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Study of Mechanical and Microstructural Properties of Polypropylene Reinforced With Al_2o_3 Nano Composites by Using Friction Stir Welding Process

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Abstract:- Friction stir welding is a solid state joining process first used for welding of Aluminum and its alloys, is now employed for welding of polymers and composite materials. Polypropylene (pp) is one of polymer materials used in many applications due to its good performance, high strength to weight ratio and excellent processing properties, its application is limited due to its weak abrasive properties, impact resistance at low temperatures. Al2O3 reinforcement used to modify the properties of polymermatrix due to its excellent dielectric properties, good thermal conductivity, high strength and resistance even at the elevated temperatures. In this study ball milling of Al2O3 powder particles was carried out, particles reduced to nano composites size and produces Al2O3 nano composites. The volume percentage of nano sized Al2O3 particles ranged from 5% to 15% in polypropylene matrix. From microscopic observations, it was clear that the distribution of reinforcing particles was uniform. Moreover tensile and micro-hardness tests have been utilized to investigate the mechanical properties of prepared samples in different volume percentages. It has been observed that the samples with high percentage of nano sized Al2O3 powder show higher micro-hardness number as well as higher ultimate tensile strength.

Keywords:- fsw, pp composites,reinforcingdistribution,mechanicalproperties.

I. INTRODUCTION

Polypropylene (PP) is one of the Polymeric materials which has an extensive applications in aeronautics, automobiles, constructions, oil and gas Industries. Polypropylene (PP) is used in automotive industry and electronic applications due to its good performance, high strength to weight ratio and excellent processing properties as well as low cost. However, its application is limited due to its weak abrasive properties, relatively poor impact resistance at room or low temperatures and low hardness. The use of inorganic fillers has been a common practice in the plastics industry to improve the mechanical properties of thermoplastics, such as heat distortion temperature, hardness, toughness, stiffness, and mould shrinkage. Therefore, so much attention has been paid to improve the mechanical properties of PP thermoplastic in the last few decades.

