



Influence of tool pin profiles on mechanical properties of FSP processed aluminium 6063

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Abstract: FSP provides intense plastic deformation of material especially in processed zone which causes material mixing, and thermal exposure, resulting in significant micro structural refinement and enhancement of mechanical properties, densification, and homogeneity of the processed zone due to the stirring action of non consumable tool profile (mostly circular pin profile). In this research effort is made to find out the effect of other tool pin profile on mechanical properties (impact strength and Rockwell hardness) of aluminium material (6063). There were four tool profiles used (circular, pentagonal, threaded and square tool pin profile) of HSS material having Rockwell hardness 58. All the parameter were kept constant and aluminium sample plates (150*100*6 mm) were processed under vertical milling machine with 1000 number of rotations and feed rate 19mm/min. All these parameter were kept constant during all four profiles. CNC Vertical milling machine used for processing. Final results carried out based on mechanical testing of FSP processed aluminium 6063 plates. All specimens processed with four tool pin profile show better result than base plate. But out of four pin profile pentagonal pin profile show better results than other three pin profiles. Result show that microstructure were fine grains without any cracks in processing zone by using pentagonal tool pin profile with better mechanical properties (micro hardness, impact strength and Rockwell hardness), because pentagonal pin profile provided more stirring action and crystallizations in nugget zone. Better results by profiles are as (1) pentagonal tool pin profile (2) square tool pin profile (3) circular tool pin profile (4) threaded pin profile.

Keywords: Friction stir processing, Tool pin profiles, FSPed aluminium mechanical properties

I. Introduction

Friction stir processing (FSP) is solid state process in which a non consumable stirring (rotating) tool plunged into work piece up to half thickness, which causes intense plastic deformation, material mixing, and thermal exposure, resulting in refinement of micro structural, enhancement of mechanical properties and homogeneity of the processed (nugget) zone. In friction stir processing, a rotating tool with pin and shoulder is (made from material like HSS, mild steel etc). inserted up to 1/2 thickness of workpiece, and shoulder touches the workpiece surface.

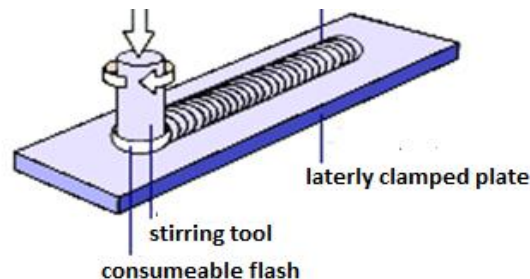


Fig.1.1: friction stir processing principle

The FSP technique is emerging as a very effective solid-state processing (material remains in plastic state) technique that can provide localized modification and control of microstructures of soft materials in the near-surface layers of processed metallic components. In the relatively short duration after its invention, increasing applications are being found for FSP in the fabrication, processing, making composites etc. Friction stir process is quite simple process

which can well controlled by using numerical controlled machines. The use of FSP generates significant frictional heating and intense plastic deformation, thereby resulting in the occurrence of dynamic recrystallization in the stirred zone (SZ) or nugget zone (NZ). Furthermore, the FSP technique has been used for the fabrication of a surface composite on aluminum substrate and the homogenization of powder metallurgy (PM) aluminum alloys, metal matrix composites, and cast aluminum alloys. Compared to other metalworking techniques, In FSP, the major processing parameters are the tool rotating rate, the tool traversing speed and proper tool pin profile there are different types of tool profiles. The intense plastic deformation around the tool and the friction between the tool and the work piece both contribute to the temperature increase in the stirred zone (SZ).SZ is processing zone where tool starting stirring (rotating). Generally, an increase in the ratio of the rotation rate to the traversing speed will increase the peak temperature in FSP. In the present thesis it is try to find out proper tool pin profile in friction stir processing. In the present study, the effect of the tool pin profile on mechanical properties is to be examined that how these profile effect mechanical properties of aluminium 6063.

II. Experimentation

Friction stir processing of the base plate (6063 Al) was performed on a CNC vertical milling machine, (made by HAAS automations INDIA) a using a FSP tool, as described earlier. Before FSP, the plate having dimension 150*100*6mm, was gripped in the fixture. The fixture containing duly gripped base plate was placed and tightened with the bed of CNC vertical milling machine. Commands are given to machine with spindle speed of 1000rpm and feed rate 19mm/min. Tool depth given 3mm in work piece surface. Tool firstly start rotating in air and then plunged into work piece where tool start stirring at 1000rpm (nugget zone). All the procedure repeated by each four profiles i.e. pentagonal, rectangular, threaded and circular tool pin profile at same constant parameters. Tool holder holds tool by pneumatic action, so it was very easy to change tool again and again during operation. Four plates were processed by four tool pin profiles with one each. Results obtained are discussed in next section.

