International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-6 Issue-4, April 2017

# Surface Alloying of Aluminum Alloy (Lm4) With Iron Powder using Tig Welding

**Purushottam Sahu, Santosh Kumar Mishra, Shatendra Kumar Sahu**

***Abstract:*** ***Development of Fe–Al composite layer by utilizing combination surface alloying process with blend of Al and Fe powders has been examined to enhance the surface hardness of cast aluminum amalgam LM4, business Al–Si compound substrate. Tungsten Arc welding procedure is utilized to adjust the surface. Components, for example, welding current, welding speed, terminal to work separation are changed to the composite the surface of LM4 with preplaced press covering on the substrate at different levels of welding current (3-6mm/sec) and cathode to work remove (2-3mm) in the argon gas protecting. The microstructure of the alloyed layer changed with expanding Fe content from hypo-eutectic structure to hyper-eutectic structure. Hardness of the surface changed LM4 combination shifts from HV98.96 to HV141.9 as for the elements chose and their levels [25]. The alloyed examples with low warmth input demonstrates high hardness when terminal to work separation is kept steady, as the cathode to work remove increments small scale hardness additionally increments. The greatest increment in hardness is 40.25% accomplished at Welding current 100A, welding speed 5mm/sec, Electrode to work separate 3mm because of the best possible dissemination of iron particles into the substrate bringing about the arrangement of Al-Fe intermetallic.***

***Keywords:*** ***HV98.96 to HV141.9, LM4, Utilizing Combination, (3-6mm/sec), Intermetallic.***

## I. INTRODUCTION

Aluminum composites are amalgams in which aluminum (Al) is the overwhelming metal [1]. The common alloying components are copper, magnesium, manganese, silicon and zinc. There are two main orders, to be specific throwing composites and fashioned combinations, both of which are further subdivided into the classifications warm treatable and non-warm treatable. Dominant part of aluminum compound is as created items. Illustrations are moved plate, foils and expulsions. Thrown aluminum compounds yield financially savvy items because of the low dissolving point, despite the fact that they for the most part have bring down rigid qualities than created combinations. The most essential cast aluminum combination framework is Al–Si, where the large amounts of silicon (4.0–13%) add to give great throwing attributes. Aluminum amalgams are additionally generally utilized as a part of aviation application, since the presentation of metal cleaned air ship.

**Manuscript published on 30 April 2017.**
***** Correspondence Author (s)
**Purushottam Sahu,** Student, Department of Mechanical Engineering, Production Engineering, BIT Durg (C.G.), India.
**Santosh Kumar Mishra,** Assistant Professor, Department of Mechanical Engineering, Production Engineering BIT Durg (C.G.), India.
**Shatendra Kumar Sahu,** Assistant Professor, Department of Mechanical Engineering, Production Engineering BIT Durg (C.G.), India.



Aluminum-magnesium compounds are both lighter than other aluminum amalgams and are inflammable than different composites that contain a high rate of magnesium. Aluminum amalgam surfaces will plan a white, Defensive layer of consumption aluminum oxide if left unprotected by anodizing or potentially remedy painting techniques. In a wet situation, galvanic erosion can happen when an aluminum composite is put in electrical contact with different metals with more negative consumption possibilities than aluminum, and an electrolyte is available that permits particle trade. Alluded to as disparate metal consumption this procedure can happen as peeling or intergranular erosion. On the off chance that the aluminum amalgams are not appropriately warm treated, then it prompts to interior component detachment and the metal erodes from the back to front. Airplane businesses bargains frequently with aluminum amalgam consumption[24].

