STATIC INVESTIGATION OF MAGNESIUM WITH $CaCo_3$ WITH REINFORCED MMC

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER

EXTERNAL EXAMINER

ABSTRACT

COMPOSITE MMC process in which the relative motion between the tool and the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion. This method relies on the direct conversion of mechanical energy to thermal energy to form the weld without the application of heat from conventional source. The rotational speed of the tools, the axial pressure and COMPOSITE MMC speed are the principal variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld. These parameters are adjusted so that the interface is heated into the plastic temperature range (plastic state) where COMPOSITE MMC can take place. During the last stage of COMPOSITE MMC process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials. The functional behavior of the weldments is substantially determined by the nature of the weld strength characterized by the tensile strength, metallurgical behavior, surface roughness, weld hardness and micro hardness. In this project an attempt is made to determine and evaluate the influence of the process parameters of MMC on the weldments. The tensile strength, weld hardness, macro structure and micro structure are considered for investigation by varying tool speed, tool feed and maintaining constant depth of penetration of weld. Experiments were conducted on MAGNESIUM WITH CaCo3 and AA6201 Magnesium with CaCo3 alloy in a CNC Vertical Machining Centre. The output factors were measured and results show strong relation and robust comparison between the weldment strength and process parameters. Hence FSW process variable data base is to be developed for wide variety of metals and alloys for selection of optimum process parameters for efficient weld.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Fusion COMPOSITE MMC MMC of dissimilar aluminum alloys is very challenging mainly due to the formation of low melting eutectics by the constituent elements resulting in weld solidification cracking (hot cracking). Solidification cracking in aluminum alloys is extremely sensitive to weld metal composition, which depends on the composition of the filler metal, composition of the base metal, and amount of dilution. Therefore, one must carefully choose the filler composition and COMPOSITE MMC parameters such that the resultant weld composition is not susceptible to solidification cracking. This can be done without much problem in the case of fusion COMPOSITE MMC of similar aluminum alloys.

FSW processes are ideally suited for COMPOSITE MMC of dissimilar aluminum alloys. Because these processes do not involve melting, the issue of weld solidification cracking does not arise. Similarly, friction stir COMPOSITE MMC processes overcome a variety of other problems in fusion COMPOSITE MMC of aluminum alloys such as porosity, segregation, brittle intermetallic formation, and heat affected zone liquation cracking. Friction stir COMPOSITE MMC MMC is very attractive for COMPOSITE MMC of dissimilar aluminum alloys as it is suitable for producing welds in a variety of joint configurations, including butt joints.

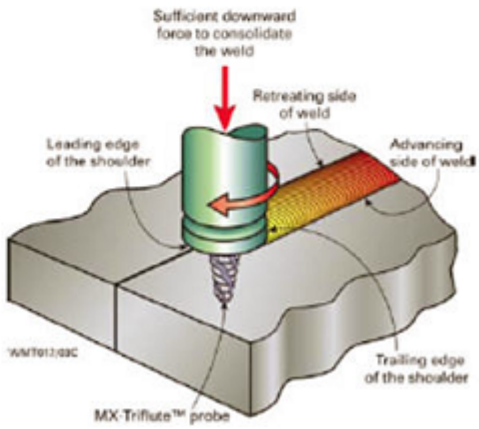


Fig 1.1 FSW

1.2 FEATURES

The main features of the project include the following:

- The COMPOSITE MMC of two metals become easy by the friction stir COMPOSITE MMC process.
- Good mechanical properties in the as-welded condition
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables - a threaded pin made of conventional tool steel, e.g., hardened H13, can weld over 1 km of magnesium with CaCo3, and no filler or gas shield is required for magnesium with CaCo3.
- Easily automated on simple milling machines - lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after COMPOSITE MMC.

- Low environmental impact.

1.3 OBJECTIVE OF THE PROJECT

The FSW of dissimilar magnesium with CaCo3 alloys of the work piece to be welded by the tools of high carbon high chromium of M2 grade with and without coating of tool. The work pieces to be welded by keeping the constant axial force, varying the rotation speed and COMPOSITE MMC speed or feed of the tools. Finally the mechanical properties and parameters of the welded plate were studied.

CHAPTER 2

LITERATURE SURVEY

2.1 FRICTION COMPOSITE MMC PROCESS

The first successful application of this process is COMPOSITE MMC of metals which were reported from Russia in 1956. Earlier this process has been used for joining thermoplastic polymers. In this process one of the pieces to be welded is rotated and the other is made to rub the first one under the axial load resulting in increased friction which helps in heat generation and joining of the two pieces when the pieces are subjected to rest under an enhanced axial load, the joint made by this friction COMPOSITE MMC method is similar to the ones produced by electrical resistance butt COMPOSITE MMC process of flash and upset COMPOSITE MMC. Filler metal, shielding gas or flux is not required by this friction COMPOSITE MMC method. This process is not only used for COMPOSITE MMC cylindrical pieces like tube or rod but, it can also be used to weld in case if one of the components to be welded is symmetrical in shape and can be easily rotated.

2.2 TYPE OF FRICTION COMPOSITE MMC PROCESS

Friction COMPOSITE MMC processes are classified into following:

a) Energy Based classification

b) Relative motion classification

2.2.1 ENERGY BASED CLASSIFICATION

DIRECT DRIVE OR CONTINUOUS

Continuous drive process is a variant where power or energy is provided by an infinite duration source and maintained for a preset period.

STORED ENERGY

The process variant where the energy for COMPOSITE MMC is supplied by the kinetic energy stored in a rotating system or fluid storage system.

HYBRID SYSTEM

It is the combination of some of the features of both the above method.

2.2.2 RELATIVE MOTION BASED CLASSIFICATION

ROTATIONAL

It is a method in which one component is rotated relative to and in contact with the mating face of another component.

LINEAR OSCILLATION

In this method, one component is moved in a linear oscillating motion relative to and in contact with the mating face of another component.

ANGULAR OSCILLATION

In this method, one component is moved in angular oscillating motion about a common component axis relative to and in contact with the mating face of another component.

ORBITAL

In this method, one component is moved in a small circular motion relative to and in contact with the mating face of another component either with components rotating about its own central axis or with components rotating in the same direction about their own axes and at the same speeds but with their axes displaced.

2.3 LITERATURE REVIEWS

2.3.1 FIRST PAPER

M. Koilraj, V. Sundareswaran, S. Vijayan, and S.R. Koteswara Rao have investigated its Friction stir COMPOSITE MMC of dissimilar aluminum alloys AA2219 to AA5083 –Optimization of process parameters using Taguchi technique.

Title	Year	Work Piece	Tool	Testing	Conclusion
FSW of AA2219-AA5083	19 August 2010	Length-150mm Width-65mm Thickness-10mm	Straight Cylindrical Pin (SCP)	Microstructures, Hardness, Tensile test	R.S= 700rpm Feed= 15mm/min D/d= 3

Table 2.1 Details of first paper

Tool	Rotational Speed (rpm)	Feed (mm/min)	D/d	Mean Strength (Mpa)	Soundness of weld
(SCP)	400	15	1.5	105	Defect
(SCP)	550	30	2	239	Defect Free
(SCP)	700	45	2.5	247	Defect Free
(SCP)	800	60	3	158	Defect

Table 2.2 Properties of first paper

2.3.2 SECOND PAPER

P. Cavaliere, and F. Panella have explained the Effect of tool position on the fatigue properties of dissimilar 2024-7075 sheets joined by friction stir COMPOSITE MMC.

Title	Year	Work Piece	Tool	Testing	Conclusion
Effect of tool position on the fatigue properties of 2024-7075 sheets	6 December 2007	Length-200mm Width-80mm Thickness-4mm	Different position of tool	Microstructures, Micro hardness, Tensile, Residual stresses	Increases largely with rising the distance from the weld line up to 1mm

Table 2.3 Details of second paper

Material	Yield Stress (Mpa)	Ultimate tensile strength (Mpa)
2024-7075 0mm	325	424
2024-7075 0.5mm	340	435
2024-7075 1mm	395	460
2024-7075 1.5mm	385	390

Table 2.4 Properties of second paper

2.3.3 THIRD PAPER

D. Muruganandam, K.S. Sreenivasan, S. Ravi Kumar, Sushilal Das and V. Seshagiri Rao did the study of process parameters in friction stir COMPOSITE MMC MMC of dissimilar magnesium with CaCo3 alloys.