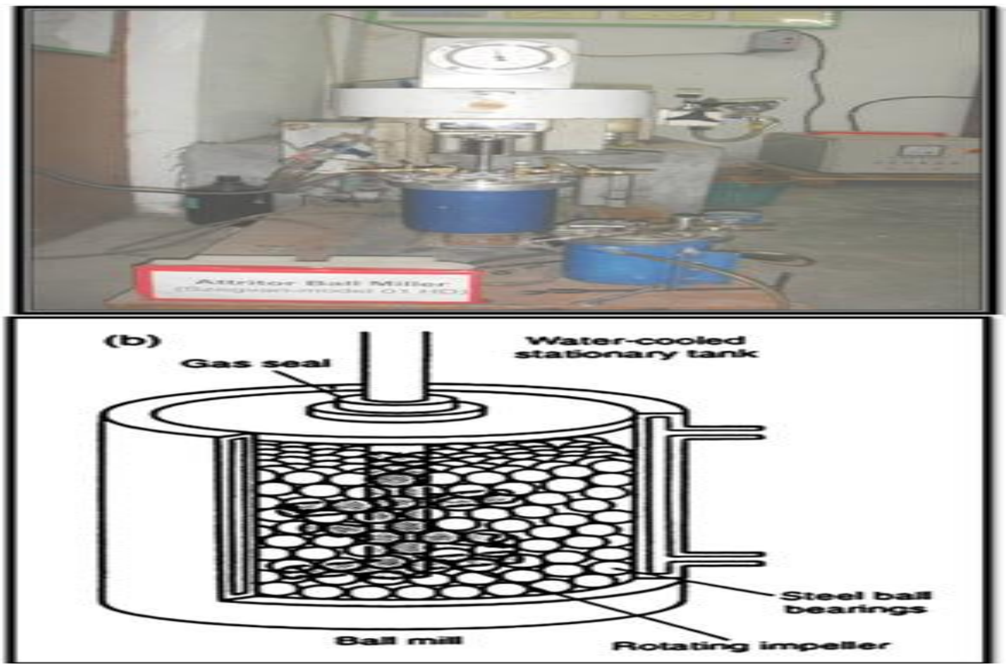
Polypropylene sheets

The effects of filler on the mechanical and physical properties of the composites strongly depend on its shape, particle size, aggregate size, surface characteristics and degree of dispersion. As the filler/matrix interfacial bonding and filler dispersion are crucial for the final composite performance, different surface treatments will be applied to the alumina nano fillers. In general, the mechanical properties of composites filled with micron-sized filler particles are inferior to those filled with nano particles of same filler. Nano particles are entities with diameters in the range of 1–100 nm. When nano particles are embedded in polymer, the resulted composite material is known as polymer nano composite Recently, the methods utilized for preparation of nano composites and properties of manufactured nanocomposite are much under attention. Among reinforcement utilized to modify mechanical properties, alumina (Al2O3) has received large interest because of its excellent dielectric properties, good thermal conductivity, high strength, and resistance to strong acid and bases even at elevated temperatures. In this study ball milling of Al2O3 powder was carried out in order to produce Al2O3 nano composites.

nanoparticles are formed in a mechanical device, referred to as a “mill,”in which energy is imparted to a course-grained material to effect a reduction in particle size. the resulting particulate powders can exhibit nanostructural characteristics . the particles possess a distribution of sizes, can be “nanoparticles” if their average characteristic dimension is less than 100nm .

The objectives of milling include particle size reduction (grinding);amorphization; particle size growth; shape changing(flaking); agglomeration; solid-state blending (incomplete alloying); modifying, changing, or altering properties of a material (density, flow ability, or work hardening); and mixing or blending of two or more materials or mixed phases. However, the primary objective of milling is often purely particle size reduction.

The fundamental principle of size reduction in mechanical attrition devices lies in the energy imparted to the sample during impacts between the milling media. The Figure represents the moment of collision, during which particles are trapped between two colliding balls with in as pace occupied by a dense cloud, dispersion, or mass of powder particles .



FIG; Process of trapping an incremental volume of powder between two balls in a randomly agitated charge of balls and powder

The first stage of compaction starts with there arrangement and restacking of particles. Particles slide past one another with a minimum of deformation and fracture, producing some fine, irregularly shaped particles. The second stage of compaction involves elastic and plastic deformation of particles .Cold welding may occur between particles in metallic systems during this stage. The third stage of compaction, involving particle fracture, results in further deformation and/or fragmentation of the particles.

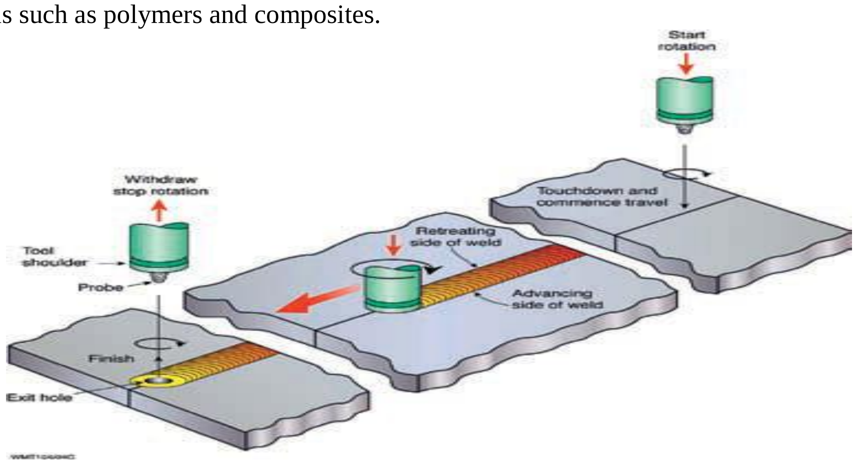
The size and shape of powder particles may be determined accurately with direct methods of either scanning electron microscopy (SEM) for relatively coarse powders or transmission electron microscopy (TEM) for fine powders. The high-energy ball mill is typically used to produce particles in the nano scale size range. Particle size reduction is effected over time in the high-energy ball mill.

