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Improving Surface Hardness in Aluminum Plate by Adding Alumina Powder (Al_2O_3) through Friction Stir Processing

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ABSTRACT

Friction-stir processing (FSP) is an emerging surface-engineering technology that can locally eliminate casting defects and refine microstructures, thereby improving strength and ductility, increase resistance to corrosion and fatigue, enhance formability, and improve other properties. In this work, Alumina particles were dispersed in the surface of AA6063 Al alloy through FSP process. It was observed from the micro hardness results that the strength of friction stir processed surface composite exhibited is increased as compared to unprocessed area .The improved mechanical properties of AA6063 alloy reinforced with Al2O3 will be well suitable for aircraft applications.

KEYWORDS:Friction stir Processing, AA 6063, Alumina particles, surface hardness, etc.

1. INTRODUCTION:

Friction-stir processing (FSP) is an emerging surface-engineering technology that can locally eliminate casting defects and refine microstructures, thereby improving strength and ductility, increase resistance to corrosion and fatigue, enhance deformability, and improve other properties [Wang et al, 2009]. FSP can also produce fine-grained microstructures through the thickness to impart super plasticity. FSP zones can be produced to depths of 0.5 to 50 mm, with a gradual transition from a fine-grained, thermodynamically worked microstructure to the underlying original microstructure. Essentially, FSP is a local thermo mechanical metal working process that changes the local properties without influencing properties in the remainder of the structure.

A schematic illustration of FSP is shown in Fig.1.1. To friction process a location within a plate or sheet, a specially designed cylindrical tool is rotated and plunged into the selected area. The tool has a small diameter pin with a concentric larger diameter shoulder. When descended to the part, the rotating pin contacts the surface and rapidly friction heats and softens a small column of metal. The tool shoulder and length of entry probe control the penetration depth. When the shoulder contacts the metal surface, its rotation creates additional frictional heat and plasticizes a larger cylindrical metal column around the inserted pin. The shoulder provides a forging force that contains the upward metal flow caused by the tool pin.

During FSP, the area to be processed and the tool are moved relative to each other such that the tool traverses, with overlapping passes, until the entire selected area is processed to a fine grain size. The rotating tool provides a continual hot working action, plasticizing metal within a narrow zone, while transporting metal from the leading face of the pin to its trailing edge. The processed zone cools, without solidification, as there is no liquid, forming a defect-free recrystallized, fine grain microstructure. Essentially, FSP is a local thermomechanical metal working process that changes the local properties without influencing properties in the remainder of the structure.

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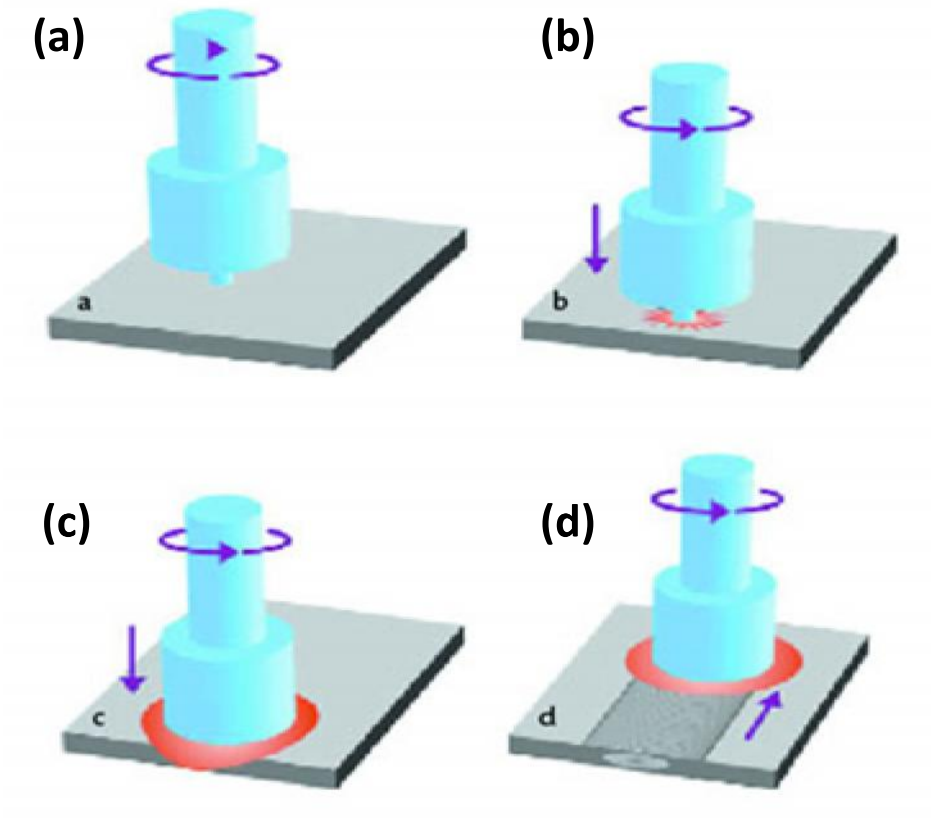

