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Mechanical Properties of Al6061 Sheets Through Shot Peen Forming

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Abstract:

Shot peening is a room temperature die-less forming process that involves subjecting the surface of a workpiece to pressure from small, round steel shots. Each shot acts as a miniature hammer, resulting in elastic stretching of the upper surface. The impact pressure from the shots induces local plastic deformation, leading to residual compressive stress. This stress combined with the stretching, causes the material to develop a convex curvature on the peened side. In this project, the chosen material for shot peening is Al6061, an alloy known for its corrosion resistance and non-heat treatable properties. A 0.5mm thick sheet, measuring 150mm in length and 60mm in width, is placed in a Los Angeles abrasive machine. To compress the sheets during peening, 240g of steel balls (six balls, each weighing 60g) are utilized as the impact load. The process is performed for varying numbers of revolutions: 100, 200, and 300, with durations of 3, 6, and 9 minutes respectively for each revolution. The shot-peened deformed sheets are subsequently tested for area and hardness to assess the degree of deformation and strength. Results indicate that as the number of revolutions increases, the area of the deformed sheets decreases, while their hardness increases. The highest observed hardness of 72HRB is obtained for the sheets subjected to 300 revolutions during the cold working process of shot peening.

Keywords **—Short Peen, Impact load, Hardness, Abrasive machine.**

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I. INTRODUCTION

Peen forming is a room temperature die less forming process that involves subjecting the workpiece surface to pressure exerted by small, spherical steel shots. This method, performed at high velocities, induces beneficial compressive stresses within the metal's surface layer. The resultant compressive stresses contribute to enhanced fatigue strength, wear resistance, and corrosion resistance of the metal, thereby significantly improving its durability and extending its lifespan.

II. PRINCIPLEOF PEENING

Peening serves as a valuable technique in situations where the welding of cast iron or post-weld heat treatment is impractical. Moreover, it finds utility in the flattening of sheet metal, particularly as a primary method for flattening steel belts utilized in industrial conveying and pressing applications. Figure 1 illustrates the fundamental principle of peening

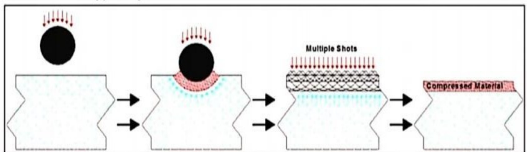

Fig.1 Principleofpeening

III. METHODOFSHOT PEENING

1. Mechanical Shot Peening
2. Dual peening
3. Laser-shock peening
4. Ultrasonic peening.

IV. PROPERTIES OF AL6061

The Al6061 alloy exhibits a range of mechanical properties, which are influenced by the tempering process. The tensile strength varies between 124-290 MPa, while the yield strength ranges from 55-240 MPa, both dependent on the specific tempering condition. The hardness, as measured on the Brinell hardness scale, falls within the range of 40-95, again depending on the tempering state. The density of Al6061 is approximately 2.7 g/cm3. Its melting point is estimated to be around 580°C. In terms of thermal conductivity, the alloy demonstrates values ranging from 151-202 W/m-K. The electrical conductivity of Al6061 is approximately 40-50%.

V. OPTIMISATIONOFPROCESS PARAMETER

1. Weight of the Balls are 6x400 = 2400 grams
2. No. of revolutions of the Drum are 100, 200, 300
3. Time of Operation are 3minutes, 6 minutes, 9minutes

VI. EXPERIMENTAL PROCEDURE

The Al6061 sheets are meticulously prepared to meet the specified dimensions. Subsequently, these sheets are carefully positioned within the Los Angeles Abrasion machine, as depicted in Figure 2, which is equipped with steel balls of precise size and weight. The drum undergoes controlled rotation at a specific speed for a predetermined duration. Throughout this controlled operation, the sheets are subjected to repetitive impacts from the steel balls, resulting in the occurrence of abrasion and wear on the surface of the material being tested.

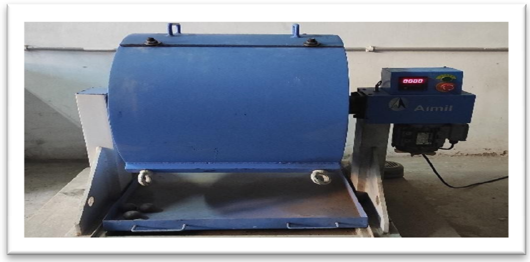

Fig.2 LosAngeles abrasionmachine

A total of six steel balls, each weighing 400 grams, were carefully loaded into the abrasion machine to impart a sudden load onto the sheet. The drum of the machine was then rotated in a clockwise direction for 100, 200, and 300 revolutions, corresponding to durations of 3 minutes, 6 minutes, and 9 minutes, respectively. Following the completion of the specified number of rotations, the peen-formed sheets were extracted from the machine to facilitate the examination of their mechanical and metallurgical properties. The deformed sheets are presented in Figures 3, 4, 5, 6, and 7.

