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"Numerical and experimental investigation of processing parameters of friction stir processing on engineering materials"

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ABSTRACT- *Traditional grain refinement techniques involve thermo-mechanical processing which is costly, time consuming, and affects negatively the environment because of high energy consumption. Friction Stir Processing (FSP) can be used to effectively produce ultrafine grain and homogenized structure.*
Friction stir processing (FSP) enhances mechanical properties by localized microstructure modification in the engineering material like Stainless steel, Aluminum.Friction between the workpiece and tools resulted into localized heating that softens and plasticizes the workpiece. A volume of processed material is produced by materials movement from the front of the pin to the back of the pin. During this process, the material undergoes highly plastic deformation and this results in significant grain refinement. The tool's geometry profile is an important parameter in determining the size and shape of the stir zone and its corresponding regions. Also high refinement of grain structure obtain if amount of heat generated at contact between tool and workpiece is removed instantly. In this paper we will study effect the different parameters of Friction stir processing on hardness of material

Index Terms-FSP, Tribology, plastic deformation, Grain refinement.

I. INTRODUCTION

304 stainless steel is used for a variety of household and industrial applications such as screws, machinery parts, car headers, and food-handling equipment. 304 stainless steel is also used in the Architectural field for exterior accents such water and fire features. However, it is susceptible to corrosion from chloride solutions (notably saline environments with high amounts of sodium chloride). Chloride ions can create localized areas of corrosion, called "pitting," which can spread beneath protective chromium barriers to compromise internal structures. Solutions with as little as 25 ppm of sodium chloride can begin to have a corrosive effect. Hence if the surface hardness and high surface finish is achieve then it enhances tribological properties of SS304mechanical properties of polycrystalline metallic materials without need to change their chemical compositions. It is well established that ultrafine grained alloys exhibit superior strength, excellent superplastic behavior, and higher fatigue and wear resistance as well as enhanced diffusivity than the course grained ones. Therefore, the production of bulk ultrafine grained alloys especially in sheet form appeals for a wide range of commercial applications. Among engineering materials,

Austenitic stainless steels due to their excellent corrosion resistance and good weldability are of practical importance. However, application of these alloys in structural components is restricted because of their low mechanical strengths. In the absence of phase transformations, severe plastic Deformation is the most promising method for refining the grain structures of these materials. So far, several attempts have been made to fabricate ultrafine grained structures in austenitic stainless steels by high pressure torsion.

Friction stir processing (FSP), Friction stir processing (FSP) is a new solid-state processing technique that can be used for surface hardening through microstructural modification. This process is an off shoot of the friction stir welding (FSW) process used for solid state joining of two separate pieces of metallic materials. Basically, FSP involves the use of a non-consumable rotating tool with a pin and shoulder inserted into a single piece of material and traversed along the desired path .This action results in significant microstructural changes in the processed zone as a result of severe plastic deformation, mechanical mixing, and thermal exposure of the material. In this process, a specially designed rotating tool is plunged into the sheet to be processed and traversed along the line of interest. The localized heating is produced by friction between the tool shoulder and the sheet surface as well as shear plastic deformation of the material in contact with the tool. Depending on the process parameters, the peak temperature at the stir zone rises to 0.6–0.95Tm, where Tm is the absolute melting temperature of the material. Thus, FSP is considered to introduce severe plastic deformation at elevated temperatures.[4]Severe plastic deformation (SPD) is a generic term describing a group of metal-working techniques involving very large strains which are imposed without introducing any significant changes in the overall dimensions of the specimen or work-piece. Processing by SPD provides the opportunity to achieve remarkable grain refinement in bulk crystalline solids. Typically, materials processed by SPD have grain size in sub micrometer and nanometer range [5].

