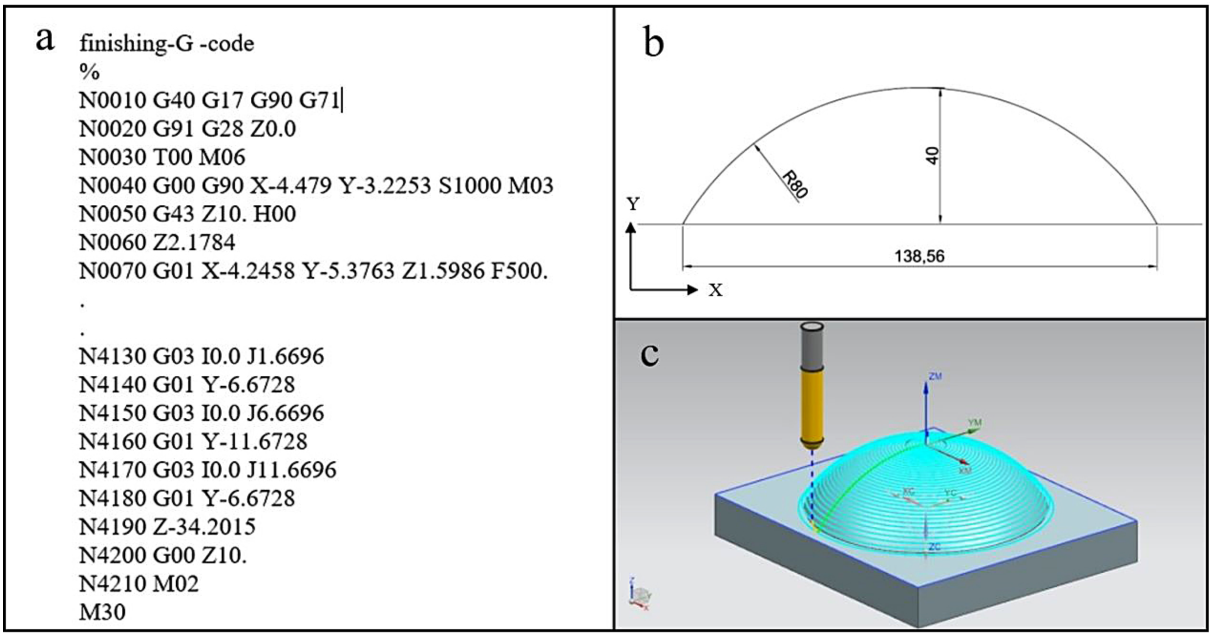


Fig. 2. Geometry of forming part, a) G-Code, b) CAD Model and c) Tool path

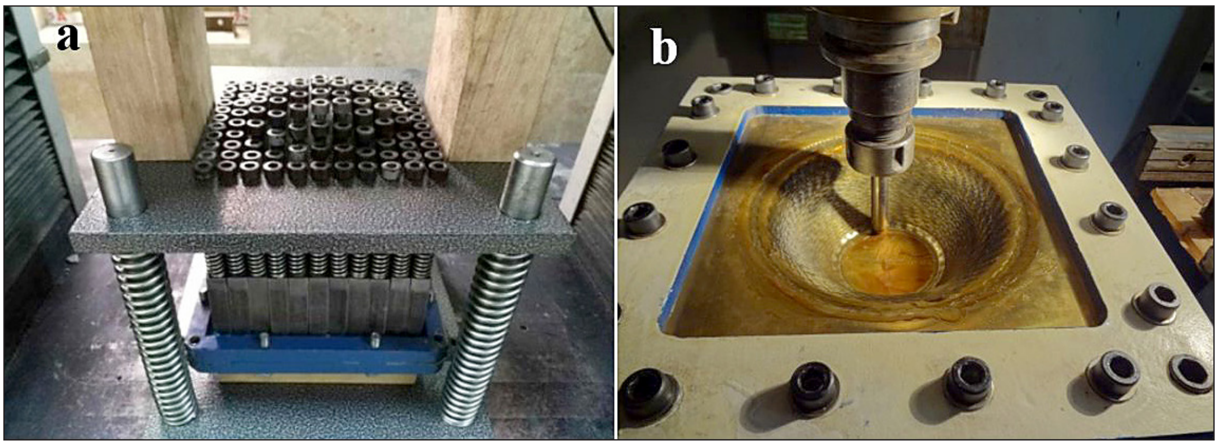


Fig. 3. The experimental setup of a) MPF and b) SPIF processes

The process sequence of the Hybrid MPF and SPIF Process consists of:
- Applied the forming process using just SPIF.
- Applied the forming process using just MPF.
- Applied the pre-forming process using MPF at forming depth (15 mm) and after that finish this work using SPIF process to the desired product geometry (Hybrid of MPF and SPIF).
- Applied the pre-forming process using MPF at forming depth (25 mm) and after that finish this work using SPIF process to the desired product geometry (Hybrid of MPF and SPIF).