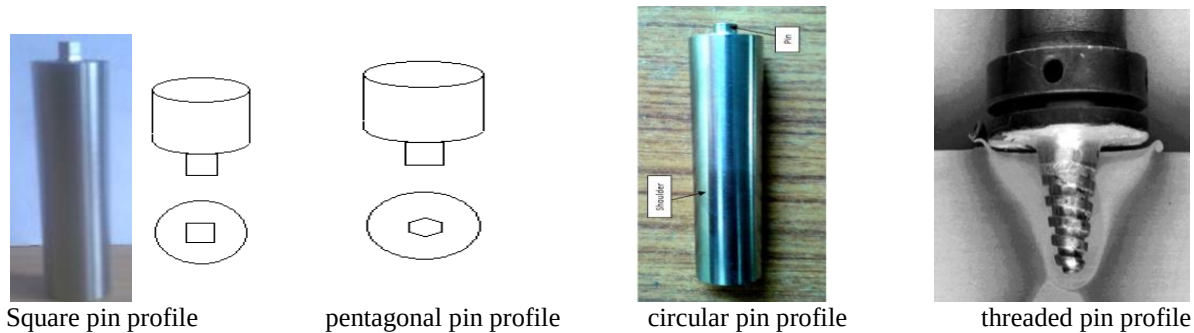


Fig.2.1: different tool pin profile used

Table.2.1: process parameter for each profile

Tool profile	Process parameter
Pentagonal tool pin profile	Spindle speed=1000 feed rate=19mm/min
Threaded tool pin profile	Spindle speed=1000 feed rate=19mm/min
Circular tool pin profile	Spindle speed=1000 feed rate=19mm/min
Square tool pin profile	Spindle speed=1000 feed rate=19mm/min

In this study the FSP was performed on plate made of 6063 aluminium alloy. Chemical compositions is as following

Table.2.2: base material composition

Element	wt%		
Cu	0.082	Zn	0.061
Mg	0.619	Pb	0.046
Si	0.600	Ti	0.024
Fe	0.350	Titanium	0.015
Magnese	0.044	Cr	0.007
Ni	0.006	Al	97.94

A. Characterization and testing of samples

A.1 Izod impact strength testing

Impact tests provide information on the resistance of a material to sudden fracture where a sharp stress riser or flaw is present. In addition to providing information not available from any other simple mechanical test, these tests are quick and inexpensive. The data obtained from such impact tests is frequently employed for engineering purposes. Impact testing on FSP aluminium 6063 conducted because Al 6063 is domestically used material (used in window, door frame and architecture engineering) where impact load always act on material. So it is necessary to find out impact strength of material before and after FSP. In present study izod test conducted on al 6063 specimens as shown in following diagrams.