Title	Year	Work Piece	Tool	Testing	Conclusion
Study of Process Parameters in FSW of dissimilar Al alloys	-	5456-7075	Cylindrical pin	Radiography, Tensile, Bend test	Tool 600-1200rpm no defect occurs

Table 2.5 Details of third paper

Speed (rpm)	Breaking load (N)	Tensile strength (Mpa)	Fracture position	Root bend	Face bend
600	8850	101	Weld nugget	No cracks	No cracks
800	9250	106	Weld nugget	Cracks occurs at 90°	No cracks

Table 2.6 Properties of third paper

CHAPTER 3

TOOL

3.1 TOOL MATERIAL

Tool steels are groups into six types: high speed, hot work, cold work, shock resisting, special purpose and water hardening. High-speed steels are very efficient with heavy cuts and high speeds they are incapable, at slow speeds and lighter cuts, of holding the keen edge necessary for obtaining a very smooth finish on certain articles. Special steels have been produced for this purpose, known as finishing steels, which are capable of retaining a keen cutting edge for much longer periods than carbon steel used under similar conditions. This steel has good resistance to oxidation at elevated temperatures, high hardness and good wearing properties. It is suitable for intricate sections, dies for blanking, coining, toller threading and drop forging hard materials. High Tungsten-chromium Steel is the best type of steel for hot work except where resistance to scaling or oxidation is important. It is used for hot-drawing, hot-forging, extrusion dies and dies for die casting magnesium with CaCo3, brass and zinc alloys. Die-casting die steels often fall through surface cracking caused by cyclic expansion and contraction, aggravated by the erosive action of the molten metal.

3.1.1 HIGH SPEED STEEL

High speed steel (HSS or HS) is a subset of tool steels, commonly used in tool bits and cutting tools. It is often used in power saw blades and drill bits. It is superior to the older high carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name high speed steel. At room temperature, in their generally recommended heat treatment,HSS grades generally display high hardness and abrasion resistance compared to common carbon and tool

3.1.1.1 TYPES OF HIGH SPEED STEEL

High speed steels belong to the Fe-C-X multi-component alloy system where X represents chromium, tungsten, molybdenum, vanadium, or cobalt. Generally, the X component is present in excess of 7%, along with more than 0.60% carbon. In the unified numbering system (UNS), tungsten-type grades (e.g. T1, T15) are assigned numbers in the T120xx series, while molybdenum (e.g. M2, M48) and intermediate types are T113xx. ASTM standards recognize 7 tungsten types and 17 molybdenum types. The addition of about 10% of tungsten and molybdenum in total maximizes efficiently the hardness and toughness of high speed steels and maintains these properties at the high temperatures generated when cutting metals.

Grade	C	Cr	Mo	W	V	Co	Mn	Si
T1	0.65–0.80	3.75–4.00	-	17.25–18.75	0.9–1.3	-	0.1–0.4	0.2–0.4
M2	0.95	4.2	5.0	6.0	2.0	-	-	-
M7	1.00	3.8	8.7	1.6	2.0	-	-	-
M35	0.94	4.1	5.0	6.0	2.0	5.0	-	-
M42	1.10	3.8	9.5	1.5	1.2	8.0	-	-

Table 3.1 Alloying compositions of common high speed steel grades (by %wt)

M2

M2 is a high speed steel in tungsten-molybdenum series. The carbides in it are small and evenly distributed. It has high wear resistance. After heat treatment, its hardness is the same as T1, but its bending strength can reach 4700 MPa, and its toughness and thermo plasticity are higher than T1 by 50%. It is usually used to manufacture a variety of tools, such as drill bits, taps and reamers. Its decarburization sensitivity is a little bit high.

M35

M35 is similar to M2, but with 5% cobalt added. The addition of cobalt increases heat resistance. M35 is also known as HSSE or HSS-E.

M42

M42 is a molybdenum series high speed steel alloy with additional 8% cobalt. It is widely used in metal manufacturing because of its superior red-hardness as compared to more conventional high speed steels, allowing for shorter cycle times in production environments due to higher cutting speeds or from the increase in time between tool changes. M42 is also less prone to chipping when used for interrupted cuts and cost less when compared to the same tool made of carbide. Tools made from cobalt-bearing high speed steels can often be identified by the letters HSS-CO.

3.1.2 HOT WORK STEEL

H-type tool steels were developed for strength and hardness during prolonged exposure to elevated temperatures. All of these tool steels use a substantial amount of carbide forming alloys. H1 to H19 are based on a chromium content of 5%; H20 to H39 are based on a tungsten content of 9-18% and a chromium content of 3–4%; H40 to H59 are molybdenum based.

3.1.3 COLD WORK STEEL

These tool steels are used on larger parts or parts that require minimal distortion during hardening. The use of oil quenching and air hardening helps reduce distortion as opposed to higher stress caused by quicker water quenching. More alloying elements are used in these steels, as compared to water-hardening grades. These alloys increase the steels harden ability, and thus require a less severe quenching process. These steels are also less likely to crack and are often used to make knife blades.

3.1.4 SHOCK RESISTING STEEL

S-type tool steel is designed to resist shock at both low and high temperatures. Low carbon content is required for the necessary toughness. Carbide-forming alloys provide the necessary abrasion resistance, harden ability, and hot-working characteristics. This family of steels displays very high impact toughness and relatively low abrasion resistance, it can attain relatively high hardness. This type of steel is used in applications such as jackhammer bits.

3.1.5 WATER HARDENING STEEL

W-type tool steel gets its name from its defining property of having to be water quenched. W-grade steel is essentially high carbon plain carbon steel. This type of tool steel is the most commonly used tool steel because of its low cost compared to other tool steels. They work well for small parts and applications where high temperatures are not encountered; above 150 °C (302 °F) it begins to soften to a noticeable degree. Harden ability is low so W-grade tool steels must be quenched in water. These steels can attain high hardness (above HRC 60) and are rather brittle compared to other tool steels.

The toughness of W-type tool steels are increased by alloying with manganese, silicon and molybdenum. Up to 0.20% of vanadium is used to retain fine grain sizes during heat treating.

3.1.6 SPECIAL PURPOSE

- P-type tool steel is short for plastic mold steels. They are designed to meet the requirements of zinc die-casting and plastic injection molding dies.
- L-type tool steel is short for low alloy special purpose tool steel. L6 is extremely tough.
- F-type tool steel is water hardened and substantially more wear resistant than W-type tool steel.

3.2 TOOL PROFILE

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible COMPOSITE MMC MMC speed.

It is desirable that the tool material is sufficiently strong, tough, and hard wearing at the COMPOSITE MMC MMC temperature. Further it should have a good oxidation resistance and a low thermal conductivity to minimize heat loss and thermal damage to the machinery further up the drive train. Hot-worked tool steel such as AISI H13 has proven perfectly acceptable for COMPOSITE MMC MMC magnesium with CaCo3 alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composite MMC MMCs or higher melting point materials such as steel or titanium.

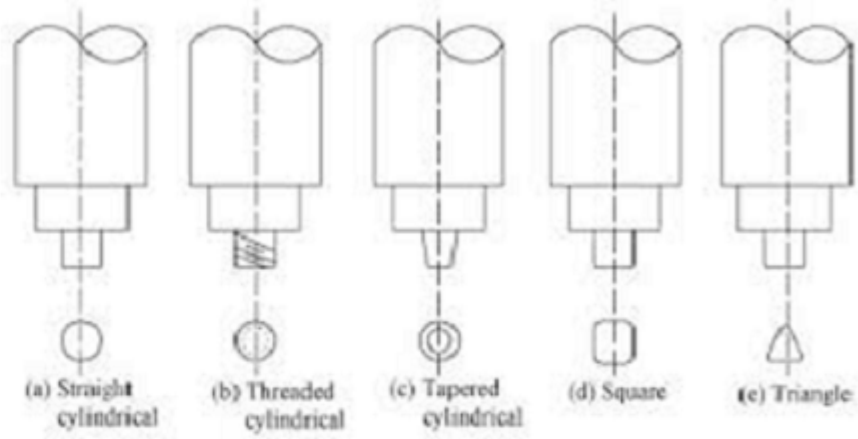


Fig 3.1 Tool Profiles

Improvements in tool design have been shown to cause substantial improvements in productivity and quality. TWI has developed tools specifically designed to increase the penetration depth and thus increasing the plate thicknesses that can be successfully welded. An example is the "whorl" design that uses a tapered pin with re-entrant features or a variable pitch thread to improve the downwards flow of material. Additional designs include the Triflute and Trivex series. The Triflute design has a complex system of three tapering, threaded re-entrant flutes that appear to increase material movement around the tool. The Trivex tools use a simpler, non-cylindrical, pin and have been found to reduce the forces acting on the tool during COMPOSITE MMC MMC.

The majority of tools have a concave shoulder profile which acts as an escape volume for the material displaced by the pin, prevents material from extruding out of the sides of the shoulder and maintains downwards pressure and hence good forging of the material behind the tool. The Triflute tool uses an alternative system with a series of concentric grooves machined into the surface which are intended to produce additional movement of material in the upper layers of the weld.

3.3 SELECTED TOOL DESIGN

The material is of high carbon high chromium steel of M2 Grade. M2 is a high speed steel in tungsten-molybdenum series. The carbides in it are small and evenly distributed. It has high wear resistance. It is usually used to manufacture a variety of tools, such as drill bits, taps and reamers. Its decarburization sensitivity is a little bit high.