RESULTS AND DISCUSSIONS

In order to exam the feasibility of the hybrid process several parts have been performed including SPIF, MPF and MPF-SPIF for with primary forming depth 15 mm and 25 mm, as present in Figure 4.

The forming process techniques has a significant effect on the microstructure of the processed parts. Figure 5 present the microstructure at the middle forming zone of the as received brass (Cu-65 Zn 35) sheet, and formed specimen with SPIF, MPF, MPF-SPIF at 15 and 25 mm. the microstructure of the as received brass sheet is consisted of fine equiaxed grains with average grain size of about 40µm along with some coarse grains exist of approximate 15 µm as presented in Figure 5b.

The microstructure of the sample produced with Single point incremental forming SPIF process exhibited microstructure refinements [14, 15], with twins deformation mechanism dominates this is probably presented due to the effects of local plastic deformation which is result in surface mechanical enhancement [16], as shown in Figure 5c. The sample produced with MPF process is presented in Figure 5d, the sample showed a similar microstructure to that of the initial brass material with small amount of twins deformation effects.

The samples produced with hybrid process of MPF up to 15 and 25 mm followed by SPIF presents in Figures 5e, f. The microstructure shows a high refinement in grain size with low amount of elongation in the longitudinal direction. Increased the starting deformation with MPF from 15 mm to 25 mm results in increase the amount of elongation.

Figure 6 present low and high magnification SEM images of the as received brass and the samples formed with SPIF and MPF process, again the SPIF microstructure exhibited twins deformation mechanism results of the effects of local plastic deformation (Fig. 6a, b).

The effects of MPF/SPIF processes on the microhardness of Cu-65 Zn 35 brass alloy is presented in Figure 7, the microhardness test performed at the same zone of the microstructure investigation which is presented in Figure 5a. The SPIF processed sample exhibited a highest hardness with 127 HV, this is probably due to microstructure development during process with grain refinement and twins effects (Fig. 5c). However, the minimum hardness of 101 HV recorded with the sample processed with MPF technique which is almost equal to the microhardness of the as received brass with 101.9 HV, again this is can be attributed to the unchanged of the brass microstructure during process (Fig. 5b, d).

The applying of new hybrid MPF/SPIF process led to slightly increase the microhardness with 117.1 and 108.2 as compared to the as received material, which also attributed to micro structure development during process Figure 5e, f.