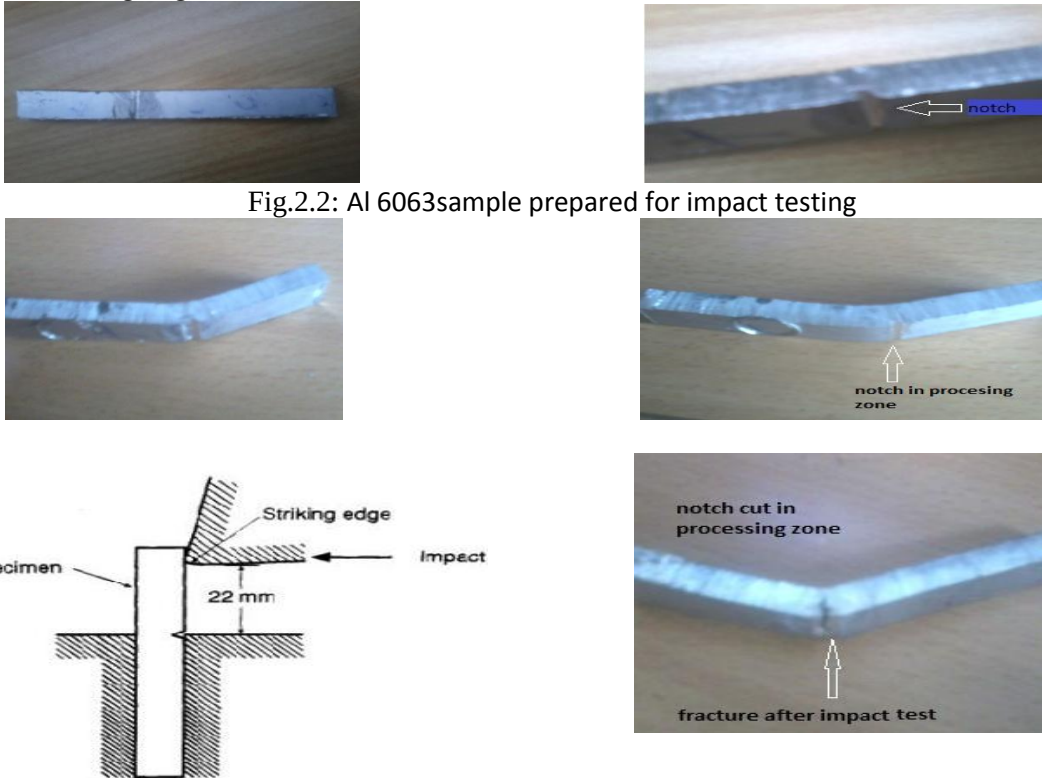


Fig.2.2: Al 6063 sample prepared for impact testing

Fig.2.3: striking position and specimen fracture after izod impact test

Various standard impact tests are widely employed in which notched specimens are broken by a swinging pendulum. In this testing IZOD impact testing used to find out the impact strength. For this purpose specimen cut into desired shape by hand hacksaw and notch cut up to 2mm in processing zone for weaken the processing zone area so that impact strength of processed area can be measured as shown in above diagram. Above diagrams show standard dimensions of specimen for hold on vice and R.H.S. diagram show specimen after impact testing. Results of test for each profile are discussed in next chapter.

A.2 Rockwell hardness testing

To check the Rockwell hardness processed specimens grinded into 10*10 mm sizes. 1kg of load applied on plate surface after which different results were obtained which are discussed in next chapter. Pyramid shape indenter was used for testing size of 1/6" ball.



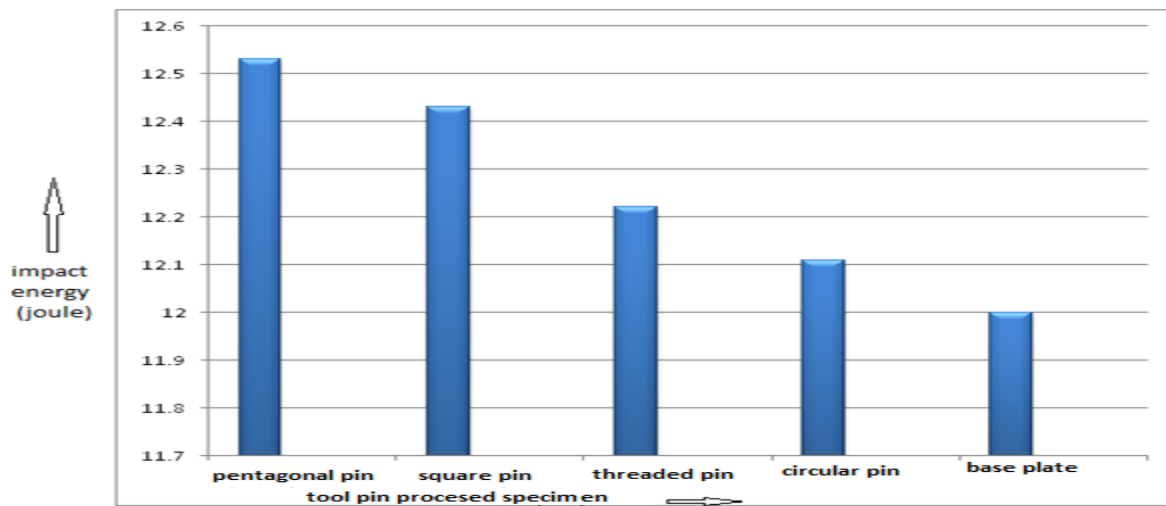
Fig.2.4: Pyramid shape indenter and indenter marks in processed zone

III. Results of impact strength

Aluminium specimen both processed and unprocessed were tested to find out impact strength variation in which test shows that material bends, deforms and does not completely break as brittle material (cast iron). Impact strength of processed specimens was measured in the processed zone area by providing a notch in the processed zone (as shown in the previous chapter) and base plate also. After results it has been found that the processed zone has more impact strength (12.53) than the base plate (12 joule). It is clear that there is also an increase in impact strength of FSP processed specimen.