Fig. 1.1. Schematic illustration of friction stir processing: (a) rotating tool prior to contact with the plate; (b) tool pin makes contact with the plate, creating heat; (c) shoulder makes contact, restricting further penetration while expanding the hot zone; and (d) plate moves relative to the rotating tool, creating a fully recrystallized, fine grain microstructure.

2. EXPERIMENTATION

2.1 PROBLEM DESCRIPTION

Based on the literature survey, it was observed that more researches have been successfully made in surface reinforcement of bulk material using Friction Stir Processing (FSP) technique. Even though the microstructures of the bulk materials are improved by this process, it is necessary to increase the refinement of grain structure and to increase the surface hardness further. This has been improved by incorporating nano particles on the surface of the bulk materials using FSP. Few studies have been carried out by incorporating different nano particles on different bulk materials. However, there is no work on fabrication of AA 6063 Al alloy surface reinforced with Al_2O_3 via FSP. Therefore, the present work investigates the study on microstructure and mechanical behavior in terms of hardness for AA 6063 Al alloy reinforced with Al_2O_3 via FSP.

2.2 PRODUCING NANO COMPOSITE USING FSP

In general, the conventional metals/alloys are having poor mechanical properties especially in light weight based metals/alloys. To eradicate this problem, grain refinement plays an important role for improvement of mechanical properties. Recently, much attention has been paid to a new surface modification technique called friction stir processing (FSP) to get improved mechanical properties.

During FSP, a rotating tool will be inserted into a substrate of the work material and that will produce a highly plastically deformed zone. This stir zone will consists of fine and equiaxed grains formation in the surface of the work material which may be due to dynamic recrystallization. By stirring the substrate of the metals/alloys, the strength can be improved. Further improvement of strength in the metals/alloys is necessary for high temperature aircraft, space and automotive applications.

This can be achieved by incorporating the nano particles on the surface of the metals/alloys via FSP technique. In this work, alumina particles are going to be dispersed in the AA 6063 alloy in order to improve the mechanical properties of AA 6063 alloy which will be well suitable for aircraft applications.

2.3 INCORPORATING ALUMINA PARTICLES ON THE SURFACE OF ALUMINUM ALLOY AA6063 BY FSP

Commercially available alumina powder (mean diameter: 1µm, 99.9% pure) was used. The alumina powder was filled on surface of AA6063 plate (150×150×10mm) before the FSP. The FSP tool made of HSS has a cylindrical shape (Ø16 mm) with a probe (Ø4 mm, length: 3.6 mm). The probe was inserted into the groove filled with the alumina powder. A constant tool rotating rate of 500 rpm was adopted and the constant travel speed was changed from 25 to 200 mm/min. The geometry of FSP tool used in the present investigation is shown in Fig 2.3

2.4 PROPERTIES OF ALUMINUM AA6063

Table 2.1 Composition

Element	**Weight %**
Al	98.9
Si	0.40
Mg	0.70

Table 2.2 Properties of AA6063

Properties		**Conditions** **T (°C)**
Density (×1000 kg/m^3)	2.7	25
Poisson's Ratio	0.33	25
Elastic Modulus (GPa)	70-80	25
Tensile Strength (Mpa)	90	25
Yield Strength (Mpa)	48	
Hardness (HB500)	25	25
Shear Strength (MPa)	69	25
Fatigue Strength (MPa)	55	25
Thermal Expansion (10^{-6}/ºC)	23.4	20-100
Thermal Conductivity (W/m-K)	218	25