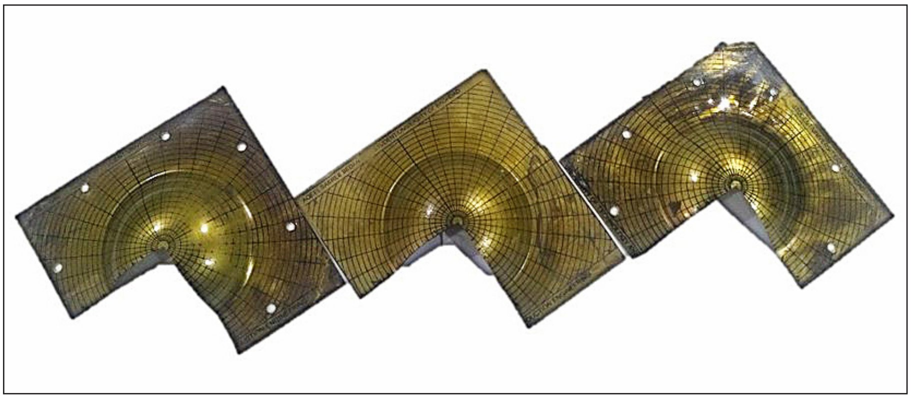
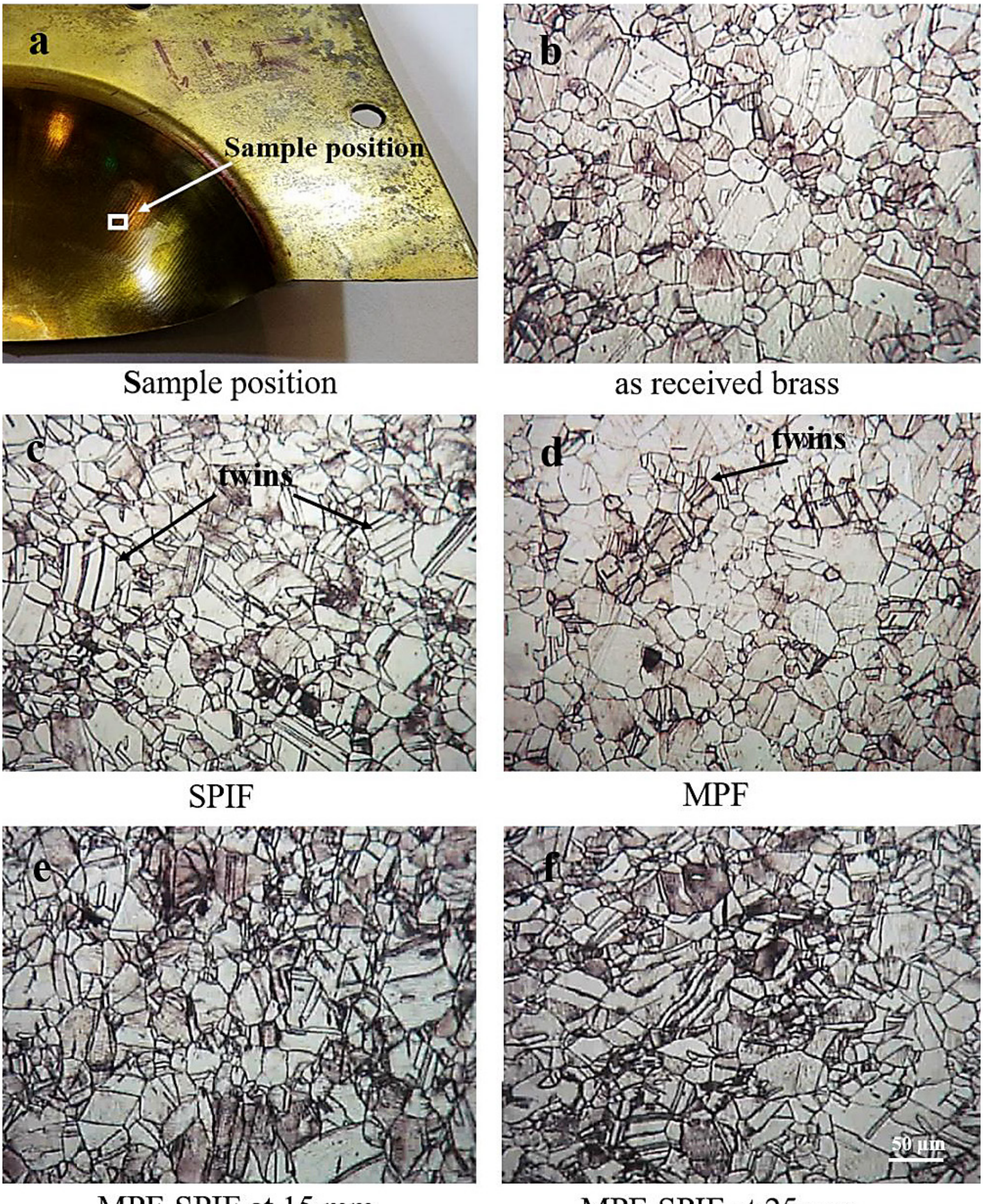


Fig. 4. Forming parts using hybrid of MPF and SPIF



Sample position

as received brass

SPIF

MPF

MPF-SPIF at 15 mm

MPF-SPIF at 25 mm

Fig. 5. Sample position and microstructure of the as received brass and processed samples