Fig 3.2 Tool Material

3.3.1 TOOL PROFILE

Based on the literature survey tapered pin profile was chosen and two tools were machined with one coated and other non coated tool.

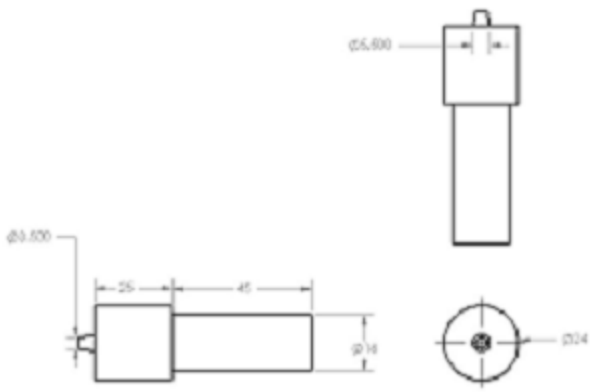


Fig 3.3 Tool Design

3.3.2 MACHINED TOOLS

Two tools were machined with one coated and other non coated tools. Tools were machined in lathe turning machine, heat treated and hardened done at ambattur estate, Chennai.

3.3.2.1 NON COATED TOOL

The high carbon high chromium of M2 grade steel was machined and having the shoulder dia of 18mm and taper pin of upper dia of 6mm and lower dia of 4mm. Then the tool was heat treated and hardened up to 45 HRC.

Fig 3.4 Non coated tool

3.3.2.2 COATED TOOL

The high carbon high chromium of M2 grade steel was machined and having the shoulder dia of 18mm and taper pin of upper dia of 5.5mm and lower dia of 3.5mm with the heat treated and hardened up to 45HRC. Then it was coated with TiAlN or AlCrN for high speeds and higher wears resistance.

Fig 3.5 Coated tool

Using these two tools the work piece was welded based on the parameters of the friction stir COMPOSITE MMC MMC process. By varying the different parameters of the process the experiments was conducted.

CHAPTER 4

WORK PIECE

4.1 WORK PIECE MATERIAL

Magnesium with CaCo3 alloys are alloys in which magnesium with CaCo3 (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of magnesium with CaCo3 is used for wrought products, for example rolled plate, foils and extrusions. Cast magnesium with CaCo3 alloys yield cost effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast magnesium with CaCo3 alloy system is Al-Si, where the high levels of silicon (4.0% to 13%) contribute to give good casting characteristics. Magnesium with CaCo3 alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Alloys composed mostly of magnesium with CaCo3 and magnesium has been very important in aerospace manufacturing since the introduction of metal skinned aircraft. Magnesium with CaCo3-magnesium alloys are both lighter than other magnesium with CaCo3 alloys and much less flammable than alloys that contain a very high percentage of magnesium.

Magnesium with CaCo3 alloy surfaces will keep their apparent shine in a dry environment due to the formation of a clear, protective layer of magnesium with CaCo3 oxide. In a wet environment, galvanic corrosion can occur when an magnesium with CaCo3 alloy is placed in electrical contact with other metals with more negative corrosion potentials than magnesium with CaCo3.

4.2 TYPES OF MAGNESIUM WITH CACO3 ALLOYS

4.2.1 CAST MAGNESIUM WITH CACO3 ALLOYS

Magnesium with CaCo3 casting alloy compositions parallel wrought alloy compositions in many respects. Casting represents the shortest route from raw materials to finished parts – a fact which has been known for five thousand years. Through continuous further development and, in part, by a selective return to classic methods such as the lost-form process, casting has remained at the forefront of technical progress. The most important advantage of the casting process is that the possibilities of shaping the part are practically limitless. Castings are, therefore, easier and cheaper to produce than machined and joined components. The general waiving of subsequent machining not only results in a good density and path of force lines but also in high form strength. Furthermore, waste is also avoided. As a rule, the casting surface displays a tight, fine-grained structure and, consequently, is also resistant to wear and corrosion. Economic realities, i.e. the optimization of investment expenditure and costs in relation to the number of units. With casting, the variable weighting of production costs and quality requirements are also possible. When designing the shape of the casting, further possibilities arise from the use of inserts and/or from joining the part to other castings or work pieces. In the last decade, magnesium with CaCo3 has attained a leading position among cast metals because, in addition to its other positive material properties, this light metal offers the greatest possible variety of casting and joining processes.

Alloys	Characteristics	Representative Alloys
Al-Si Alloys	Good castability	AC4A, AC4C AC94
Al-Mg Alloys	Good corrosion resistance	AC7A, AC7B
Al-Cu Alloys	Increases in strengths by heat treating	AC1A, AC2A, AC5A

Table 4.1Characteristics of cast magnesium with CaCo3 alloys

4.2.2 WROUGHT MAGNESIUM WITH CACO3 ALLOYS

Wrought alloys are divided into 8 groupings called series. Each series has one or more alloying metals mixed with the magnesium with CaCo3 but always one or two main ones. For example the 6063 is part of the 6000 series and so the main alloying constituents are Magnesium and Silicon, but can also contain very low quantities of Iron, Copper, etc. The alloy mix will determine the natural corrosion resistance, extrudability, tensile strength, heat treatability, 24pecializ ability, etc...

With regards to corrosion resistance, the purer the magnesium with CaCo3 the better the natural corrosion resistance of the metal. Copper has the most detrimental effect on corrosion resistance and Magnesium the least. That's why 2000 series alloys with Copper as the main alloying constituent performs poorly and the 5000 series of alloy with Magnesium as the alloying constituent has the best corrosion resistance, with the exception of pure magnesium with CaCo3. The wrought magnesium with CaCo3 alloys consists of seven series and their characteristics, purpose and alloy number are given in the following table.

Alloy	Characteristics	Purpose	Alloy Number
1000 (Pure aluminum)	Excellent corrosion resistance, machinability, electrical/thermal conductivity. Good surface treatability.	Various containers, electrical appliances, reflector plates	1070 1100
2000 (AL-Cu Alloys)	Duralmin alloys, high strength, cuts well. Corrosion resistance and surface treatability is inferior.	Aircrafts, transfer equipment, machine parts	2017 2024
3000 (AL-Mn Alloys)	High strength with corrosion resistance. Press forms well, surface treats well	General objects, cans, construction material	3003 3004
4000 (AL-Si Alloys)	Low melting points. Naturally anodize coloring alloy	Brazing/COMPOSITE MMC MMC fillers, construction material	4043
5000 (AL-Mg Alloys)	Wide alloy variety based on Mg content variations. High strength/corrosion resistance. Surface treats	Construction, structural, ship vessels, can lids, optical	5005 5052 5056 5083

	well.		
6000 (AL-Mg-Si Alloys)	Good corrosion resistance, increase in strength by heat treating. Extrudes and surface treats well.	Door framing, structural	6061 6063
7000 (AL-Zn-Mg Alloys)	Highest strength aluminum alloy. Good weldability.	Aircraft, sporting equipment, railway vehicles, welded structural material	7075 7N01

Table 4.2 Types of wrought magnesium with CaCo3 alloys

4.3 SELECTED WORK PIECE MATERIAL

The Magnesium with CaCo3 series of 6xxx will be used for many applications. This series are mostly used in aircraft and aerospace structures, automotive extrusions etc, so we decided 6201 and 6063 magnesium with CaCo3 alloys for the friction stir COMPOSITE MMC. The selected work piece dimensions of thickness 6mm, length 100mm and width 50mm.

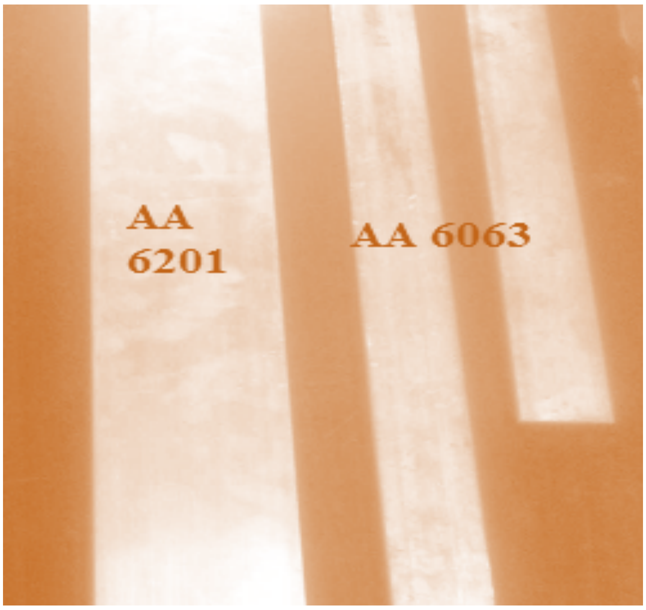


Fig 4.1 Work piece Material

4.3.1 AA6201 OF MAGNESIUM WITH CACO3 ALLOY SERIES

Aluminum alloys are known for their strong corrosion resistance. They are sensitive to high temperatures ranging between 200 and 250°C (392 and 482°F). However, the strength of aluminum alloys can be enhanced at subzero temperatures, thus making them perfect low-temperature alloys.