Aluminum combination pieces are enlisted with the Aluminum Affiliation. Numerous associations distribute more particular benchmarks for the produce of aluminum compound. They are Society of Car Specialists principles association, particularly its aviation measures subgroups, and ASTM Global Ease of Use

This alloy conforms with British Standards 1490 LM4 and is similar to the obsolete specifications BS.L79. LM4 also conforms to the American Association or American Standards for Testing and Materials AA 319 and Al – Si5Cu3 to Indian Standards [2].Chemical composition of LM4 are Cu (2%- 4%) Mg (0.15%) Si (4%-6%) Fe (0.8%) Mn (0.2%-0.6%) Ni(0.3%) Zn(0.5%) Pb (0.%1)Sn(0.1%) Ti(0.2%) and remaining aluminium. Physical properties of LM4 are Coefficient of thermal expansion (0.000021/$^0$C at 20-100$^0$C), Thermal conductivity (0.29Cal/cm$^2$/$^0$C at 25$^0$C) Specific gravity (2.73) ,Freezing rang (625-525$^0$C), atomic Number (26) and Atomic weight (55.845g/mol), Poisson ratio (0.29), Young modulus (21) SURFACE Designing is a multidisciplinary action planned to tailor the properties of the surfaces of building segments so that their capacity and serviceability can be moved forward. The ASM Handbook characterizes surface designing as "treatment of the surface and close surface districts of a material to permit the surface to perform capacities that are particular from those capacities requested from the greater part of the material" Surface adjustment is the way toward altering the surface of a material by bringing physical , substance or natural qualities unique in relation to the ones initially found on the surface of a material[3]. This alteration is normally made to strong materials, yet it is conceivable to discover cases of the adjustment to the surface of particular fluids[22].


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### A. TUNGSTEN Dormant GAS WELDING (TIG):

In Gas tungsten circular segment welding (GTAW) or Tungsten Inactive Gas welding (TIG), a curve is struck between a non-consumable tungsten terminal and the base metal. The circular segment is protected by the idle argon or helium or argon-helium blend. A filler wire might possibly be utilized. Whenever utilized, it is bolstered remotely into the circular segment as pole or strip by the welder[23]. The Welder additionally needs to control the circular segment length and bend travel speed. An Air conditioner control source or DC source is utilized for welding assortment of metals. GTAW is most ordinarily used to weld thin segments of stainless steel and non-ferrous metals, for example, aluminum, magnesium, and copper compounds. The procedure concedes the administrator more noteworthy control over the weld than contending procedures, for example, protected metal bend welding and gas metal circular segment welding, taking into consideration more grounded, higher quality welds. One of the constraints of GTAW is, it is slower than most other welding methods. A related procedure, plasma bend welding, utilizes a somewhat unique welding light to make a more engaged welding circular segment and accordingly is regularly robotized. From literature survey it is found that continuous wave $CO_2$ laser beam with the power of 2200 W was irradiated to the preplaced mixture powder on the substrate at various defocused distance of laser beam (30–150 mm up on the substrate) at the constant traveling speed (100 mm/min) in the argon gas shielding. The thickness of the laser alloyed layer varied from 0.5 to 7.0 mm. The wear resistance of the laser alloyed layer increased with increasing the hardness. Surface alloying of commercially pure aluminium with nickel was carried out using a pulsed Nd-YAG laser[4] .Improving the wear resistance of AA 6061 by laser surface alloying with NiTi[21] .To improve the wear resistance of aluminium alloy AA 6061, a 1.5 mm thick hard surface layer consisting of Ni–Al and Ti–Al intermetallic compounds was synthesized on the alloy by laser surface alloying technique[5].

### B. Literature Conclusion:

From the literature review it is found that mechanical properties such as hardness, wear resistance, corrosion resistance etc... can be improved by the surface modification. Surface modification techniques include treatments by flame, plasmas, photons, laser beams, electron beams, ion beams, X-rays. In this project we used plasma produced by Tungsten Inert Gas Welding (TIG) to modify the surface of the material. From the literature review we found out that addition of iron powder to aluminium increases strength and decreases ductility. The Main objective of my work is,To improve the surface hardness of the Cast Aluminium Alloy LM4 with adding iron as the alloying element and to study the micro structural changes at the surface. The scope of this work is to modify the surface of LM4 with addition of iron into the surface using the Plasma Arc of the TIG welding to improve the surface hardness of the alloy and to study the micro structural changes occurred at the surface of the alloy. TIG welding is done at different parameters, different levels to find which parameter(s) and which level yields the best results. Normally LM4 alloy is used in crankcase, junction boxes and gear boxes, so the increase in hardness of the material gives better performance and improvement in automobile industry.