FIG.4 SHOWS REDUCTION OF AL_2O_3 PARTICLES

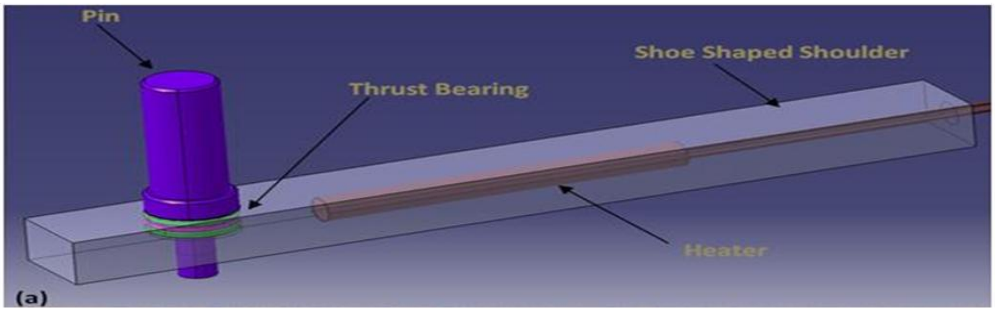
Al2O3 particles before milling and after different milling time

II. EXPERMENTAL SETUP

Friction stir welding (FSW) is a solid state joining process, considered recent development in the welding technology saving costs and weights for steadily expanding the range of applications of light weight, metallic structures. This method first used for welding of Aluminum and its alloys, is now employed for welding of other materials such as polymers and composites.



The tool used in the present study is designed based on the tooling system that has been developed (Strand, 2004). It consists of a shoe, a rotating pin and a heater, which is located at the back of the pin. The designed tool provides the mixing and joining of plastic parts together in the presence of heat. Additionally, a specially designed fixture was utilized to assure that the tool works in its best performance. The shoulder is stationary relative to pin, whereas in FSW of metals, the shoulder rotates with the pin.. The tooling system is as shown in Figure . The main role of pin is to produce frictional heat for softening the work piece and stirring material within the joint. The tool's shoulder is similar to a shoe, which is utilized to contain the displaced material and hold it on the weld, while it is cooled. A heater, equipped with a closed-loop thermo-controller, is primarily responsible for supplying additional heating for the work piece and slowing down the cooling rate of material.



III. RESULTS

TABLE 3.SHOWS MECHANICAL PROPERTIES OF PP+ Al_2O_3 NANO PARTICLES BEFORE WELDING

S .no	MECHANICAL PROPERTY ISO (or) UL TEST PROPERTY	% of PP at 100%	At 95%pp+5% **Al_2O_3 Nano particles**	At 90%pp+10% **Al_2O_3 Nano particles**	At 85%pp+15% **Al_2O_3 Nano particles**
1	YOUNG'S MODULUS (Mpa)	1491	1400	1430	1493
2	ULTIMATE STRENGTH(Mpa)	34.7	35.8	36.2	36.9
3	DEFLECTION (mm)	14.7	13.3	12.5	12.4
4	HARD NESS ROCKWELL no	30	40	48.22	58.32
5	NOTCH IZOD IMPACT STRENGTH (J/m)	21	23.2	24.26	26.22
6	FLEXURAL MODULUS(Mpa)	49.6	45.6	43.33	40.12
7	THERMAL CONDUCTIVITY (W/mK)	0.22	12.2	19.5	22.31