Fig. 3 Arrangementofballsandplates

Fig.4 Before peening al6061

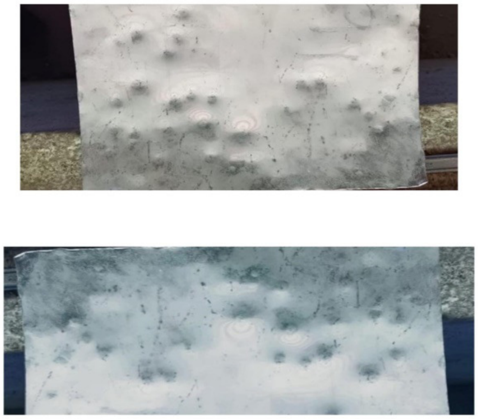

Fig.5 Before peening al6061

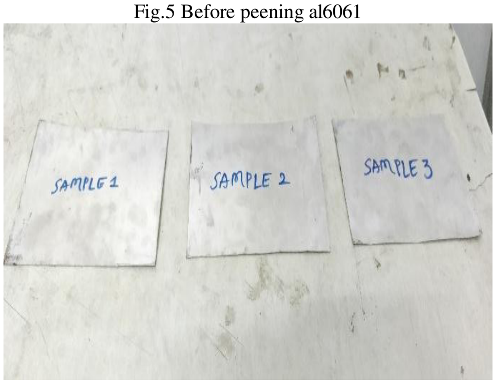

Fig.6 Al6061 Before deformation

Fig. 7 Al6061sheetafter deformation

VII. CALUCATION OF AREA FOR DEFORMED SHEETS

ReductionintheAreaofAl6061sheetsarecalculatedafterpeenformingusingthe following equations.

Ra=FA-IA/IA*100

1. RA=REDUCEDAREA,MM^2
2. FA = FINAL AREA , MM^2
3. IA=INITIALAREA,MM^2

VIII. HARDNESS

The Rockwell hardness tester is a widely utilized instrument for accurately measuring the hardness of metallic materials. In the case of Al6061 peen-formed sheets, their hardness was evaluated using this reliable testing device. The test procedure involved the application of a precisely controlled load of 150 kg to the sheet's surface, maintained for a dwell time of 20 seconds. A 1/16" ball indenter was employed to perform the test, and the resulting hardness value was determined using the B-scale, denoted as Rockwell Hardness (HRB).

The Rockwell hardness tester operates on the fundamental principle of indentation testing, wherein a carefully calibrated load is exerted on the material's surface through the use of a diamond or tungsten carbide ball. The hardness assessment process consists of the following key steps:

Preparing the sample: The Al6061 peen-formed sheet is meticulously prepared, ensuring a clean and flat surface, which is essential for precise hardness measurements.

Applying the load: The predetermined load of 150 kg is meticulously applied to the sheet's surface for a specific dwell time of 20 seconds, ensuring consistent testing conditions.

Measuring the depth of indentation: The resulting indentation on the sheet's surface is accurately measured to determine the depth of penetration, reflecting the material's hardness characteristics.

Determining the hardness value: The measured depth of indentation, in conjunction with the standardized B-scale and corresponding Rockwell Hardness (HRB) values, allows for the precise determination of the hardness of the Al6061 peen-formed sheet.

Fig. 8 Rockwellhardnesstester

IX. RESULTS AND DISCUSSIONS

1. *CalculationofAreaforDeformedSheets.*

Based on the data presented in Table 2, it is evident that there is a reduction in the area of the deformed sheets as the number of revolutions increases. The application of sudden impact load from the steel balls onto the Al6061 sheets results in a decrease in both the thickness and width of the sheets. Moreover, the increasing number of revolutions leads to a noticeable change in the curvature radius, indicating significant deformation of the sheets through cold working processes.

Table 2 Percentage Reduction Area.

No. of REVOLUTIONS	INITIAL AREA(mm^2)	FINAL AREA(mm^2)	REDUCTION AREA(mm^2)
100	155x60	150x60	0.032
200	155x60	148x60	0.054
300	155x60	145x60	0.065

2. *HardnessValues*

The hardness of Al6061 sheets demonstrates an incremental trend as the number of revolutions increases. In the annealed condition, the actual hardness of Al6061 is measured at 54 HRB, while the hardness of the as-received plate stands at 65 HRB. With an increase in the number of revolutions, the hardness rises from 68 HRB to 72 HRB. This increase in hardness can be attributed to the impact load applied to the sheets, resulting in compression and subsequent grain refinement. The refinement of the grains contributes to the elevated hardness value, progressing from 65 HRB to 72 HRB.

Additionally, the increased curvature observed along the Al6061 sheets with an increasing number of revolutions signifies improved mechanical properties during cold working. This ability of the sheets to undergo deformation under cold working conditions renders them suitable for various applications in marine and sea water environments. Table 3 presents the comprehensive data depicting the aforementioned observations.

Table 3. Hardness values

NO. OF REVOLUTIONS	LOAD (Kgs)	HARDNESS (HRB)
AS RECIEVED	150	65
100	150	68
200	150	70

CONCLUSIONS

The following conclusions have been drawn based on the obtained results and subsequent discussions:

1. Al6061 sheets have been effectively processed through the peen forming technique.
2. Cold working of the sheets during the peen forming process has yielded significant enhancements in their mechanical properties.
3. The reduction in sheet width has led to a corresponding decrease in the sheet's area, facilitating successful deformation during peening.
4. The observed deformation indicates a potential increase in grain refinement and a subsequent confirmation is required through optical micrograph analysis.
5. Peen forming has resulted in an increase in the hardness of Al6061 sheets, elevating it from 60 HRB to 72 HRB.
6. An increase in the number of revolutions

has shown a corresponding increase in hardness and a reduction in sheet area.

7. Shot peening induces plastic deformation in the grains, leading to the formation of dislocations and residual stresses within them.
8. The rearrangement of dislocations can result in the formation of sub grains, increasing the number of grain boundaries and subsequently improving the material's mechanical properties.

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