## II. METHODLOGY

### 2.1. Selection Criteria of Primary Material:

The International Alloy Designation System is the most widely accepted naming scheme for Cast Alloys[6]. Like the wrought alloy system, the cast alloy designation system also has four digits, but differs from the wrought alloy system in that a decimal point is used between the third and fourth digits to make clear that these are designations to identify alloys in the form of castings or foundry ingot. Aluminium castings alloys are based on the same alloy system of those in the wrought categories. They are strengthened by the same mechanisms, except strain hardening and are similarly classified into non heat treatable and heat treatable types. The major difference is that the casting alloys using in the greatest volumes containing alloying additions of silicon far in excess of the amounts in most wrought alloys[19]. Silicon is the alloying element that literally makes the commercial viability of the high volume aluminium casting industry possible. Silicon contents from 4 to the eutectic level of 12 reduce scrap losses, permit production of more intricate designs with greater variation in section thickness and yield castings with higher surface and internal qualities. These benefits are from the effects of silicon in increasing fluidity, reducing cracking and improving feeding to minimize shrinkage porosity.Cast Aluminium alloy 300 series is selected as primary matrix.

### 2.2. Selection Criteria of Alloying Element:

Iron powder is powdered iron. Powdered irons are used in production of magnetic alloys and certain types of steels. Iron powder is formed as a whole from several other iron particles. The particle sizes vary anywhere from 20-200 $\mu$m. The iron properties differ depending on the production method and history of a specific iron powder. There are three types of iron powder classifications: reduced iron powder, atomized powder, and electrolyte iron powder. Each type is used in various applications depending on their properties. There is very little difference in the visual appearances of two types of iron powder.In this project iron powder of 99.5 pure and size of 100 microns is selected. Literature survey reveals that when iron is added to aluminium its strength increases due to the formation of Al-Fe intermetallic and decreases the ductility.

### 2.3. Experimental Setup for TIG Welding and Vicker Hardness:

TIG welding is an electric arc welding process in which the fusion energy is produced by an electric arc struck between the work piece and the tungsten electrode. During the welding process the electrode, the arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert shielding gas[20].


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By means of a gas nozzle the shielding gas is lead to the welding zone where it replaces the atmospheric air. TIG welding differs from the other arc welding processes by the fact that the electrode is not consumed like the electrodes in other processes such as MMAW. If it is necessary to use filler material, it is added either manually or automatically as a bare wire.

**Fig 2.1 Experimental Setup (Amrita Vishva Vidyapeetham Coimbtore)**

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. If the specimen is subjected to the fixed force (load) with the appropriate indenter, the smaller the indentation, the harder the material. 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[16]. 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 unit of hardness given by the test is known as the **Vickers Pyramid Number** (**HV**) or **Diamond Pyramid Hardness** (**DPH**).The indenter shape should be capable of producing geometrically similar impressions, irrespective of size; the impression should have well-defined points of measurement; and the indenter should have high resistance to self-deformation[17]. A diamond in the form of a square-based pyramid satisfied these conditions. The HV number is then determined by the ratio *F/A*, where *F* is the force applied to the diamond in kilograms-force and *A* is the surface area of the resulting indentation in square millimeters [7].

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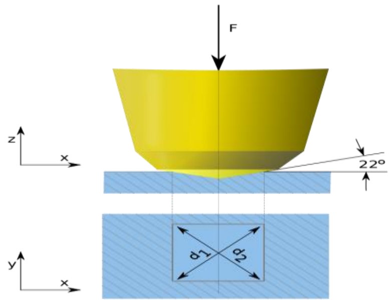


*A* can be determined by the formula

$$A=\frac{d*d}{2\sin 66} \quad \text{---equation 1}$$

Which can be written as

$$A=\frac{d*d}{1.8544} \quad \text{---equation 2}$$

Where *d* is the average length of the diagonal left by the indenter in millimeters. Hence,

$$HV=\frac{F}{A} \quad \text{---equation 3}$$

Where *F* is in gmf and *d* is in millimeters.