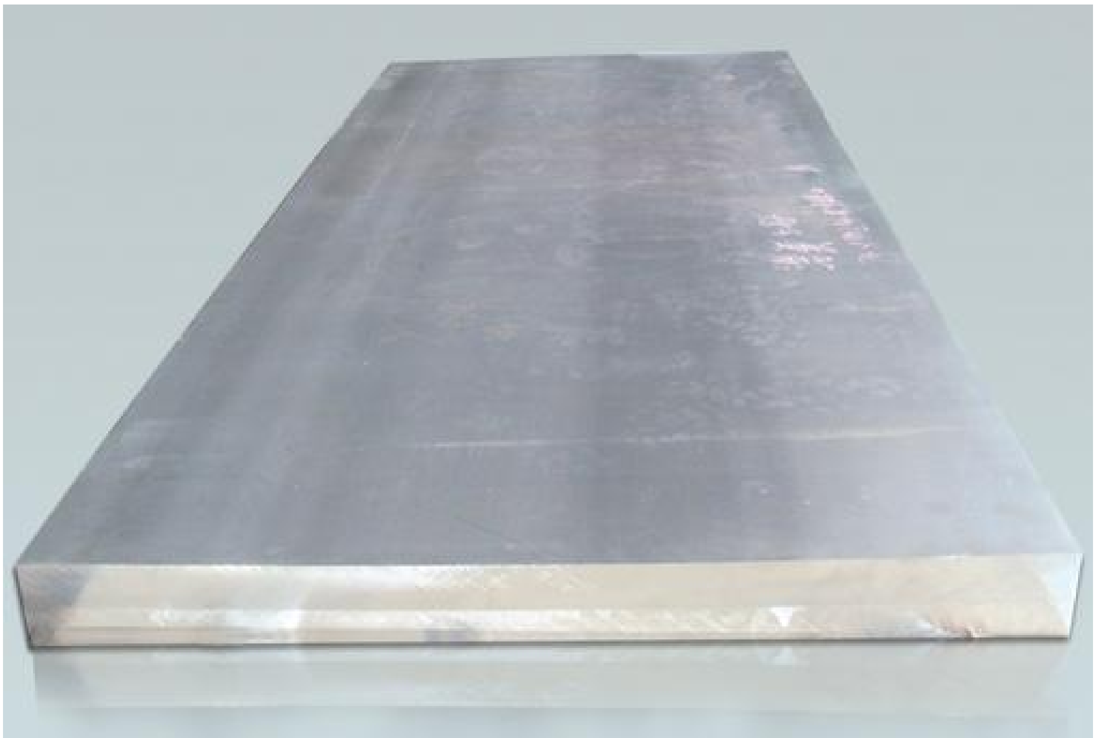

Fig 2.1 Aluminium plate AA6063

Fig 2.2 Nano particle Alumina powder Al_2O_3

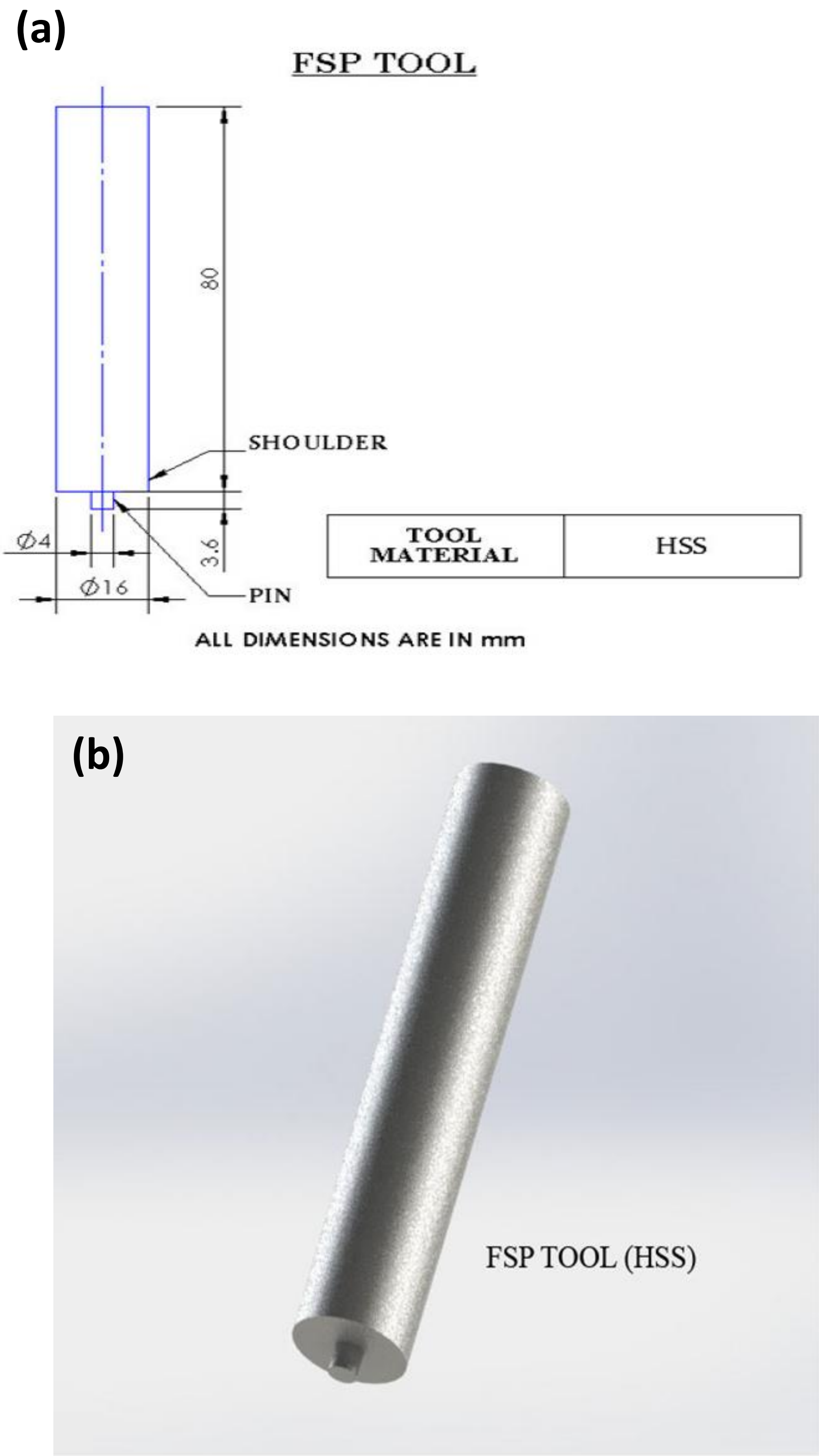

Fig 2.3 (a) The design geometry FSP tool;
(b) The 3D design view of FSP tool used in the present investigation

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Fig 2.4 Processing image

3.0 RESULTS & DISCUSSION

The BRINELL and ROCKWELL hardness is chosen to calculate the hardness of the plate. This is tested before and after the process and compared later. This will shows us whether the hardness is increased or decreased.

3.1.1 BRINELL-HARDNESS BEFORE FSP:

Table 3.1 Brinell hardness Before FSP

Material	**Diameter ofIndendator(D) mm**	**Diameter of Indentation(d) mm**	**Load (N)**	**Brinell Hardness**
AA6061	5	3.5	500	44.553 BHN
AA6061	5	3.6	500	41.605 BHN
AA6061	5	3.6	500	41.605 BHN
			AVG	**42.587 BHN**