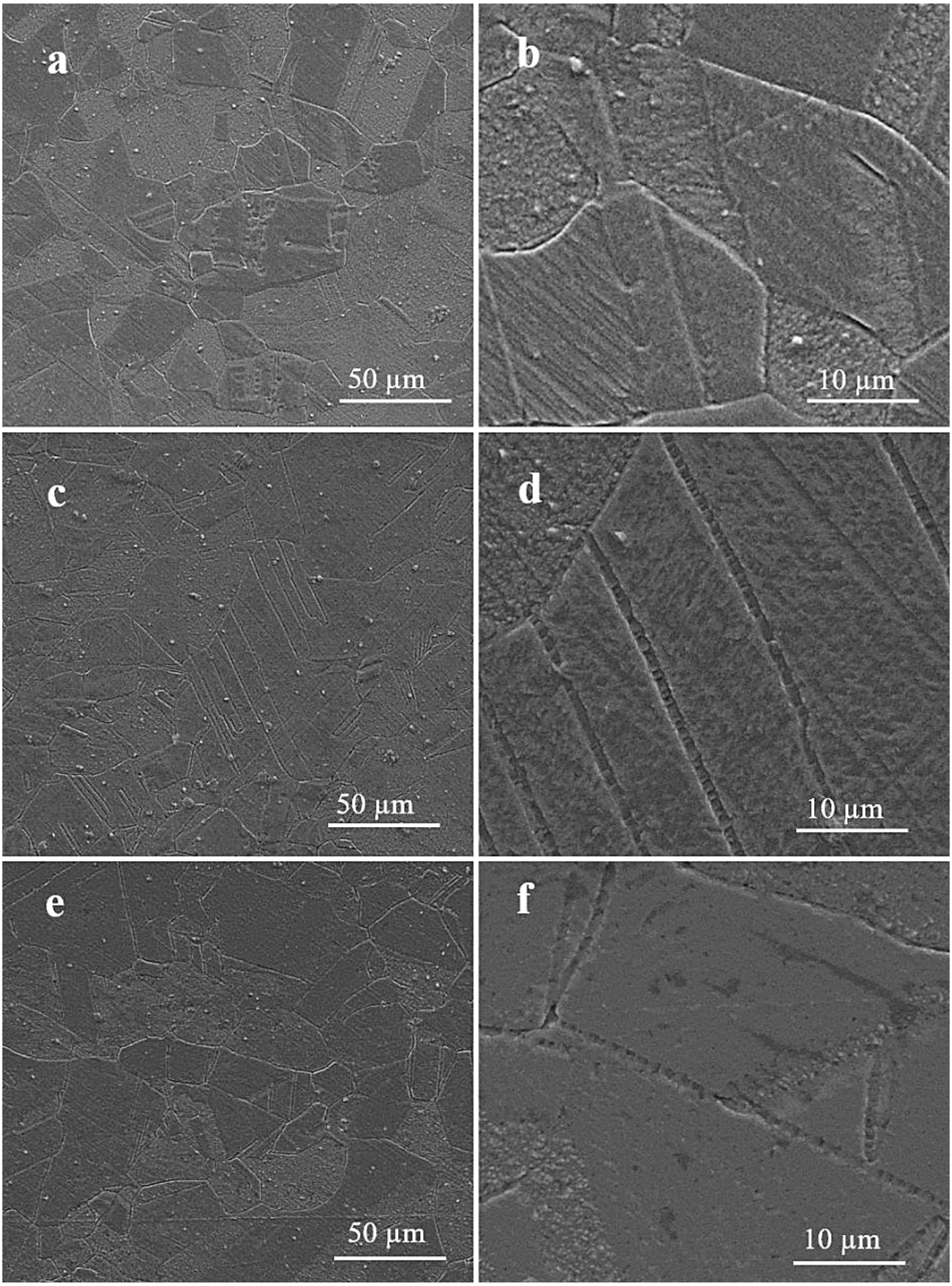


Fig. 6. Microstructure of (a, b) low and magnification of as received brass sheet, (c, d) low and high magnification of SPIF, (e, f) low and high magnification of MPF

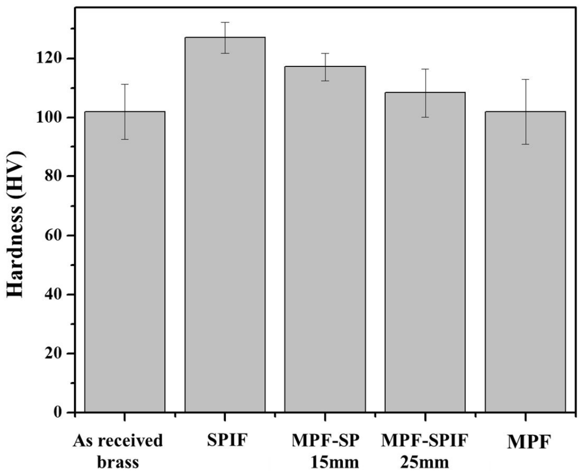


Fig. 7. Microhardness of the as received and processed samples

CONCLUSIONS

In this work a hybrid flexible MPF- SPIF forming process as compared to SPIF and MPF forming process was investigated, the results showed that:

1. A hybrid flexible MPF- SPIF can be considered as a feasible and effective way of developing the forming technique.
2. The microstructure of SPIF process samples exhibited a twins deformation mechanism due to the effects of local plastic deformation. However, the sample produced with MPF process showed a similar microstructure to that of the initial brass material with small amount of twins deformation effects.
3. The samples processed with hybrid process of MPF followed by SPIF showed a good improve in microstructure with refinements in grain size and twins.
4. The sample produced with hybrid process showed a high microhardness as compared to the sample produced using MPF process.

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