Table.3.1: impact strength results

Tool profile	Impact load (kg)	Impact strength (in Joule)
Pentagonal pin profile	5	12.53
Square pin profile	5	12.43
Threaded tool profile	5	12.22
Circular tool profile	5	12.11
Base plate	5	12.00



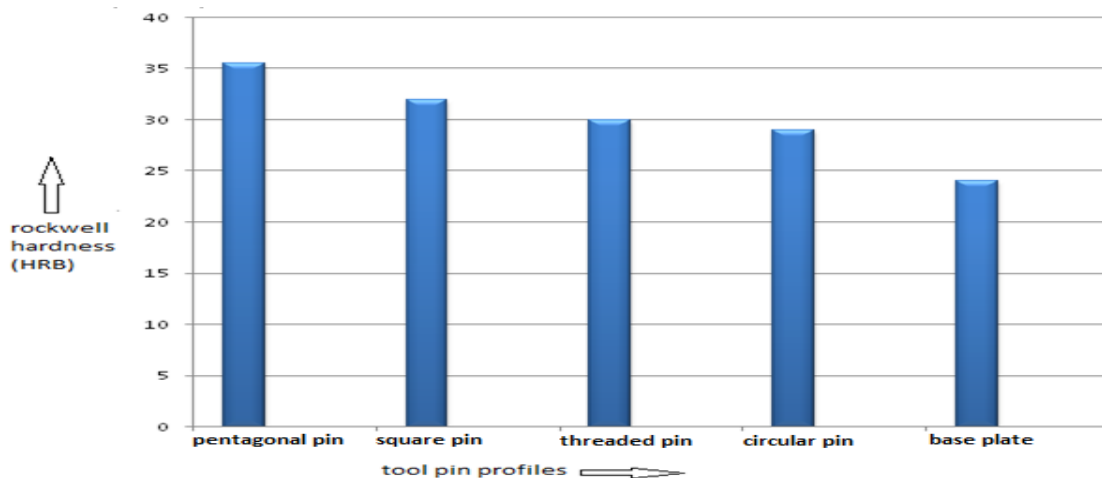
Out of the processed specimen, the pentagonal tool pin profile specimen shows more impact strength (12.53 joule) than the other three profiles as shown in table 3.1. It is also clear that FSP processed material having fine grained microstructure has maximum mechanical properties than the unprocessed base plate of aluminium 6063.

A. Rockwell hardness testing result

Friction stir processed sample plates show more hardness than base metal because the processed plate has a fine grain crystallized homogeneous microstructure which is responsible for more hardness than the unprocessed base plate. Rockwell hardness of each processed specimen was measured in the center and sides and the mean of three values was evaluated. It was observed that the side of the nugget zone sides has slightly more Rockwell hardness than its center as shown in table 4.4. Out of four tool pin profiles, the pentagonal tool profile processed plate specimen has maximum Rockwell hardness HRB 35.5.

Table.3.2: Rockwell hardness result

Tool pin profile	Parameter(load)	Results(hardness)
Pentagonal tool pin processed specimen	1kg	HRB 35.5
Square tool pin processed specimen	1kg	HRB 32
threaded tool pin processed specimen	1kg	HRB 30
circular tool pin processed specimen	1kg	HRB 29
Base plate specimen	1kg	HRB 24



Finally Best results obtained by profiles (in all tests) are as
 Pentagonal tool pin profile $\square$ square tool pin profile $\square$ threaded tool pin profile $\square$ circular tool pin profile

IV. Conclusion

- First of all it is clear that all FSP processed specimen gives maximum mechanical properties than Al 6063 base plate (unprocessed).
- Secondly, effect of each tool pin profile examined by conducting the test on specimens, processed by each profile. Results show that pentagonal tool pin profile processed plate gives best result in mechanical tests. Reason behind that pentagonal tool pin profile having sharp edges with which are responsible for more stirring action and crystallizations in nugget zone hence fine grain microstructure.
- There is slightly increase in impact strength 12.53 joule with pentagonal tool pin profile than base plate and remaining three tool pin profiles (table 3.1). Rockwell hardness 35.5 HRB of pentagonal tool pin profile processed plates than base plate Al 6063

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