

Characterising the Effects of Sand Blasting on Formed Steel Samples

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Abstract—The present research study focuses on the investigation of the influence of sand blasting on formed mild steel samples. The investigation involved the examinations on the parent material and a sand blasted material. The results were compared to the mechanically formed materials (sand and non-sand blasted) as well as a laser formed material (sand and non-sand blasted). Each material was characterized for the grain sizes and hardness. The percentage change in the grain sizes was quantified and correlation to the microhardness values was established. The Ultimate Tensile Strength (UTS) of the materials was also quantified using the obtained hardness values. The investigations revealed that the sand blasting causes an increase in the Vickers microhardness values of all the materials which also led to an increase in the UTS. After the forming operation, the microstructure revealed elongated grains as compared to almost equiaxed obtained from the parent non-sand blasted materials.

Keywords—Grain size, hardness, metal forming, sand blasting, ultimate tensile strength.

I. INTRODUCTION

THE importance of metals in modern technology is mainly due to its ease to be formed into useful shapes such as tubes, rods, sheets and plates. Besides its strength; availability, versatility, properties and economic advantages compare to other engineering materials makes metal a top on the range. Metal forming is an important aspect in manufacturing processes to obtain a finished product. Widely used metal shapes can be made in three basic ways: by casting, mechanical forming (plastic deformation processes) and machining processes. The metal shapes generated by deformation are with better mechanical properties than those by casting and machining [1]. In modern metal forming practice, metal is usually first cast into a shape near the final product and then further deformed into the final product. In this way, the deformation steps can be reduced to minimum, and metal deformation is more uniform. As a matter of fact, the plastic forming plays two roles at the same time: (1) to reach a specific shape; (2) to improve the mechanical

(sometimes also other physical) properties [1]-[4].

Hundreds of processes have been developed for specific metalworking applications. However, these processes may be classified into only a few categories on the basis of the type of forces applied to the workpiece as it is formed into the desired shape [1]. Metal bending is one of the metal forming techniques employed in the manufacturing industry to obtain metal sheet. There are a number of industrial products that make use of sheet and plate metals, these include among many; truck and car bodies, locomotives, railway cars, airplanes, construction equipment and appliances [2]. There are various metal forming processes amongst which includes mechanical forming and laser forming. Mechanical forming technique is a process that involves exerting a specific load on the upper die which presses into the clamped sheet of metal into the lower die creating a component with specific shape geometry. In particular, the metal bending and forming techniques is commonly used in the automobile industry where metal sheets are bent to a particular angle or curvature of specific geometry and dimensions [1].

Laser forming is considered a viable process for the shaping of metallic components and a means of rapid prototyping and aligning. Laser Beam Forming (LBF) is of significant value to industries that previously relied on expensive presses and stamping dies for prototype evaluation. Some of the relevant industry sectors include the aerospace, automotive, shipbuilding and microelectronics. In contrast with conventional forming techniques, this method requires no mechanical contact and thus promotes the idea of "Virtual Tooling." It also offers many of the advantages of process flexibility associated with other laser manufacturing techniques, such as laser cutting and marking [5], [6].

Sandblasting is a process of using compressed air to propel an abrasive grits at a very high speed at an object in order to remove oxide layer or any other debris from the surface of a material. Due to the impacting and cutting effect of the abrasive sand, the workpiece surface is completely cleaned and at the same time the surface quality and the mechanical properties are improved [7]. Silica, which is also known as quartz is the most common type of sandblasting grit. It is good for sandblasting because the particles are fairly uniform in size and the nearly microscopic sharp edges of the individual grains makes it very effective for removing material from the material being sandblasted.

In view of the above, the present study is aimed at investigating the influence of sand blasting on the properties of different formed steel materials.

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II. EXPERIMENTAL SET UP

Three different test materials made from mild steel sheets with dimensions of $200 \times 50 \times 3 \text{ mm}^3$ were used. These materials include Parent Material (PM), Mechanically Formed materials (MF), and Laser Formed materials (LF). Three other samples produced by these methods are the sand blasted using Silicon Carbide (SiC) sand to remove the oxide layer deposited on the surface of the materials. The sand blasting was performed inside sand blasting equipment shown in Fig. 1. The materials used in this study are labeled as represented below:

- PM = Parent Material
- PM_SB = Parent Material Sand Blasted
- MF = Mechanically Formed Material
- MF_SB = Mechanically Formed Sand Blasted
- LF = Laser Formed Material
- LF_SB = LASER Formed Sand Blasted

The mechanical bending process was carried out on a 20 ton capacity mechanical press. The detailed description of the entire process is given elsewhere [8]. For the laser forming, a 4.4kW Nd: YAG laser (Rofin DY 044), at the Council for Scientific and Industrial Research, National Laser Centre (CSIR-NLC), Pretoria, South Africa was employed to laser form the materials. The samples were successfully formed to about 120mm curvature at 1.9m/min scan speed, beam diameter of 12mm, power of 1.7kW, and 25% beam overlap. An argon gas was used to cool the irradiated materials, with the argon nozzle positioned immediately after the laser beam cooling the irradiated surface at a flow rate of 10l/min. The direction of the scanning path is defined as the X- axis, Z-axis as the thickness direction and the Y-axis as the length of the material.