Aluminum 6201 alloy is a wrought alloy type. The following datasheet will provide more details about aluminum 6201 alloy.

Class	Element	Weight %
Wrought alloy	Al	98.5
	Si	0.70
	Mg	0.80

Table 4.3 Composition of AA6201

Properties		Conditions	
		T (°C)	**Treatment**
Density (×1000 kg/m^3)	2.6-2.8	25	
Poisson’s Ratio	0.33	25	
Elastic Modulus (Gpa)	70-80	25	
Tensile Strength (Mpa)	330	25	T6
Yield Strength (Mpa)	300		T6
Elongation (%)	17		T6
Reduction in Area (%)			T6
Hardness (HB500)	90	25	T6
Thermal Conductivity (W/m-K)	205	25	T81
Electric Resistivity (10^{-9}□-m)	32	25	T81

Table 4.4 Properties of AA6201

4.3.2 MAGNESIUM WITH CACO3 OF MAGNESIUM WITH CACO3 ALLOY SERIES

Magnesium with CaCo3 alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions.

It has a good surface finish and high corrosion resistance is readily suited to COMPOSITE MMC and can be easily specialized. Most commonly available as T6 temper, in the T4 condition it has good formability.

6063 is mostly used in extruded shapes for architecture, particularly window frames, door frames, roofs, and sign frames. It is typically produced with very smooth surfaces fit for anodizing.

6063-O

Un-heat-treated 6063 has maximum tensile strength no more than 19,000 psi (131 Mpa), and no specified maximum yield strength. The material has elongation (stretch before ultimate failure) of 18%.

6063-T4

T4 temper 6063 has an ultimate tensile strength of at least 19,000 psi (131 Mpa) in thicknesses up to 0.5-inch (13 mm), and 18,000 psi (124 Mpa) from 0.5 to 1.0-inch (25 mm) thick, and yield strength of at least 10,000 psi (69 Mpa) up to 0.5-inch (13 mm) and 9,000 psi (62 Mpa) from 0.5 to 1.0-inch (25 mm). It has elongation of 14%.

6063-T6

T6 temper 6063 has an ultimate tensile strength of at least 30,000 psi (196 Mpa) and yield strength of at least 25,000 psi (165 Mpa). In thicknesses of 0.124-inch (3.1 mm) or less, it has elongation of 8% or more; in thicker sections, it has elongation of 10%

Element	6063 % Present	6063A % Present
Si	0.2 to 0.6	0.3 to 0.6
Fe	0.0 to 0.35	0.15 to 0.35
Cu	0.0 to 0.1	0.1
Mn	0.0 to 0.1	0.15
Mg	0.45 to 0.9	0.6 to 0.9
Zn	0.0 to 0.1	0.0 to 0.15
Ti	0.0 to 0.1	0.1
Cr	0.1 max	0.05
Al	Balance	Balance

Table 4.5 Composition of MAGNESIUM WITH CACO3

Temper	O	T4	T6
Minimum Proof Stress 0.2% (Mpa)	50	65	160
Minimum Tensile Strength (Mpa)	100	130	195
Shear Strength (Mpa)	70	110	150
Elongation A5 (%)	27	21	14
Hardness Vickers (HV)	25	50	80

Table 4.6 Properties of MAGNESIUM WITH CACO3

By using the selected work piece of two dissimilar magnesium with CaCo3 alloys COMPOSITE MMC was done by the coated and non coated tools.

CHAPTER 5

FRICTION STIR COMPOSITE MMC PROCESS

Friction-stir COMPOSITE MMC MMC is a solid-state joining process (the metal is not melted) and is used when the original metal characteristics must remain unchanged as much as possible. It mechanically intermixes the two pieces of metal at the place of the join, then softens them so the metal can be fused using mechanical pressure, much like joining clay, dough, or plasticize. It is primarily used on magnesium with CaCo3, and most often on large pieces that cannot be easily heat-treated after COMPOSITE MMC MMC to recover temper characteristics.

It was invented and experimentally proven at The COMPOSITE MMC Institute UK in December 1991. TWI holds patents on the process, the first being the most descriptive.

5.1 PRINCIPLE OF OPERATION

A constantly rotated cylindrical-shouldered tool with a profiled nib is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The nib is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface.

Frictional heat is generated between the wear-resistant components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face forces specialized material to the rear where clamping force assists in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a 32pecialized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

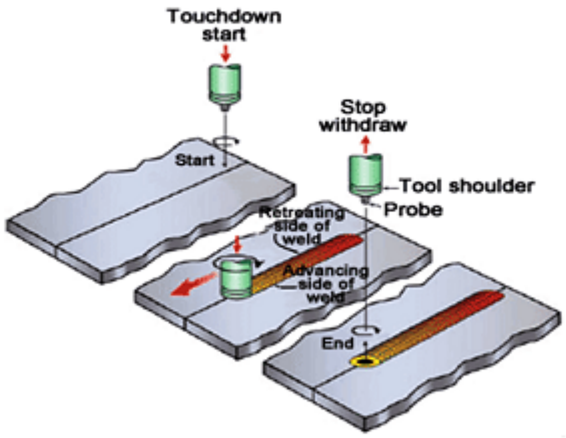


Fig 5.1 FSW PROCESS

5.2 IMPORTANT COMPOSITE MMC PARAMETERS

In the friction stir COMPOSITE MMC process, COMPOSITE MMC parameters are very important during COMPOSITE MMC like tool rotational and transverse speeds, tool tilt and plunge depth, tool design and its details are given below.

5.2.1 TOOL ROTATION AND TRAVERSE SPEEDS

There are two tool speeds to be considered in friction-stir COMPOSITE MMC; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient COMPOSITE MMC cycle. The relationship between the COMPOSITE MMC speeds and the heat input during COMPOSITE MMC is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

Excessively high heat input, on the other hand may be detrimental to the final properties of the weld. Theoretically, this could even result in defects due to the liquation of low-melting-point phases (similar to liquation cracking in fusion welds). These competing demands lead onto the concept of a “processing window”: the range of processing parameters viz. tool rotation and traverse speed that will produce a good quality weld. Within this window the resulting weld will have a sufficiently high heat input to ensure adequate material plasticity but not so high that the weld properties are excessively deteriorated.

5.2.2 TOOL TILT AND PLUNGE DEPTH

The plunge depth is defined as the depth of the lowest point of the shoulder below the surface of the welded plate and has been found to be a critical parameter for ensuring weld quality. Plunging the shoulder below the plate surface increases the pressure below the tool and helps ensure adequate forging of the material at the rear of the tool. Tilting the tool by 2–4 degrees, such that the rear of the tool is lower than the front, has been found to assist this forging process. The plunge depth needs to be correctly set, both to ensure the necessary downward pressure is achieved and to ensure that the tool fully penetrates the weld. Given the high loads required, the COMPOSITE MMC machine may deflect and so reduce the plunge depth compared to the nominal setting, which may result in flaws in the weld. On the other hand, an excessive plunge depth may result in the pin rubbing on the backing plate surface or a significant under match of the weld thickness compared to the base material. Variable load welders have been developed to automatically compensate for changes in the tool displacement while TWI has demonstrated a roller system that maintains the tool position above the weld plate.

5.2.3 TOOL DESIGN

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible COMPOSITE MMC speed. It is desirable that the tool material is sufficiently strong, tough, and hard wearing at the COMPOSITE MMC temperature. Further it should have a good oxidation resistance and a low thermal conductivity to special heat loss and thermal damage to the machinery further up the drive train. Hot-worked tool steel such as AISI H13 has proven perfectly acceptable for COMPOSITE MMC magnesium with CaCo3 alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composite MMC MMCs or higher melting point materials such as steel or titanium.

Widespread commercial applications of friction stir COMPOSITE MMC process for steels and other hard alloys such as titanium alloys will require the development of cost-effective and durable tools. Material selection, design and cost are important considerations in the search for commercially useful tools for the COMPOSITE MMC of hard materials. Work is continuing to better understand the effects of tool material's composition, structure, properties and geometry on their performance, durability and cost.

5.3 COMPOSITE MMC FORCES

During COMPOSITE MMC a number of forces will act on the tool:

- A downwards force is necessary to maintain the position of the tool at or below the material surface. Some friction-stir COMPOSITE MMC

MMC machines operate under load control but in many cases the vertical position of the tool are preset and so the load will vary during COMPOSITE MMC.