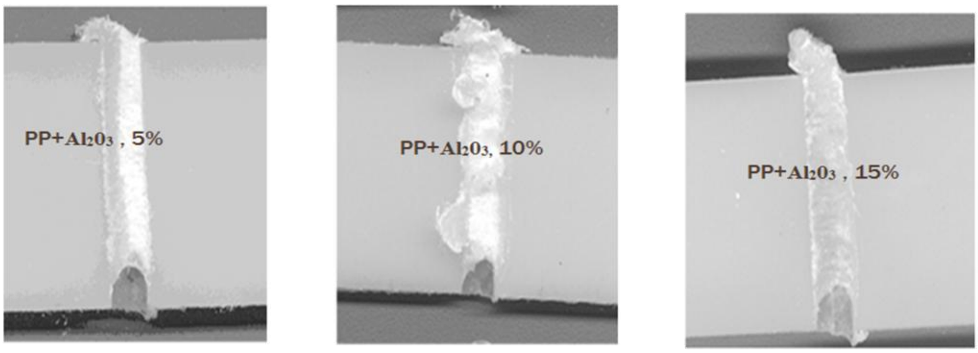
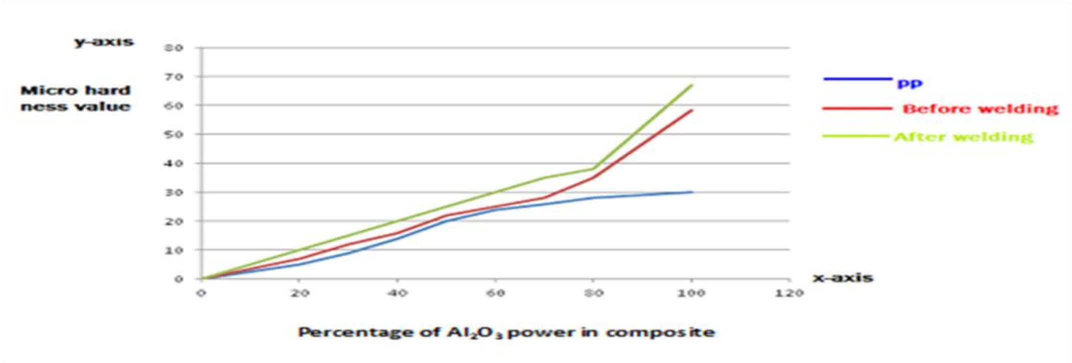


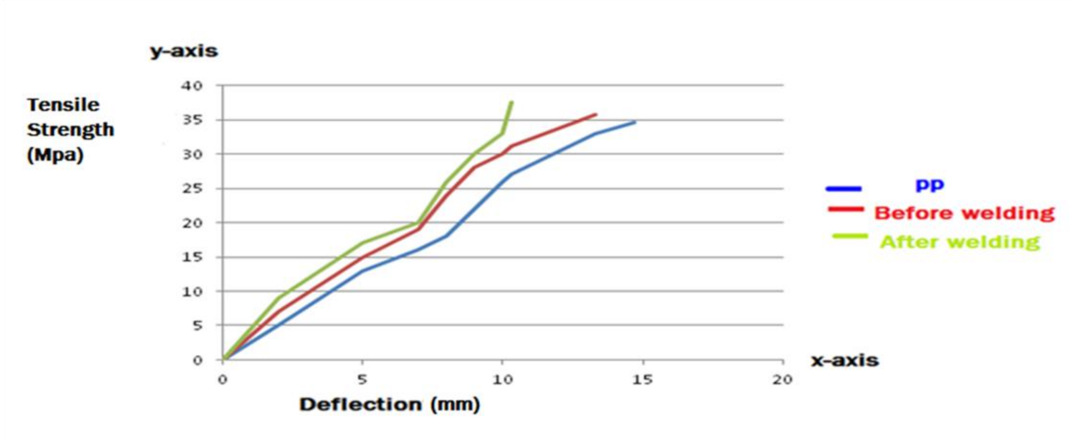
Fig .7 FSW OF PP+Al_2O_3 after welding at 5%,10%,15%.