After forming, all the samples were sectioned at 100mm. The sectioned samples of dimension $20 \text{ mm} \times 5 \text{ mm}^3$ were mounted in a polyfast thermoplastic hot mounting resin, grinded and polished to $1 \mu\text{m}$ surface finish to evaluate the resulting microstructure. The microstructure of both the sand blasted and the non-sand blasted materials were observed under an optical microscope (Olympus PMG3). The samples were etched in 2% Nital by totally submerging the samples for 10seconds to reveal the grain structure. The grain sizes were measured using the measurement tools on the optical microscope, and the average values of five individual grainsizes were taken. The Vickers microhardness profile was conducted using an FM-ARS 9000 automatic indenter according to ASTM 384 standard. The indentations were taken at about 0.2mm below the surface of the irradiated top surface to measure the Vickers microhardness so as to capture the effect of the irradiation, using a load of 300g at a dwell time of 15seconds. The indentations were taken at 0.3mm intervals according to the ASTM A3-11 standard [9] and all the indentations were manually focused and read to ensure that all the measurements were made on the specimen.



Fig. 1 Experimental set-up for sand blasting process [10]

III. RESULTS AND DISCUSSION

A. Percentage Change in the Grain Sizes

The average grain sizes of each material were measured and the percentage change against the parent material is presented in Table I.

TABLE I
RESULTS OF THE AVERAGE GRAIN SIZES MEASURED

Materials	Average Grain size (μm)	Percentage change in grain size (%)
PM	17.0 ± 1.8	-
PM_SB	24.6 ± 2.2	44.7
MF	23.1 ± 1.9	35.9
MF_SB	25.5 ± 2.8	50.0
LF	27.6 ± 1.2	62.4
LF_SB	28.6 ± 1.9	68.2

The results of the investigation showed that the average grain size of both the sand blasted and non-sand blasted material increased. This is an indication that the forming process resulted in an increase in the grain sizes. The average grain of the sand blasted materials increased more compared to the non-sand blasted materials. This is an indication that the sand blasting results into a greater degree of grain deformation. From the experimental results presented in Table I, the effect of sand blasting on the formed materials showed that as one moves from the parent materials to the laser formed materials, the degree of change in the average grain sizes increases. This implies that the degree of deformation is also influenced by the forming method efficiency. Laser forming is considered to produce enhanced material properties compared to mechanical forming [11]. The result here shows an agreement with published literature [11]. The percentage change also follows the same pattern. This is further illustrated with the graph of the average grain size against the material as shown in Fig. 2.

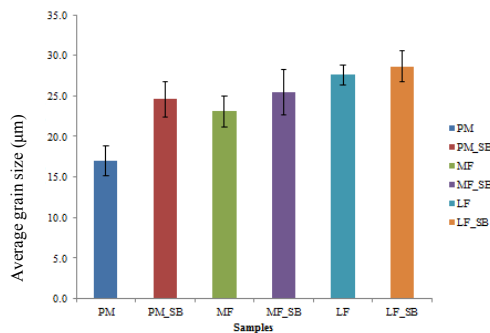


Fig. 2 Plot of the average grain sizes against material

B. Microstructural Evaluation

The microstructures of the materials are shown in Fig. 3. It is evident from observation that the formed materials experienced grain elongation compared to the parent materials.

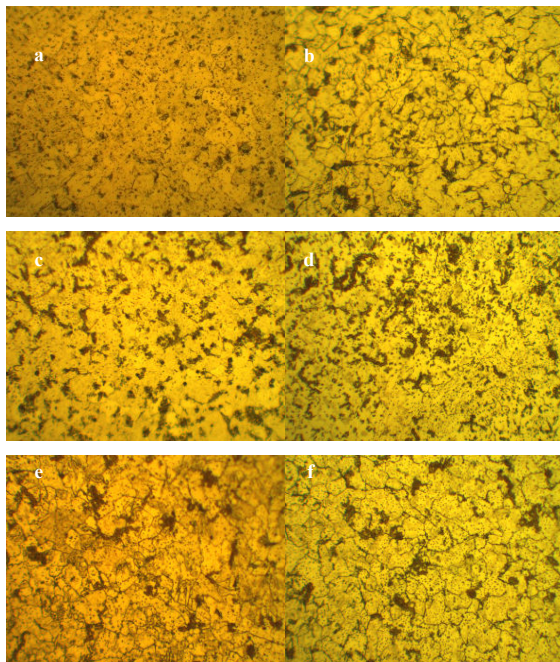


Fig. 3 Microstructural changes before and after sand blasting for all materials. (a) PM, (b) PM_SB, (c) MF, (d) MF_SB, (e) LF, and (f) LF_SB

The grain elongation is more in the sand blasted materials. This is an indication that the materials has gone through a significant structural changes. This microstructural changes may be explained by the process of mechanical deformation (in the mechanically formed materials) due to force loading and heating above its upper transformation temperature (in the laser formed materials) whereby the ferrite grain recrystallizes; as such the microstructure was transformed from the equiaxed ferrite matrix as established in the as received material to an elongated grain structure shown in Fig. 3. This observation also agrees with the authors in [11].