- The traverse force acts parallel to the tool motion and is positive in the traverse direction. Since this force arises as a result of the resistance of the material to the motion of the tool it might be expected that this force will decrease as the temperature of the material around the tool is increased.
- The lateral force may act perpendicular to the tool traverse direction and is defined here as positive towards the advancing side of the weld.
- Torque is required to rotate the tool, the amount of which will depend on the down force and friction coefficient (sliding friction) and/or the flow strength of the material in the surrounding region.

In order to prevent tool fracture and to minimize excessive wear and tear on the tool and associated machinery, the COMPOSITE MMC cycle is modified so that the forces acting on the tool are as low as possible and abrupt changes are avoided. In order to find the best combination of COMPOSITE MMC parameters, it is likely that a compromise must be reached, since the conditions that favor low forces (e.g. high heat input, low travel speeds) may be undesirable from the point of view of productivity and weld properties.

5.4 FLOW OF MATERIAL

Early work on the mode of material flow around the tool used inserts of a different alloy, which had a different contrast to the normal material when viewed through a microscope, in an effort to determine where material was moved as the tool passed. The data was interpreted as representing a form of in-situ extrusion where the tool, backing plate and cold base material from the “extrusion chamber” through which the hot, specialized material is forced. In this model the rotation of the tool draws little or no material around the front of the pin instead the material parts in front of the pin and passes down either side. After the material has passed the pin the side pressure exerted by the “die” forces the material back together and consolidation of the join occurs as the rear of the tool shoulder passes overhead and the large down force forges the material.

More recently, an alternative theory has been advanced that advocates considerable material movement in certain locations. This theory holds that some material does rotate around the pin, for at least one rotation, and it is this material movement that produces the “onion-ring” structure in the stir zone. The researchers used a combination of thin copper strip inserts and a “frozen pin” technique, where the tool is rapidly stopped in place. They suggested that material motion occurs by two processes:

- Material on the advancing front side of a weld enters into a zone that rotates and advances with the pin. This material was very highly deformed and sloughs off behind the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it was broken up into fragments. These fragments were only found in the arc shaped features of material behind the tool.
- The lighter material came from the retreating front side of the pin and was dragged around to the rear of the tool and filled in the gaps between the arcs of advancing side material. This material did not rotate around the pin and the lower level of deformation resulted in a larger grain size.

5.5 GENERATION AND FLOW OF HEAT

For any COMPOSITE MMC process it is, in general, desirable to increase the travel speed and specialize the heat input as this will increase productivity and possibly reduce the impact of COMPOSITE MMC on the mechanical properties of the weld. At the same time it is necessary to ensure that the temperature around the tool is sufficiently high to permit adequate material flow and prevent flaws or tool fracture.

When the traverse speed is increased, for a given heat input, there is less time for heat to conduct ahead of the tool and the thermal gradients are larger. At some point the speed will be so high that the material ahead of the tool will be too cold and the flow stress too high, to permit adequate material movement, resulting in flaws or tool fracture. If the "hot zone" is too large then there is scope to increase the traverse speed and hence productivity.

The COMPOSITE MMC cycle can be split into several stages during which the heat flow and thermal profile will be different:

- Dwell. The material is preheated by a stationary, rotating tool to achieve a sufficient temperature ahead of the tool to allow the traverse. This period may also include the plunge of the tool into the work piece.
- Transient heating. When the tool begins to move there will be a transient period where the heat production and temperature around the tool will alter in a complex manner until an essentially steady-state is reached.
- Pseudo steady-state. Although fluctuations in heat generation will occur the thermal field around the tool remains effectively constant, at least on the macroscopic scale.

- Post steady-state. Near the end of the weld heat may "reflect" from the end of the plate leading to additional heating around the tool.

5.6 ADVANTAGES

The advantages of FSW for COMPOSITE MMC magnesium with CaCo3 can be 38 pecialize as follows:

- As a solid state process it can be applied to all the major magnesium with CaCo3 alloys and avoids problems of hot cracking, porosity, element loss, etc. common to magnesium with CaCo3 fusion COMPOSITE MMC processes.
- As aspecialize process, FSW does not rely on 38 pecialized COMPOSITE MMC skills; indeed manual intervention is seldom required.
- No shielding gas or filler wire is required for magnesium with CaCo3 alloys.
- The absence of fusion removes much of the thermal contraction associated with solidification and cooling, leading to significant reductions in distortion; however, it is not a zero distortion technique.
- It is very flexible, being applied to joining in one, two and three dimensions.
- Excellent mechanical properties, competing strongly with welds made by other processes.

- Workplace friendly: There are no ultraviolet or electromagnetic radiation hazards as the absence of an arc removes these hazards from the process; the process is no noisier than a milling machine of similar power, and generates virtually zero spatter, fume and other pollutants.

5.7 PREPARATION OF COMPOSITE MMC

For the COMPOSITE MMC preparation, the process parameters were selected by keeping the constant axial force, varying the rotational speed and feed of the tools.

5.7.1 SELECTED PROCESS PARAMETERS

Based on the literature survey the process parameters were selected and listed below:

Speed (rpm)	Feed (mm/min)
800	10
800	13
1000	10
1000	13

Table 5.1 Process Parameters of COMPOSITE MMC

5.7.2 WELD PREPARED IN VMM

Weld was prepared in CNC based vertical milling machine for controlling the speed and feed rates. The work pieces were welded with the speed of 800 and 1000rpm and feed rate was kept 10mm/min and 13mm/min by the coated and uncoated tools and also by changing the process parameters.

Fig 5.2 CNC Vertical Milling Machine

5.7.3 WELDED PLATES

The magnesium with CaCo3 plates of two dissimilar alloys of 6201 and 6063 were welded by coated and non coated tools according to the process parameters.

5.7.3.1 WELDMENTS BY COATED TOOL

By using the coated tool, the magnesium with CaCo3 plates were welded in the CNC vertical milling machine by changing the rotating speed and feeds of the tool according to the process parameters.

Fig 5.3

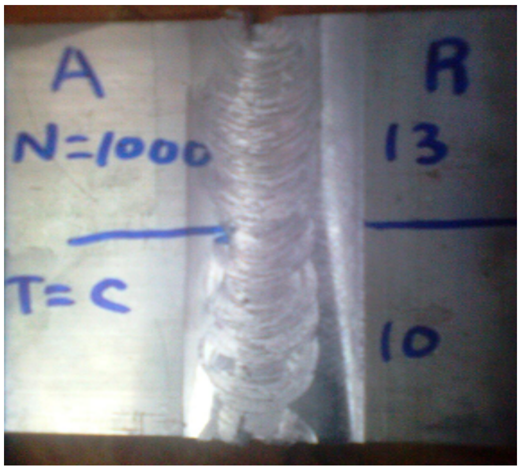


Fig 5.4

5.7.3.2 WELDMENTS BY NON COATED TOOL

By using the non coated tool, the magnesium with CaCo3 plates were welded in the CNC vertical milling machine by changing the rotating speed and feeds of the tool according to the process parameters.

Fig 5.5

Fig 5.6

After finishing the welded plates, the plates were cut into the tensile test specimens. The mechanical properties, hardness test and micro structures were tested.

CHAPTER 6

HARDNESS TEST

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness.

Hardness is depends on ductility, elasticity stiffness, plasticity, strain, strength, toughness, viscoelasticity and viscosity.

6.1 TYPES OF HARDNESS

SCRATCH HARDNESS

Scratch hardness is the measure of how resistant a sample is to fracture or permanent plastic deformation due to friction from a sharp object. The principle is that an object made of a harder material will scratch an object made of a softer material. When testing coatings, scratch hardness refers to the force necessary to cut through the film to the substrate. The most common test is Mohs scale, which is used in mineralogy.

INDENTATION HARDNESS

Indentation hardness measures the resistance of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields. The tests work on the basic premise of measuring the critical dimensions of an indentation left by a specifically dimensioned and loaded indenter.

Common indentation hardness scales are Rockwell, Vickers, Shore, and Brinell.

REBOUND HARDNESS

Rebound hardness, also known as dynamic hardness, measures the height of the "bounce" of a diamond-tipped hammer dropped from a fixed height onto a material. This type of hardness is related to elasticity. The device used to take this measurement is known as a scleroscope.

6.2 TYPES OF HARDNESS TESTER

6.2.1ROCKWELL HARDNESS

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration. When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

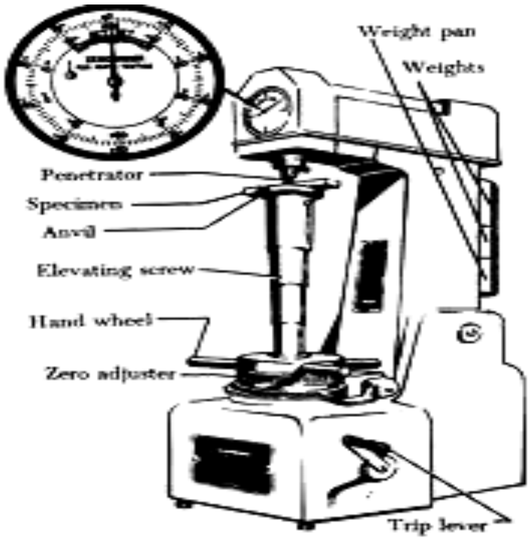


Fig 6.1 Rockwell Hardness Tester

There are two types of Rockwell tests:

- Rockwell: the minor load is 10 kgf, the major load is 60, 100, or 150 kgf.
- Superficial Rockwell: the minor load is 3 kgf and major loads are 15, 30, or 45 kgf.