### 2.4. Preparation of Specimen to Required Dimensions:

The LM4 Block is cut into 12 small pieces of width 1 inches using power hacksaw. Diesel is used as the coolant during cutting [18].

- Initially the block is placed between the vice jaws and the jaws are tighten with the screws provided.
- Markings are made on the metal with the distance of one inch upto 12 pieces.
- Now the coolant system is turned on, the coolant tube is directed towards the metal where it to be cut.
- Machine is turned on and cutting is done.

### 2.5. Machining of LM4 Pieces:

The LM4 block has made into pieces using power hacksaw is in irregular dimensions. The pieces are machined to required dimensions and surface grinding is also done. The pieces are machined are to particular dimensions Length = 60mm, Breadth = 30mm and Thickness =12mm

- Initially the markings are made on the surface of the material
- Then the 10 mm milling tool is fixed in the tool jaw.
- Using the 10 mm tool the specimen is machined to get the required dimensions.
- After machining the specimen is grinded at the surface to get the smooth surface finish for the specimen.

### 2.6. Coating of Iron Powder on the Specimen:

In this process pure iron powder is mixed with the binder Poly Vinyl Alcohol (PVA) i.e. 1gm of iron powder is mixed with 1.5gms of PVA. The exact 1gm of iron powder and 1.5gms of PVA are weighted using simple balance [8]. Now iron powder and polymer are stirred in a container for 30 minutes, then the mixture is heated using sprit flame[9].


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After heating with the sprit flame the mixture will turned into form of a paste, now that paste is applied on the markings (10mm width and 60mm length) made on the specimen.

### 2.7. Welding of Specimen- The Following are the Factors and levels used while TIG Welding

**Table 2.1 Factor Selected for the Experiment**

| S. No | Welding Current (A) | Welding Speed (mm/sec) | Contact to work Distance (mm) |
|---|---|---|---|
| 1 | 100 | 3 | 2 |
| 2 | 100 | 4 | 2 |
| 3 | 100 | 5 | 2 |
| 4 | 100 | 6 | 2 |
| 5 | 100 | 3 | 3 |
| 6 | 100 | 4 | 3 |
| 7 | 100 | 5 | 3 |
| 8 | 100 | 6 | 3 |

### 2.8. Preparing the Specimen for Hardness Testing:

For testing of micro hardness the specimen has to be polished on the surface level. This is important because then only the diamond indentation can be seen while measuring hardness. In this process the specimen is first polished using the emery grade sheets of grade 1/0, 2/0, 3/0, 4/0. The specimen is rubbed against the grade sheets parallel to the grade sheets in unilateral direction. This process is done for half hour for each specimen. After this process the specimen is polished using linisher polisher. Specimen is placed on the belt of the linisher polisher; the belt which moves at moderate speed will do the polishing[10]. Now the specimen is placed on the disk polisher; in this process the specimen is placed on the fine abrasive cloth fitted on the disk of the polisher machine which rotates at high speed will do the final polishing.

### 2.9. Testing of Micro Hardness:

Testing of Micro hardness is done using Vickers Hardness test and the load applied in the test was 100gmf.The specimen is placed on the vice and it is fixed tightly using the screw on the left side. Now by using the eye piece focus the 40X lens on the specimen and find the good polished area for the indentation. After the area is fixed now turn the 40X lens to anticlockwise so that the diamond indenter will come to exact spot as the lens .Now load of 100gf is applied on the specimen using the indenter with the loading time of 15 seconds. Now using the eyepiece place the indentation in between the two lines and measure the distances D1 and D2. After measuring the distances D1 and D2 the micro hardness value will be calculated manually by using the empirical formula or automatically the HV hardness value will be calculated and it will be displayed in the MITUTOYA hardness testing machine. The same procedure is done for 10 different places on 10 different specimens [11].

## III. RESULTS AND ISCUSSION

The surface coated specimens were applied heat source using TIG by varying the factors considered at different levels. After surface alloying the specimens are polished using linisher grinder, disk polisher, then the specimens were tested to micro hardness using Vickers hardness machine with diamond intender. All these Specimens are tested at 10 different locations for micro hardness and average of all these values is taken as the hardness valve of each specimen.