3.1.2 ROCKWELL-HARDNESS BEFORE FSP:

TABLE 3.2 ROCKWELL HARDNESS BEFORE FSP

MATERIAL	**Rockwell-Hardness**
AA6061	B55
AA6061	B40
AA6061	B32
AVG	**B42.333**

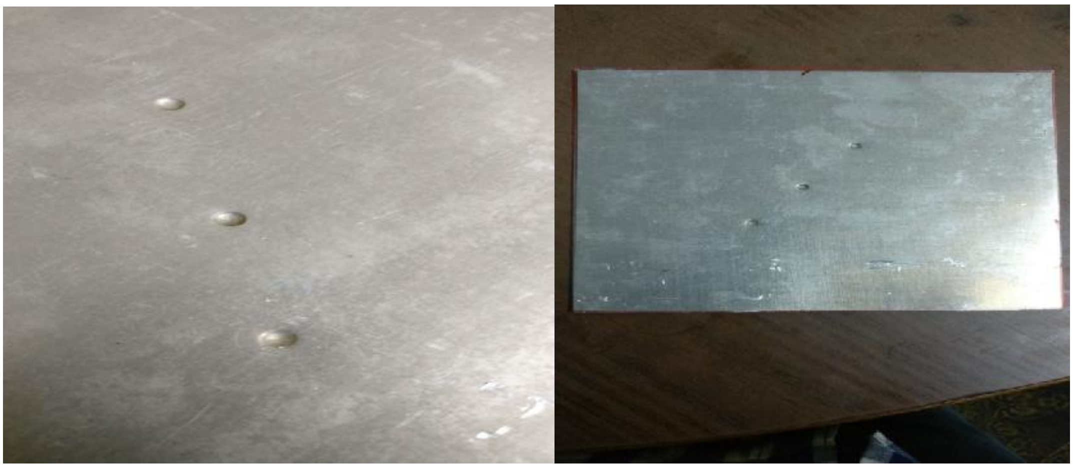

Fig 3.1 Brinell hardness indentation before FSP

3.1.3 BRINELL-HARDNESS OF AFTER FSP:

FOR 1 PASS:

TABLE 3.3 BRINELL HARDNESS AFTER FSP

Material	**Diameter of Indendator(D)mm**	**Diameter of Indentation(d)mm**	**Load (N)**	**Brinell Hardness**
AA6061	5	3.5	500	44.553 BHN
AA6061	5	3.6	500	41.605 BHN
AA6061	5	3.5	500	44.553 BHN
			AVG:	**43.000 BHN**

FOR 2 PASSES:

TABLE 3.4 BRINELL HARDNESS AFTER FSP

Material	Diameter of Indendator(D) mm	Diameter of Indentation(d)mm	Load (N)	Brinell Hardness
AA6061	5	3.1	500	59.119 BHN
AA6061	5	3.0	500	63.661 BHN
AA6061	5	3.3	500	51.190 BHN
			AVG:	**57.991 BHN**

3.1.4 ROCKWELL HARDNESS AFTER FSP:

FOR 1 PASS:

TABLE 3.5 ROCKWELL HARDNESS AFTER FSP

MATERIAL	Rockwell Hardness
AA6061	B46
AA6061	B36
AA6061	B46
AVG	**B42.666**

FOR 2 PASSES:

TABLE 3.6 ROCKWELL HARDNESS AFTER FSP

MATERIAL	Rockwell Hardness
AA6061	B43
AA6061	B42
AA6061	B50
AVG	**B45**

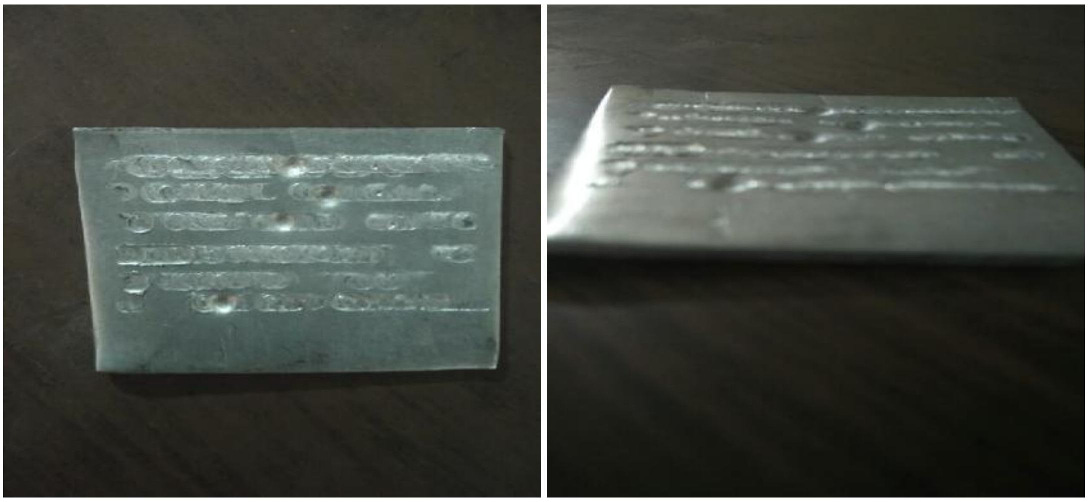

Fig 3.2Al Plates After FSP

3.2 MICROSTRUCTURE STUDIES:

It can be observed that the distributions of reinforcements in the particular matrix are fairly uniform. Further these figures reveal the homogeneity of the composites. The microphotograph also clearly reveals the increased filler contents in the composites. It can be concluded that the surface composite can easily fabricated via FSP technique.

The microstructure of the AA6061 unprocessed was observed under polarized light of an optical microscope. AA6061 sheets FS processed at various combinations of rotational and translational speeds are cut along the cross section and are prepared for metallographic study (to observe under both the optical microscope and also under transmission electron microscope for qualitative and quantitative analysis respectively).

The optical microscope pictures of the FS processed AA6061 are presented in Error! Reference source not found. The grain refinement as a result of FSP can be qualitatively analyzed using these optical microscope pictures. In order to quantify this refinement, the processed zone is observed.

3.3 MICROSTRUCTURE ANALYSIS BEFORE AND AFTER FSP:

Fig 3.3Microstructure of Al plate before FSP

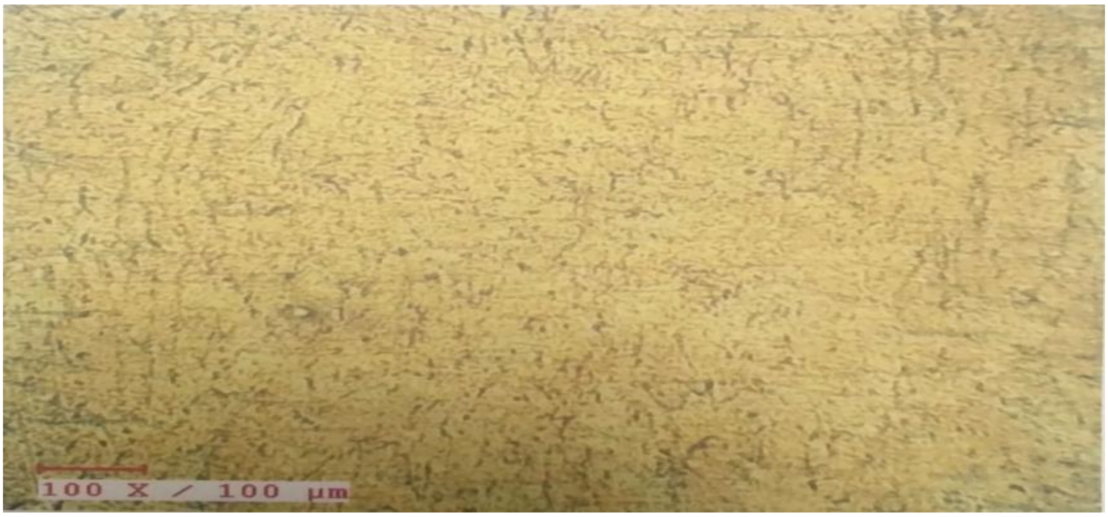

Fig 3.4Microstructure of Al plate after FSP

4. CONCLUSION

The hardness of aluminium plate AA6061 has increased after the friction stir process. This type of process in industry level is used for aerospace, automotive field, columns etc. AA6063 alloy was selected because it is non heat treated, since non heat treatable metals will not get effected by the Friction stir process. The improvement of hardness of Al plate is clearly shown by above calculations and both BRINELL and ROCKWELL hardness tests were done and the Brinellhardness increased from 1 pass to 2 passes is *34.86* percentage and hardness of Rockwell from 1 pass to 2 passes is *5.47* percentage.

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