PRINCIPAL OF THE ROCKWELL TEST

- The indenter moves down into position on the part surface.
- A minor load is applied and a zero reference position is established.
- The major load is applied for a specified time period (dwell time) beyond zero.
- The major load is released leaving the minor load applied.
- The resulting Rockwell number represents the difference in depth from the zero reference position as a result of the application of the major load.

$$HR = E - e$$

Where, HR=Rockwell hardness number,

E= a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter,

e= permanent increase in depth of penetration due to major load measured in units of 0.002 mm.

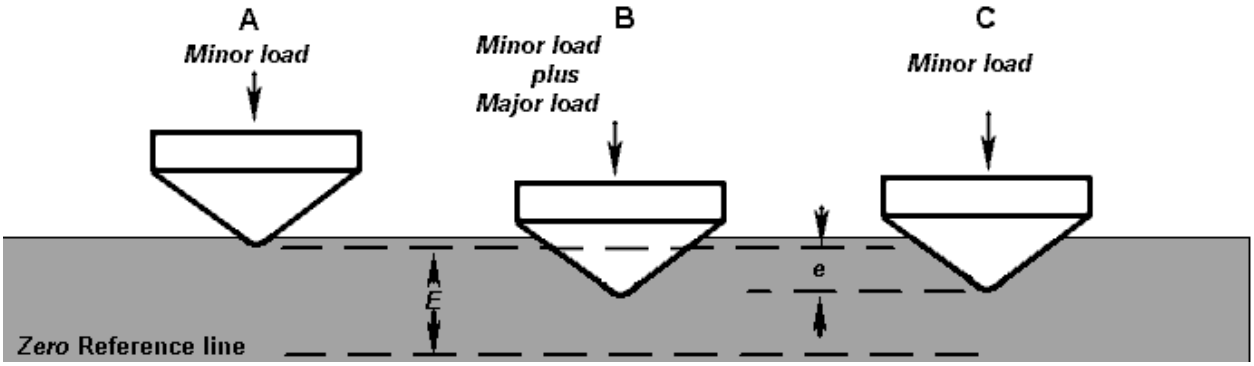


Fig 6.2 Principle of operation

6.2.2 BRINELL HARDNESS

The Brinell hardness test is commonly used to determine the hardness of materials like metals and alloys.

The test is achieved by applying a known load to the surface of the tested material through a hardened steel ball of known diameter. The diameter of the resulting permanent impression in the tested metal is measured and the Brinell hardness number is calculated as

$$BHN = 2P / (\pi D (D - (D^2 - d^2)^{1/2}))$$

Where

BHN = Brinell hardness number

P = load on the indenting tool (kg)

D = diameter of steel ball (mm)

d = measure diameter at the rim of the impression (mm)

It is desirable that the test loads are limited to a impression diameter in the range of 2.5 to 4.75 mm.

Fig 6.3 Brinell hardness tester

PRINCIPLE OF OPERATION

- The indenter is pressed into the sample by an accurately controlled test force.
- The force is maintained for a specific dwell time, normally 10 - 15 seconds.
- After the dwell time is complete, the indenter is removed leaving a round indent in the sample.
- The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device.

- The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the brinell hardness.

6.2.3 VICKERS HARDNESS

The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH). The hardness number can be converted into units of pascals, but should not be confused with a pressure, which also has units of pascals. The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not a pressure.

Fig 6.4 Vickers hardness tester

PRINCIPLE OF OPERATION

All Vickers ranges use a 136° pyramidal diamond indenter that forms a square indent.

- The indenter is pressed into the sample by an accurately controlled test force.
- The force is maintained for a specific dwell time, normally 10 – 15 seconds.
- After the dwell time is complete, the indenter is removed leaving an indent in the sample that appears square shaped on the surface.
- The size of the indent is determined optically by measuring the two diagonals of the square indent.
- The Vickers hardness number is a function of the test force divided by the surface area of the indent. The average of the two diagonals is used in the following formula to calculate the Vickers hardness.

HV = Constant x test force / indent diagonal squared

The constant is a function of the indenter geometry and the units of force and diagonal. The Vickers number, which normally ranges from HV 100 to HV1000 for metals, will increase as the sample gets harder. Tables are available to make the calculation simple, while all digital test instruments do it automatically.

6.3 HARDNESS TESTING OF THE WELDED PLATES

The hardness tests for the welded plates were done in Rockwell hardness testing machine by giving the major load of 100Kgf with the steel ball indenter. Hardness values were taken at the welded zones of different process parameters and tools respectively.

Speed N (rpm)	**Feed f (mm/ min)**	**Tool**	**Base Material**		**Welded Zone**
			6201	6063	
800	10	Non Coated	77	38	24
800	13	Non Coated	62	42	36
1000	10	Non Coated	73	38	26
1000	13	Non Coated	46	43	16
800	10	Coated	56	58	35
800	13	Coated	73	47	45
1000	10	Coated	75	42	26
1000	13	Coated	63	25	47

Table 6.1 Hardness values

CHAPTER 7

TENSILE TEST

Tensile test, also known as tension test, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials.

7.1 TENSILE TEST SPECIMEN

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

The shoulders of the test specimen can be manufactured in various ways to mate to various grips in the testing machine. Each system has advantages and disadvantages; for example, shoulders designed for serrated grips are easy and cheap to manufacture, but the alignment of the specimen is dependent on the skill of the technician. On the other hand, a pinned grip assures good alignment. Threaded shoulders and grips also assure good alignment, but the technician must know to thread each shoulder into the grip at least one diameter's length, otherwise the threads can strip before the specimen fractures.

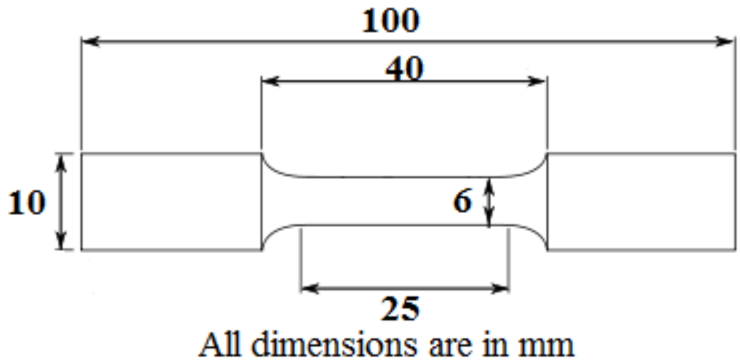


Fig 7.1 ASTM Tensile test specimen

7.2 UNIVERSAL TESTING MACHINE

The universal testing machine used in tensile testing. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. There are two types: hydraulic powered and electromagnetically powered machines.

The machine must have the proper capabilities for the test specimen being tested. There are three main parameters: force capacity, speed, and precision and accuracy. Force capacity refers to the fact that the machine must be able to generate enough force to fracture the specimen. The machine must be able to apply the force quickly or slowly enough to properly mimic the actual application. Finally, the machine must be able to accurately and precisely measure the gauge length and forces applied; for instance, a large machine that is designed to measure long elongations may not work with a brittle material that experiences short elongations prior to fracturing.

Alignment of the test specimen in the testing machine is critical, because if the specimen is misaligned, either at an angle or offset to one side, the machine will exert a bending force on the specimen. This is especially bad for brittle materials, because it will dramatically skew the results. This situation can be minimized by using spherical seats or U-joints between the grips and the test machine. A misalignment is indicated when running the test if the initial portion of the stress-strain curve is curved and not linear.

7.3 PROCESS

The test process involves placing the test specimen in the testing machine and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the engineering strain, ε, using the following equation:

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

where ΔL is the change in gauge length, L_0 is the initial gauge length, and L is the final length. The force measurement is used to calculate the engineering stress, σ, using the following equation:

$$\sigma = \frac{F_n}{A}$$

where F is the force and A is the cross-section of the gauge section. The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.

Fig 7.2 Universal Testing Machine

7.4 TENSILE TEST OF THE WELDED PLATES

The welded joints were sliced using a power hacksaw and then machined to the required dimensions in manual vertical milling machine. The tensile specimens were fabricated as per the American Society for Testing of Materials (ASTM E8) standards to evaluate the tensile strength of the joints.