In recent years much attention has been paid to FSP/FSW of ferrous alloys such as carbon steels, high strength low alloy steels, ductile irons, tool steels and stainless steels. Though interestingly, there are very few reports on the formation of ultrafine grained structures in friction stir processed steels. It is believed that the grain refinement inside the stir zone occurs through dynamic recrystallization. Moreover, [4] showed that cavitation erosion resistance of AISI 316L stainless steel is significantly improved by FSP. The current work is an attempt to evaluate the feasibility of FSP on producing ultrafine grained structures in thin AISI 316L stainless steels sheets using a pin less tool. It is found that the tool shoulder has a considerable effect on the material flow during friction stirring of relatively thin sections. It is expected that the results of this work would be helpful for development of bulk ultrafine grained stainless steel sheets in the near future. The DEFORM-3D software is used to develop a 3-D Lagrangian incremental finite element method (FEM) simulation of friction stir processing (FSP). The developed simulation allows prediction of the defect types, temperature distribution, effective plastic strain, and especially material flow.[3] The heat generation during FSP strongly depends on both rotational and transverse speed where the peak temperature was observed to be strong function of the rotational speed while the rate of heating was a strong function of the transverse speed.[1] FSP appears to induce the austenite to martensite transformation within the AISI 420, but the resulting microstructures appear to be significantly different from the conventionally heat treated material.[7] Principle of friction stir processing is to stir material of sheet by specially designed cylindrical tool , the tool consists of a hemispherical pin and a concentric larger diameter shoulder .While the tool is rotating the pin is plunged into the sheet and the shoulder comes in contact with the surface of the sheet. The friction between the tool and the sheet generates heat which softens the material without reaching the melting temperature of the material; that is why it is a solid state process. Then the tool is transverse in the desire direction while it is rotating. The rotation of the pin does the stirring action of the softened material which forces the material to undergo intense plastic deformation.

2. Experimentation

2.1 Material selection

Tool material selected is D2 tool steel, having chemical composition (%Fe-balanced) (measured by Prompt lab by spectromax analysis) as given in table

Constituent Material	%C	%Mn	%Cr	%Si	%S	%P
% in alloy	2.10	0.33	10.37	0.32	0.026	0.024

Specimen plate-stainless steel 304 (purchased from SNACO traders and tested by Lata metal testing services) having chemical compositions as shown in the below table.

Constituent Material	%Ni	%Cr	%Mn
% in alloy	8.26	18.23	1.51

2.2 Measuring different parameters

1) Temperature-

Tool used for calculating increase in temperature K type sensors, Temperature indicator manufactured by GAURAV ENGG with calibration error of 1% (as per calibration result provided)

2) Force

Force measured before taking actual experimentation by taking Static impression of tool on plate and calculating using BHN formula

BHN=2P/(3.14*D[D-√(D^2-d^2)])

D= dia of tool

d=impression dia

VHN formula

VHN=1.85*P/d^2

Here p=30kg

2.3 parameter selection

parameters\No.	1	2	3
Rotational velocity (rpm)	50	240	720
Feed(mm/s)	2	2	2
Load(in terms of lifting worktable in upward direction) (mm)	0.4	1	1.5

Table 1.parameters for friction stir process

2.4 Sample preparation

1. Cutting plates of SS304 by 150*100 mm dimension
2. Heating plates at 1060 C for 2 Hours ,and water cooled
3. Stress relieving at 400 C for 6 hours
4. Polishing surface with polish paper of grit 1200
5. Drilling holes of depth 20 mm and 2 mm diameter on plate parallel to feed of tool on sides to calculate temperature