TABLE 4.Shows Mechanical Properties of PP+ Al_2O_3 Nano particles After BUTT JOINING SHEETS 5%,10%,15% Al_2O_3

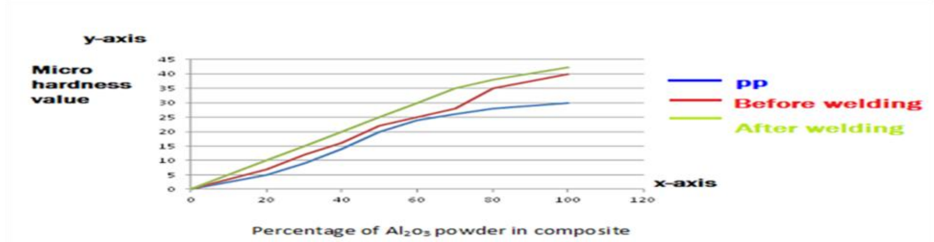
S .no	MECHANICAL PROPERTY ISO (or) UL TEST PROPERTY	% of PP at 100%	At 95%pp+5% **Al_2O_3 Nano particles**	At 90%pp+10% **Al_2O_3 Nano particles**	At 85%pp+15% **Al_2O_3 Nano particles**
1	YOUNG'S MODULUS (Mpa)	1491	1470	1573	1716.95
2	ULTIMATE STRENGTH(Mpa)	34.7	37.59	39.82	42.43
3	DEFLECTION (mm)	14.7	10.33	5.22	1.25
4	HARD NESS ROCKWELL no	30	42	53.04	67.06
5	NOTCH IZOD IMPACT STRENGTH (J/m)	21	24.36	26.68	30.15
6	FLEXURAL MODULUS(Mpa)	49.6	47.88	47.33	46.13
7	THERMAL CONDUCTIVITY (W/mK)	0.22	12.81	21.45	25.66



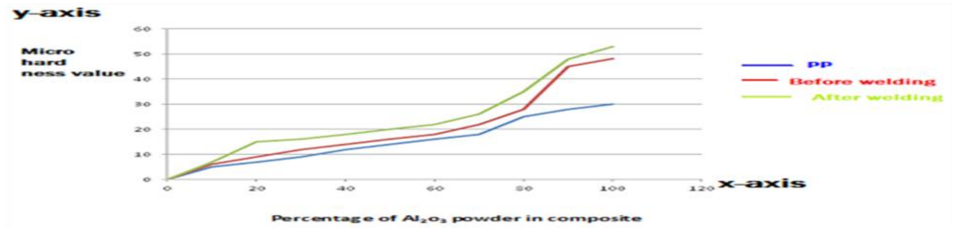
Graph.3 Microhardness test of 85%pp+15% Al_2O_3 Nano particles sheet