**Table3.1 Micro Hardness Value for LM4 and Specimens**

| Name of the specimens | welding speed (mm/s) | Electrode work distance (mm) | Test Number(Micro hardness H V) | | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| LM4 (Base) | | | 97.6 | 89.1 | 98.1 | 93.8 | 99.6 | 101 | 103 | 103 | 102.4 | 105.3 | 99.31 |
| Specimen 1 | 3 | 2 | 94.3 | 95.3 | 98.4 | 99.2 | 100.3 | 102.5 | 105 | 105.7 | 110 | 112 | 102.25 |
| Specimen 2 | 4 | | 87.5 | 88.5 | 90.4 | 93.3 | 94.7 | 98.3 | 104 | 108.2 | 111.2 | 114 | 98.96 |
| Specimen 3 | 5 | | 96.2 | 98.5 | 102.7 | 103.4 | 105 | 105.6 | 107 | 108.3 | 115.3 | 116.2 | 105.78 |
| Specimen 4 | 6 | | 127 | 135 | 139.4 | 141.5 | 142.8 | 143.2 | 143 | 144.7 | 145.3 | 156.9 | 141.9 |
| Specimen 5 | 3 | 3 | 116 | 119 | 118.9 | 120.3 | 125.3 | 129.4 | 131 | 134.8 | 138.5 | 145.3 | 127.82 |
| Specimen 6 | 4 | | 90.2 | 95.3 | 95.9 | 103.5 | 104.5 | 105.3 | 109 | 108.9 | 110.2 | 110.8 | 103.33 |
| Specimen 7 | 5 | | 123 | 150 | 168.1 | 168.4 | 173.2 | 173.5 | 174 | 175.3 | 176.4 | 180 | 166.21 |
| Specimen 8 | 6 | | 104 | 113 | 114.7 | 118.2 | 119.2 | 119.3 | 123 | 122.7 | 125.5 | 126.4 | 118.55 |



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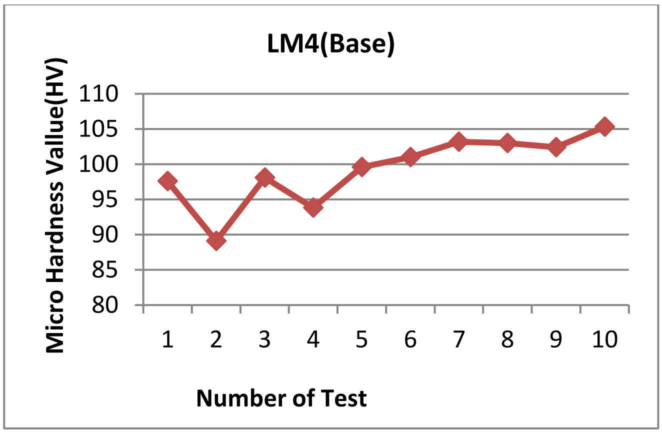
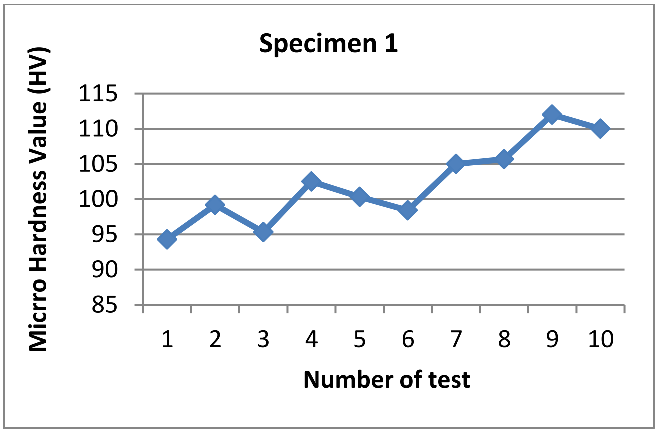
International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-6 Issue-4, April 2017