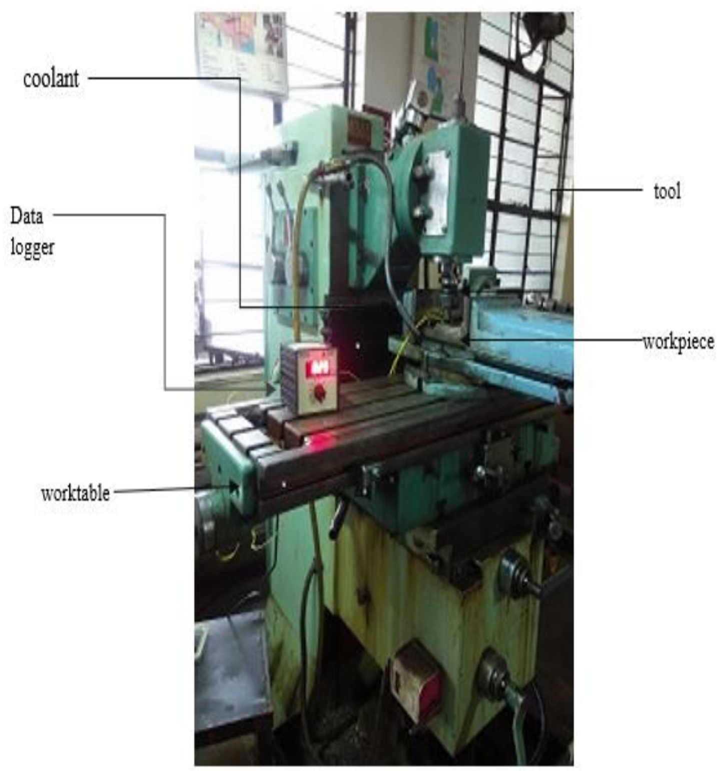


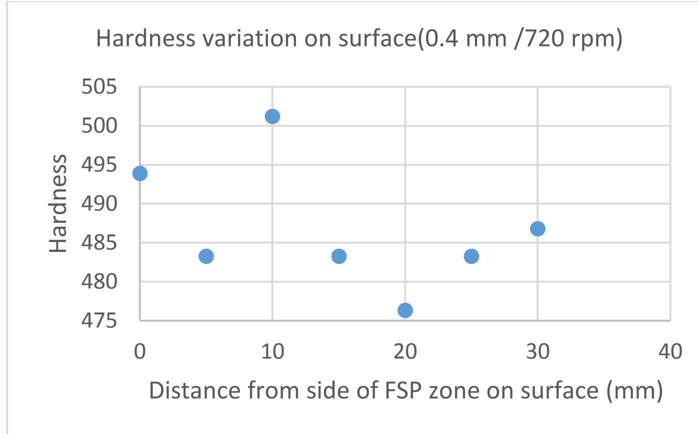
Fig.1. Experimental setup

2.5 Experimental setup

For carrying out experimentation ,vertical mill is used ,with having arrangement of working at different speed, feed is manually operated, movement of cross feed for overlapping FSP zone is also available, coolant speed is controllable and is set to be 22ml/s to 30 ml/s to extract heat generated at frictional stir processed zone for gaining microstructure and stopping grain growth, data logger used for calculating temperature generated at first pass which is at 20 mm distance from plate side , stir length is150 mm long and 30 wide , temperature measured using k type sensor which is inserted in 20 mm hole of diameter 2.2 mm, k type sensor having dia below 2 mm for adjustment in hole, milling machine work table have upward and downward motion facility and also left-right movement and incoming and out coming movement. Plate is fixed on worktable in between fixture so that it should not move from its place. Surface contact between tool checked carefully so to check alignment of plate force is applied on plate as per calculated by moving worktable in upward direction. Hardness of material is tested on Vickers hardness tester at load of 5kg on plate at 5 mm distance from side ,before calculating hardness on Vickers testing machine ,sample prepared for hardness testing by polishing surface at which hardness has to calculate.

Fig.2.Friction stir plate with worktable 0.4 mm upward and tool speed 720 rpm

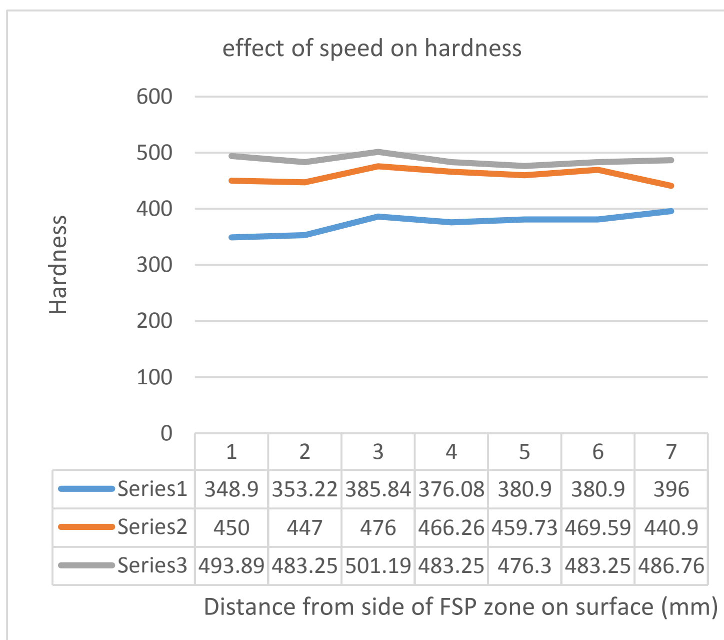
Fig.3. Friction stir plate with worktable 1.5 mm upward and tool speed 720 rpm