C. Vickers Microhardness

Six indentations were taken for each of the materials investigated. The results of the average Vickers microhardness for each sample with the percentage increase in the hardness value compared to the parent material is presented in Table II and the graphical representation is shown in Fig. 4.

TABLE II
VICKERS MICROHARDNESS MEASUREMENTS

	PM	PM_SB	MF	MF_SB	LF	LF_SB
1	97	123	138	120	144	151
2	89	128	131	136	148	148
3	80	116	136	150	133	156
4	84	119	146	149	138	146
5	84	110	132	151	152	146
6	94	113	149	150	157	163
Ave. HV0.3	88.0	118.2	138.7	142.7	145.3	151.7
% Increase	-	34.3	57.6	62.2	65.1	72.4

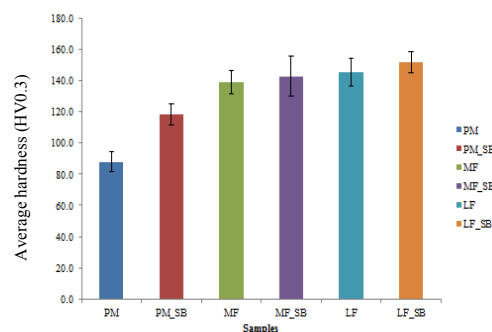


Fig. 4 Comparison of the Vickers microhardness values of all the materials

Observations from the investigations revealed that the hardness increases both for the sand blasted and the non-sand blasted materials. The degree of increase in the materials hardness is higher in the sand blasted materials compared to the non-sand blasted materials. The result here correlates with that obtained from the grain sizes characterization. The degree of the percentage increase in the hardness also varied with the forming process, with the highest degree of increase obtained in the laser formed materials. Fig. 5 shows the comparison on the percentage change in the hardness of the materials.

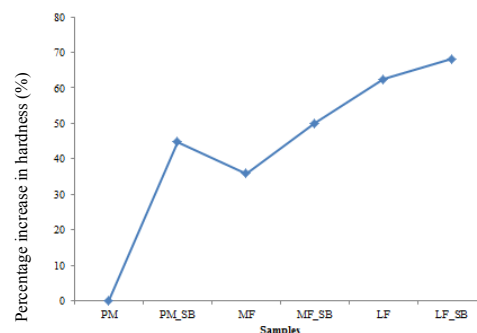


Fig. 5 Graph of percentage change in hardness materials

D. Ultimate Tensile Strength

The Ultimate Tensile Strength (UTS) for each of the investigated material was calculated based on the measured average Vickers microhardness values. The UTS was calculated from the relationship reported by Akinlabi et al., [12]. The relationship is given in (1).

$$UTS = 9.81 \left[\frac{H}{2.9} \right] \left[\frac{n}{0.217} \right]^n \quad (1)$$

where,

H= Vickers microhardness

n =Strain hardening index, (n=0.21 for low carbon steel – annealed).

The calculated UTS for the formed samples and the percentage change in the UTS are presented in Table III.

Material	Average HV0.3	UTS (MPa)
PM	88.0	296
PM_SB	118.2	396
MF	138.7	467
MF_SB	142.7	480
LF	145.7	487
LF_SB	151.7	511

The comparison of the calculated UTS values is shown in Fig. 6.

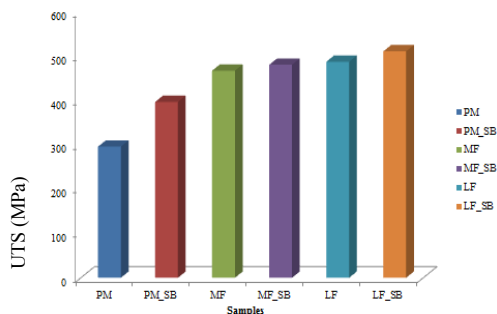


Fig. 6 Comparison of the UTS of the materials

It was observed that the UTS of the material varied with the forming process. The UTS values also follow the hardness trend wherein the sand blasted materials possess the higher values. And as such, it can be concluded that the sand blasting has the ability to alter the mechanical properties of the materials by improving and strengthening the material properties.

IV. CONCLUSION

The effects of sand blasting on the mechanical properties of formed mild steel samples have been presented and discussed. It was found that grain elongation observed in the microstructure of the formed samples varies with the forming process. Sand blasting of steel samples was found to increase the degree of grain elongation and also causes an improvement in the hardness of the material by strain hardening. This has

also resulted in an improvement in the ultimate tensile strength of the materials tested. Sand blasted materials have improved properties than the non-sand blasted materials. Comparison of the two forming processes used indicated that the laser forming process produces better and enhanced properties compared to the mechanical forming process.

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