Tool	Speed (rpm)	Feed (mm/min)	UTS (MPa)	Elongation %	Yield Stress (MPa)
Coated	800	10	76	4.53	62
	800	13	62	2.83	62
	1000	10	64	2.83	29
	1000	13	29	0.50	29
Non coated	800	10	94	6.30	93
	800	13	68	5.90	7
	1000	10	90	4.66	7
	1000	13	77	12.66	48

Table 7.1 Tensile test values

7.5 COMPARISON OF ULTIMATE TENSILE STRESS FOR THE TOOL PARAMETERS

The ultimate tensile stress values of the welded plates were compared with different values of the speeds and feeds of the coated and non coated tools respectively.

The chart clearly shows that by decreasing speed and feeds of the tools, the ultimate tensile stress was increased for both the coated and non coated tools.

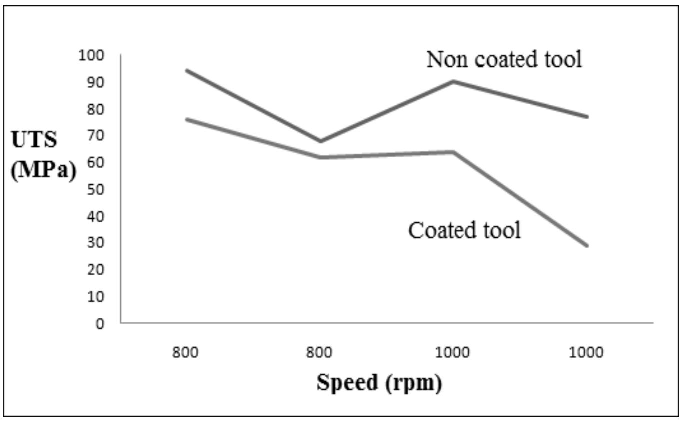


Fig 7.3 Comparison chart for UTS

7.6 COMPARISON OF ELONGATION FOR THE TOOL PARAMETERS

The elongations of the welded plates were compared with different values of the speeds and feeds of the coated and non coated tools respectively.

The chart clearly shows that by decreasing the speed and feed of the coated tools, the elongation percentage was increased. Then for the non coated tool elongation percentage increased by increasing the speed and feed of the tool.

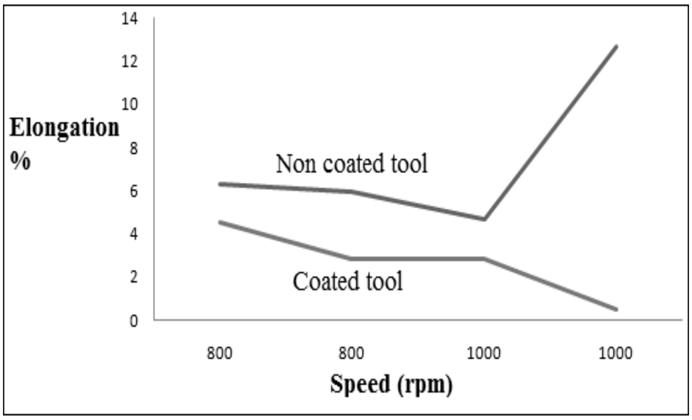


Fig 7.4 Comparison chart for elongation percentage

7.7 COMPARISON OF YIELD STRESS FOR THE TOOL PARAMETERS

The yield stresses of the welded plates were compared with different values of the speeds and feeds of the coated and non coated tools respectively.

The chart clearly shows that yield stress values were increased by increasing the feed for the coated tool and increased by decreasing the speed and feed for the non coated tool respectively.

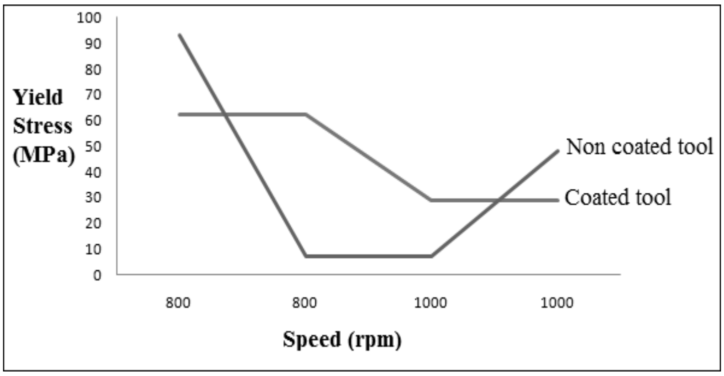


Fig 7.5 Comparison for yield stress

From the comparison charts of the tensile test results, ultimate stress, elongation percentage and yield stress values were found.

CHAPTER 8

METALLURGICAL TEST

Metallurgical research is concerned with the preparation of radioactive metals, with obtaining metals economically from low-grade ores, with obtaining and refining rare metals hitherto not used, and with the formulation of alloys. Powder metallurgy deals with the manufacture of ferrous and nonferrous parts by compacting elemental metal or alloy powders in a die. The resultant shapes are then heated in a controlled-atmosphere furnace to bond the particles so that the part will retain the shape at normal temperatures and pressures.

The structure of metals consists of their crystal structure, which is investigated by x-ray, electron, and neutron diffraction, their microstructure, which is the subject of metallography, and their macrostructure. Crystal imperfections, which provide mechanisms for processes occurring in solid metals, are investigated by x-ray diffraction and metallographic methods, especially electron microscopy. The microstructure is determined by the constituent phases and the geometrical arrangement of the microcrystals (grains) formed by those phases. Macrostructure is important in industrial metals. It involves chemical and physical in homogeneities on a scale larger than microscopic.

8.1 MICROSTRUCTURE

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification. The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice.

8.1.1 METHODS OF MICROSCOPY

8.1.1.1OPTICAL MICROSCOPY

The optical microscope, often referred to as the "light microscope", is a type of microscope which uses visible light and a system of lenses to magnify images of small samples. Optical microscopes are the oldest design of microscope and were possibly designed in their present compound form in the 17th century. Basic optical microscopes can be very simple, although there are many complex designs which aim to improve resolution and sample contrast. Historically optical microscopes were easy to develop and are popular because they use visible light so that samples may be directly observed by eye. The image from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph.

TYPES OF OPTICAL MICROSCOPY

- Reflection Microscope
- Inverted Microscope

8.1.1.2 ELECTRON MICROSCOPY

Electron microscopes are used to investigate the ultra structure of a wide range of biological and inorganic specimens including microorganisms, cells, large molecules, biopsy samples, metals, and crystals. Industrially, the electron microscope is often used for quality control and failure analysis. Modern electron microscopes produce electron micrographs, using specialized digital cameras or frame grabbers to capture the image.

The electron microscope uses electrostatic and electromagnetic lenses to control the electron beam and focus it to form an image. These electron optical lenses are analogous to the glass lenses of a light optical microscope.

8.1.1.3 X-RAY CRYSTALLOGRAPHY

X-ray crystallography is a method used for determining the atomic and molecular structure of a crystal, in which the crystalline atoms cause a beam of X-rays to diffract into many specific directions. By measuring the angles and intensities of these diffracted beams, a crystallographer can produce a three-dimensional picture of the density of electrons within the crystal. From this electron density, the mean positions of the atoms in the crystal can be determined, as well as their chemical bonds, their disorder and various other information.

8.2 ZONES OF THEMICROSTRUCTURE

- Stir zone
- Flow arm zone
- Thermo-mechanically affected zone (TMAZ)
- Heat-affected zone (HAZ)

8.2.1 STIR ZONE

The stir zone is a region of heavily deformed material that roughly corresponds to the location of the pin during COMPOSITE MMC MMC. The grains within the stir zone are roughly equaled and often an order of magnitude smaller than the grains in the parent material. A unique feature of the stir zone is the common occurrence of several concentric rings which has been referred to as an "onion-ring" structure. The precise origin of these rings has not been firmly established, although variations in particle number density, grain size and texture have all been suggested.

8.2.2 FLOW ARM ZONE

The flow arm zone is on the upper surface of the weld and consists of material that is dragged by the shoulder from the retreating side of the weld, around the rear of the tool, and deposited on the advancing side.

8.2.3 THERMO-MECHANICALLY AFFECTED ZONE

The thermo-mechanically affected zone (TMAZ) occurs on either side of the stir zone. In this region the strain and temperature are lower and the effect of COMPOSITE MMC on the microstructure is correspondingly smaller. Unlike the stir zone the microstructure is recognizably that of the parent material, albeit significantly deformed and rotated. Although the term TMAZ technically refers to the entire deformed region it is often used to describe any region not already covered by the terms stir zone and flow arm.

8.2.4 HEAT AFFECTED ZONE

The heat-affected zone (HAZ) is common to all COMPOSITE MMC processes. As indicated by the name, this region is subjected to a thermal cycle but is not deformed during COMPOSITE MMC. The temperatures are lower than those in the TMAZ but may still have a significant effect if the microstructure is thermally unstable.