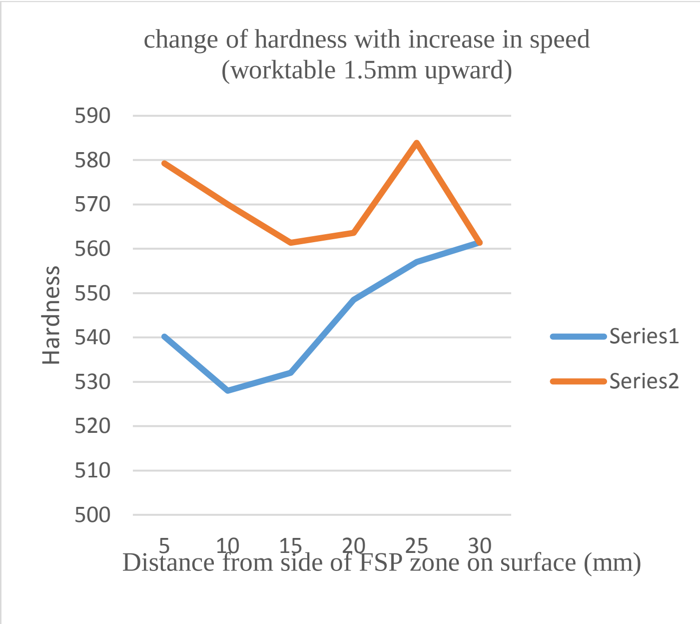
Graph.1.Hardness variation on surface (0.4 mm /720 rpm)

3. Result

The original hardness of material before FSP is found on Vickers tester is between "191-205". Temperature variation shown is negligible and is increases in the range from room temperature 1-14' C. Hardness of material increases with velocity ,with force by keeping feed parameter constant, graph 1 show hardness of material on surface is in range of 476-501 VRC which is increase from 192.40 VRC ,at speed of 720 rpm. Also graph 2 shows effect of speed on hardness, series 1 shows parameter with velocity of 50rpm, series 2 shows parameter with velocity of 240rpm, series 3 shows parameter with velocity of 720rpm, moving worktable 0.4mm upward at feed of 2mm/s, shows that hardness increase with velocity parameter

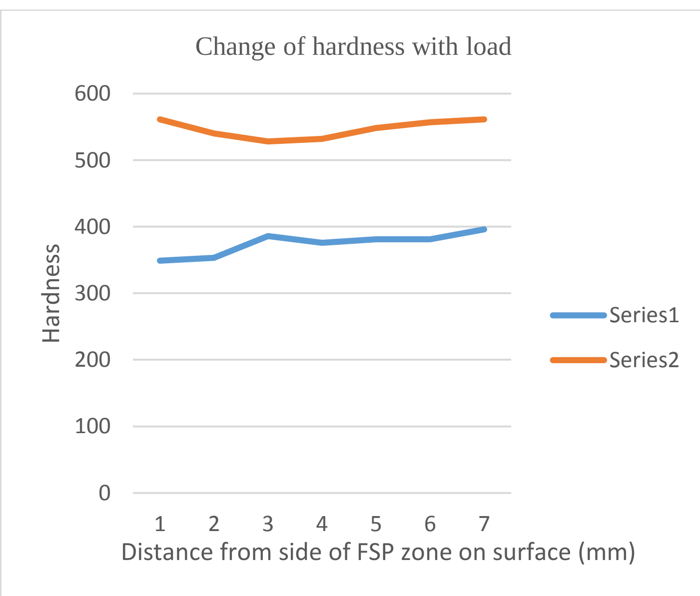


Graph.2.effect of speed on hardness



Graph.3.effect of speed on hardness

Also graph 4 shows that with increase in load, hardness increase at constant velocity 50 rpm and constant feed of 2mm/s. series 1 shows parameter with velocity of 50rpm load at 0.4mm, series 2 shows parameter with velocity of 50rpm load at 1.5mm, at constant feed of 2mm/s.



Graph.4.Change of hardness with load

4. Conclusion

- Due to FSP surface hardness increases drastically
- With increasing velocity, hardness also increases by keeping load parameter and feed constant.
- With increases in velocity hardness increases.

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