Graph.4 shows Tensile strength and deflection of 95%pp+5%Al_2O_3



Graph.1Microhardness test of 95%pp+5% Al_2O_3 Nano particles sheet



Graph.2Microhardness test of 90%pp+10% Al_2O_3 Nano particles sheet

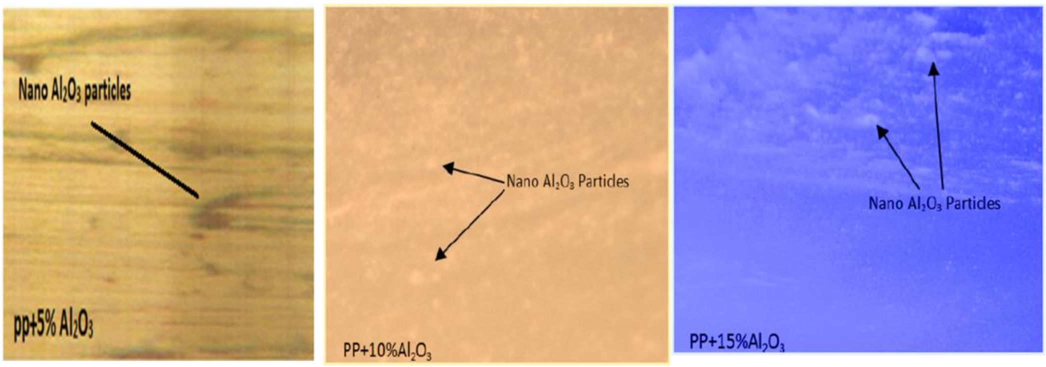
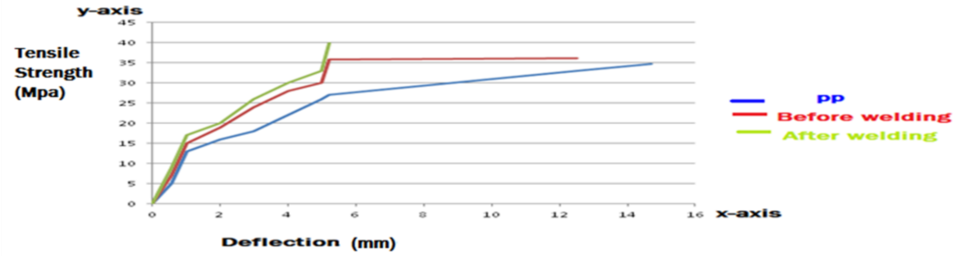
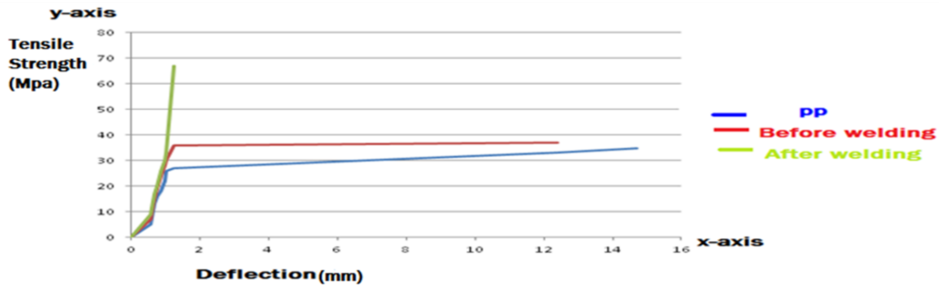


Fig .8 Microstructure properties of 85%pp+15% Al_2O_3 , N 90%pp+10% Al_2O_3, 95%pp+5% Al_2O_3 ano particles After welding at 100nm



Graph.5 shows Tensile strength and deflection of 90%pp+10%aAl_2O_3



Graph.6 shows Tensile strength and deflection of 85%pp+15%Al_2O_3

In this study, an attempt has been made to investigate the mechanical properties of nano filled PP via a new variant of friction stir processing technique and three volume percentages of nanopowder in polymeric matrix has been compared in mentioned properties. present work utilizes friction stir processing concept in which a heating system is added to promote a uniform cooling rate which significantly affects the mechanical and microstructure properties of these materials.

In this article Friction stir welding has been used for butt joining of Polypropylene composite plates reinforced with Al_20_3 Nano particles whose percentage ranges from 5 % to 15% in polypropylene matrix by volume. Tensile and micro hardness tests have been utilized to investigate the mechanical properties of the prepared samples in different volume percentages.

IV. CONCLUSIONS

It is a very effective method for the improvement in mechanical properties of these materials such as tensile strength and hardness value. Comparing with conventional friction stir processing method, designed tooling system leads to a great reduction in manufacturing time

Higher rotational speed resulted in higher tensile and flexural strength, with increasing rotational speed of pin, the local temperature of material would rise up. This can be attributed to low thermal conductivity of polymeric material, which leads to heat concentration in weld nugget.

As a result, more molten material would be presented in joint line that leads to improved stirring conditions as well as weld performance.

Higher rotational speeds and shoulder temperature caused extending weld nugget to base material, which results in good combination of molecular chains as well as reduction of incomplete penetration, as a result, higher weld performance was achieved.

A 54% increase in micro-hardness value and 10% enhancement in ultimate tensile strength were observed for the sample with 10% Nano Al2O3 content. Good distribution of reinforcement alumina particles is responsible for this enhancement.

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