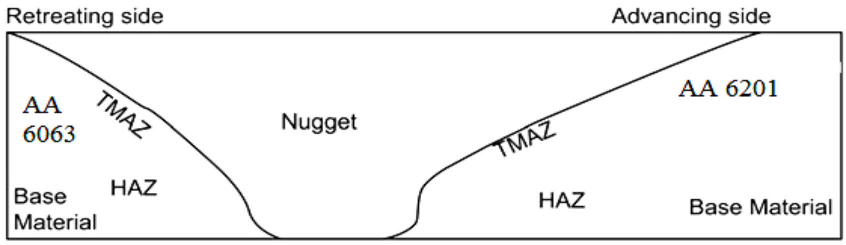


Fig 8.1 Zones of the microstructure

8.3 MICROSTRUCTURE OF THE WELDED PLATES

The microstructures of the welded plates for the coated tool were done in the de-wintor inverted trinocular metallurgical microscope. From the microstructure, the influences of the spindle speed in mechanical properties were found.

OPERATION OF INVERTED MICROSCOPE

The objective lens is, at its simplest, a very high powered magnifying glass i.e. a lens with a very short focal length. This is brought very close to the specimen being examined so that the light from the specimen comes to a focus about 160 mm inside the microscope tube. This creates an enlarged image of the subject. This image is inverted and can be seen by removing the eyepiece and placing a piece of tracing paper over the end of the tube. By carefully focusing a brightly lit specimen, a highly enlarged image can be seen. It is this real image that is viewed by the eyepiece lens that provides further enlargement.

In most microscopes, the eyepiece is a compound lens, with one component lens near the front and one near the back of the eyepiece tube. This forms an air-separated couplet. In many designs, the virtual image comes to a focus between the two lenses of the eyepiece, the first lens bringing the real image to a focus and the second lens enabling the eye to focus on the virtual image.

Fig 8.2 Inverter microscope

8.3.3 MICROSTRUCTURE SAMPLES

To evaluate the influence of the spindle speed in mechanical properties, the selected parameters are given below:

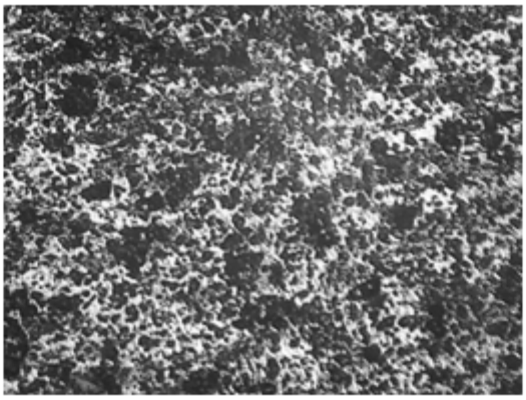
Sample no	Tool	Speed (rpm)	Feed (mm/min)
1.	Non coated	800	10
2.	Coated	800	10
3.	Non coated	1000	10
4.	Coated	1000	10

Table 8.1 Sample parameters of microstructure

SAMPLE 1:

The microstructure shows the FSW zone of the process. The grains of seemed to have fragmented in to finer sizes. This location contains both the 6063 and the 6201. At the stir zone, the grain sizes were smaller than the base metals of magnesium with CaCo3 alloys and also it contains small porosity formations.

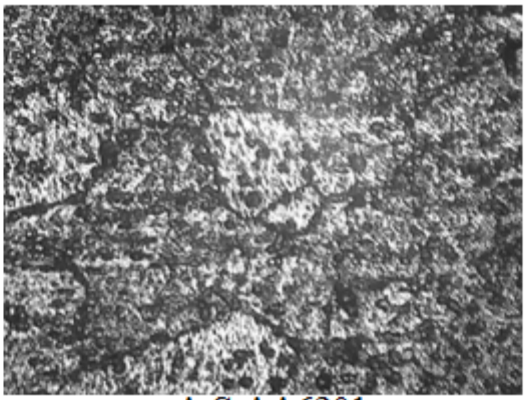
Base metal



R.S AA6063

Fig 8.3 Base metal of MAGNESIUM WITH CACO3

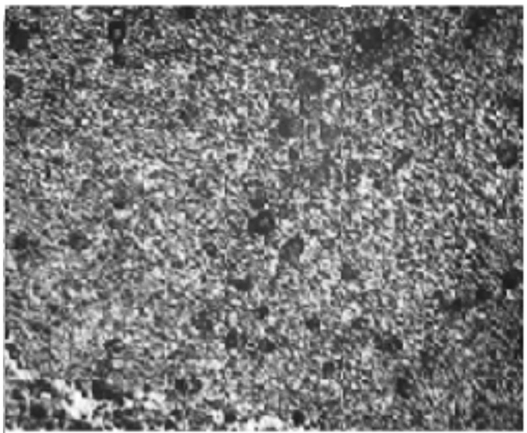
Base metal



A.S AA6201

Fig 8.4 Base metal of AA6201

Stir Zone



150µ

Fig 8.5 Stir zone of sample1

SAMPLE 2:

The microstructure shows the FSW zone of the process. The grains of seemed to have fragmented in to finer sizes. This location contains both the 6063 and the 6201.   At the stir zone, the mixing was very perfect and grains size was too fine than the base metals and it contains little porosity only.

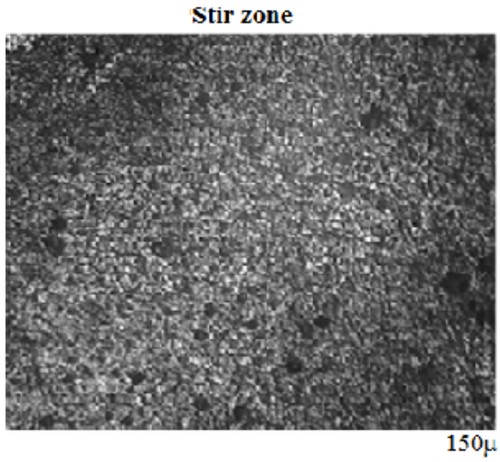


Fig 8.6 Stir zone of sample2

SAMPLE 3:

The microstructure shows the FSW zone of the process. The grains of seemed to have fragmented in to finer sizes. This location contains both the 6063 and the 6201. At the stir zone, the grain sizes were smaller than the base metals of magnesium with CaCo3 alloys and also it contains porosity formations.

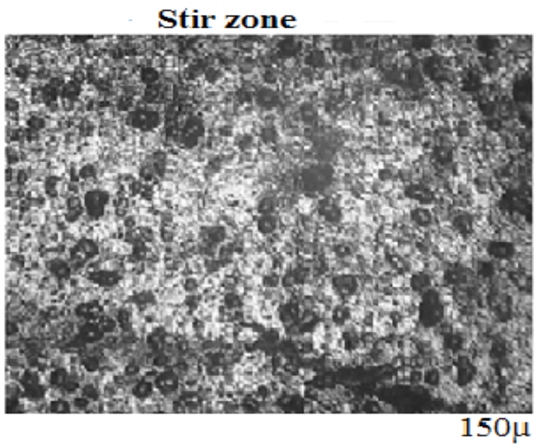


Fig 8.7 Stir zone of sample3

SAMPLE 4:

The microstructure of shows the FSW zone of the process. The grains of seemed to have fragmented in to finer sizes. This location contains both the 6063 and the 6201. At the stir zone, the grain sizes were small when compared to the base metal of the magnesium with CaCo3 alloys and it contains porosity formation. TMAZ was also formed at stir zone.

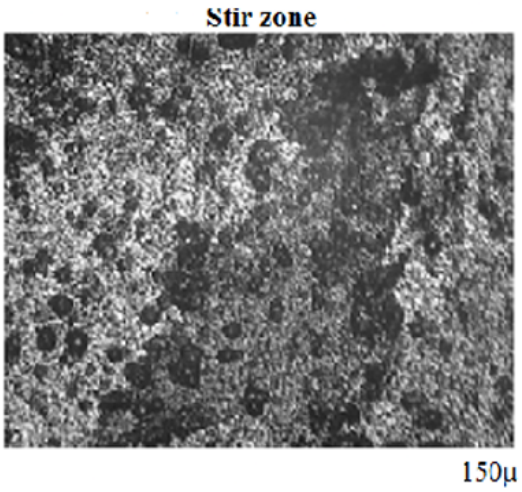


Fig 8.8 Stir zone of sample3

From the microstructure, the stir zone having smaller grains than the base metal of the magnesium with CaCo3 alloys by decreasing the spindle speed of the tools.

CHAPTER 9

RESULT AND CONCLUSION

- From the tensile test result in clearly shows that by decreasing the speed and feed of the tool, ultimate tensile stress was increased for both the coated and uncoated tools.
- At the welded zone, hardness was high at high speed and feed rates of the tools.
- Based on the microstructure the welded zone grains were highly mixed together and giving good results only at N=800rpm, f=10mm/min with the coated tool.
- From the microstructure, when compared with base material, stir zone was having fine grain structure irrespective of the parameters.

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