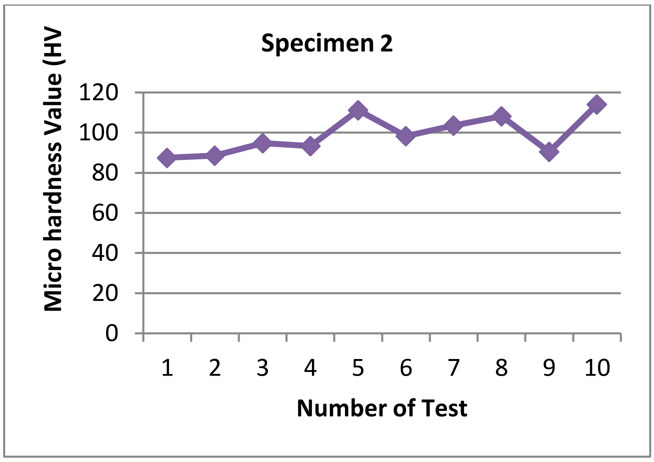
**Table3.2 Micro Hardness Value for LM4 and Percentage Changes**

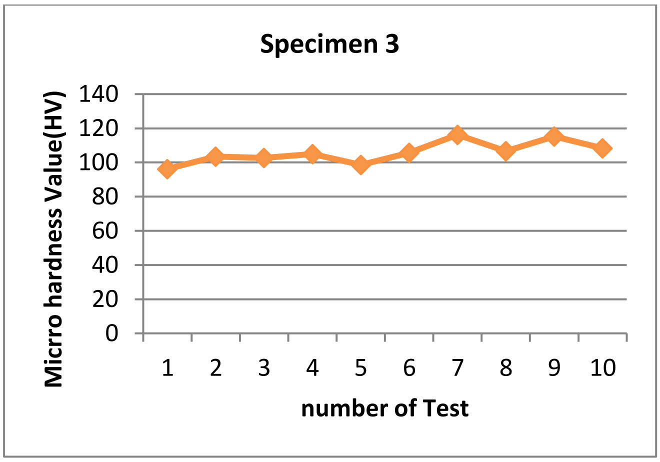
| Name of the Specimens | Welding Speed (mm/s) | Electode Work Distance (mm) | Average | % Changes In The Hardness Wrt LM4 |
|---|---|---|---|---|
| Specimen 1 | 3 | 2 | 102.25 | 2.87% |
| Specimen 2 | 4 | | 98.96 | -0.35% |
| Specimen 3 | 5 | | 105.78 | 6.11% |
| Specimen 4 | 6 | | 141.9 | 31% |
| Specimen 5 | 3 | 3 | 127.82 | 22.30% |
| Specimen 6 | 4 | | 103.33 | 3.89% |
| Specimen 7 | 5 | | 166.21 | 40.12% |
| Specimen 8 | 6 | | 118.55 | 16.22% |

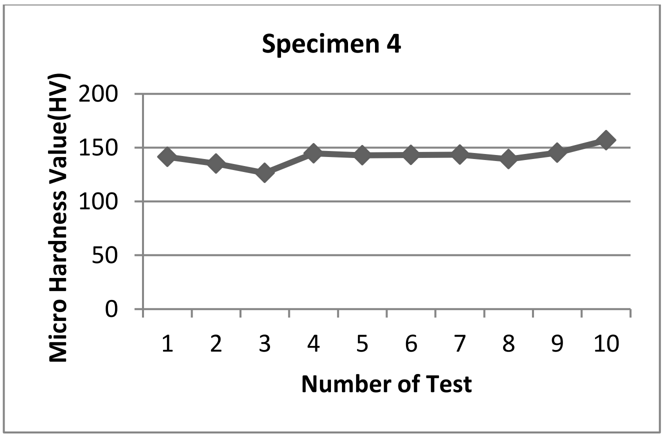
**Graphical Representation of Micro hardness Value**

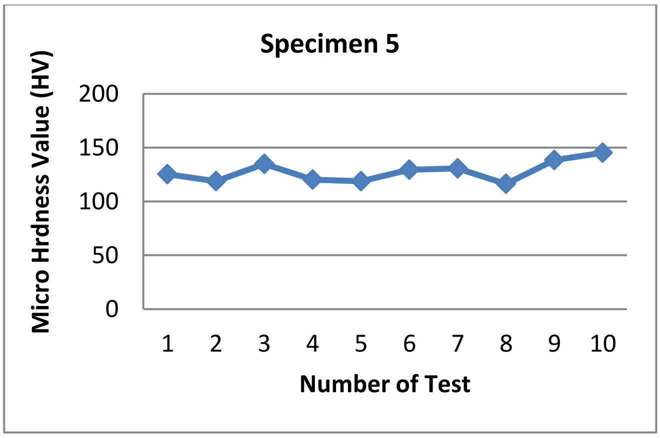


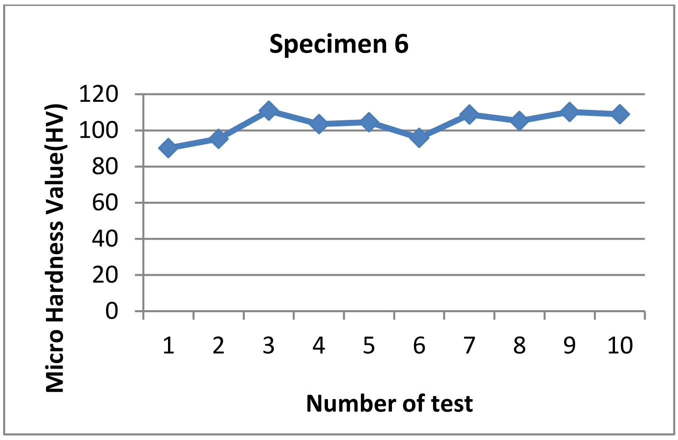



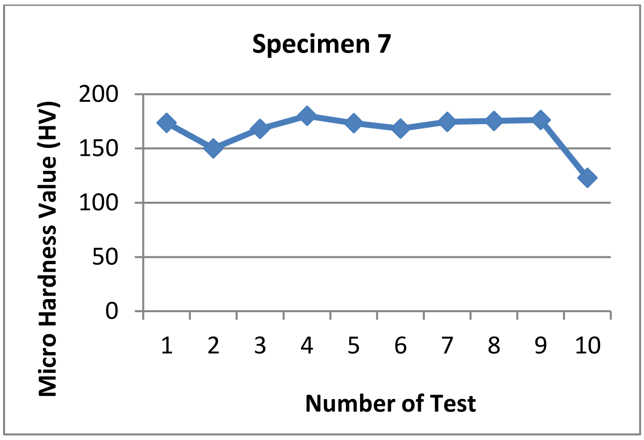



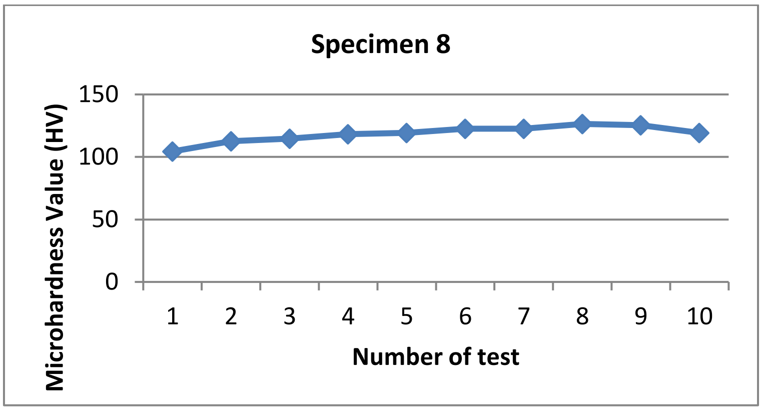



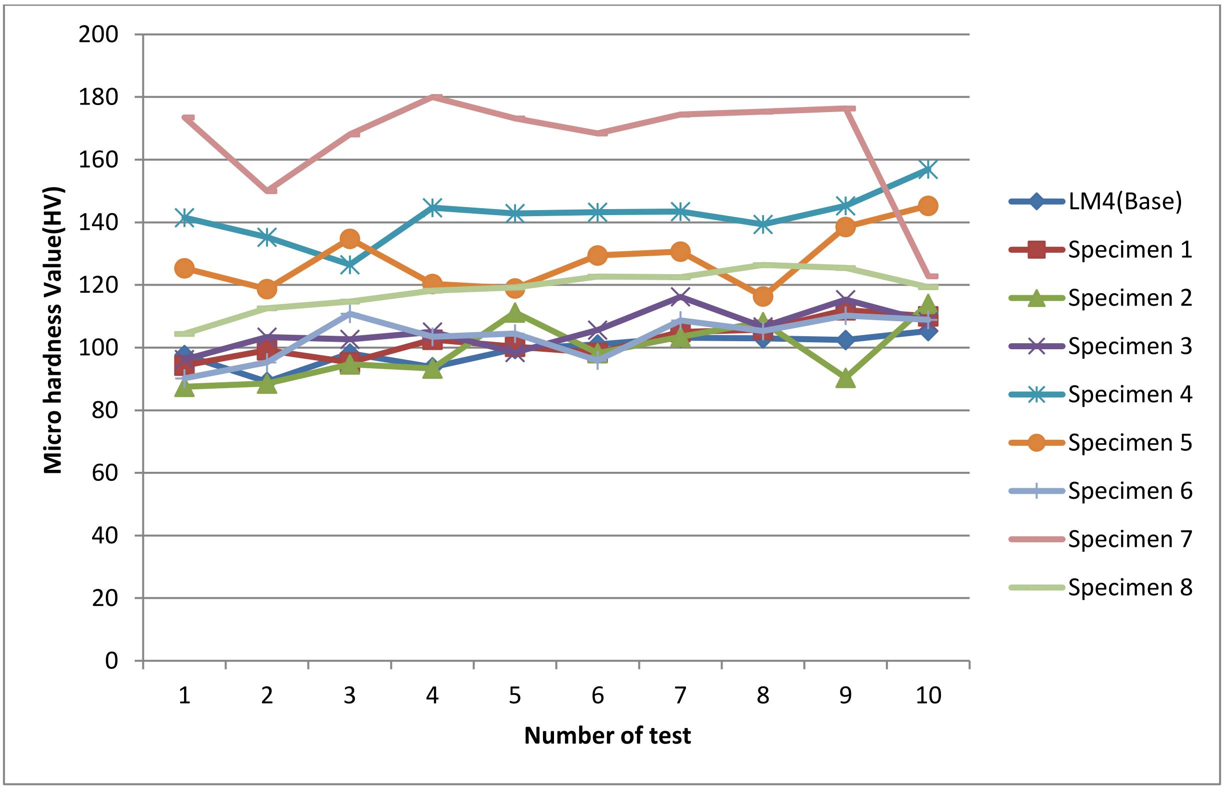






## IV. CONCLUSION

- So the hardness is maximum when welding speed is 5mm/sec
- The Maximum percentage increases in micro hardness is 40.25% (Welding Current 100A, Welding Speed 3mm/sec, Electrode to work distance 3mm) with respect to base metal LM4.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The micro hardness values of all the specimens (specimen 1, specimen 2, specimen 3, specimen 4, specimen 5, specimen 6, specimen 7, and specimen 8) will be compared with the micro hardness LM4

- The average micro hardness of LM4 is HV 99.3; the average micro hardness of the specimens with 2mm contact to work distance is HV112.2.
- The percentage of increase in hardness is 11.54%.
- For the specimens with 3mm electrode tip to work distance hardness increases but not proportionately to the 2mm electrode tip distance with the welding speed, because the weld strength of aluminium alloys increases as the heat input per unit length of the weld per unit thickness of the work piece decreases. So the hardness is maximum when welding speed is 5mm/sec
- The average micro hardness of LM4 is HV 99.3; the average micro hardness of the specimens with 3mm contact to work distance is HV 128.9.
- The percentage of increase In hardness is 22.99%
- The Maximum percentage increases in micro hardness is 40.25% (Welding Current 100A, Welding Speed 5mm/sec, Electrode to work distance 3mm) with respect to base metal (LM4).

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