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Optimization of MMC formed by Reinforcement of Aluminium LM24 with Al_2O_3 and Graphite

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Abstract**—— Aluminium alloy are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metal and alloy. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of application both from scientific and technological view point. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. Present work is focused on the study of behaviour of aluminium cast alloy (LM 24) with graphite and Al2O3 composite produced by the stir casting technique.**

Index Terms**— LM 24, Graphite, Alumina, Metal Matrix Composite**

I. INDRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced in situ from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications.In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fibre reinforced pistons and aluminium crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disk.

These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. The possibility of combining various material systems (metal – ceramic – non-metal) gives the opportunity for unlimited variation. The properties of these new materials are basically determined by the properties of their single components. The allocation of the composite materials into groups of various types of materials.

II. SELECTION OF MATERIALS

ALUMINIUM LM24: Aluminium is the most abundant metal available in earth's crust, the most abundant element after Oxygen and silicon. Aluminium is mostly used for its high strength to low weight ratio. Aluminium has high electrical and thermal conductivity along with good corrosion property. Aluminium can also be anodized as it is corrosion resistant.

ALUMINA (Al_2O_3): Aluminum oxide (Al_2O_3) is a hard refractory ceramic, which has been investigated for high temperature structural and substrate applications because of its good strength and low thermal expansion coefficient. Nevertheless, like other monolithic ceramics, Al2O3 is apt to suffer from low ductility and low fracture toughness. Therefore, metals (e.g. aluminium, cobalt, and niobium) or alloys are added to ceramics to improve their toughness.

GRAPHITE: The effect of graphite powder with respect to the performance of final Plastic Metallurgy parts is not fully understood yet. The same is valid for the interaction of graphite with other additives, especially lubricants, which plays a major role for flow ability and agglomeration. For the latter, the selection of raw materials and the many processing options available, result in a wide range of property variation

III. EXPERIMENTAL WORK

Considered experimental materials, metal matrix composites are, a good alternative to traditional materials, due to their hardness, specific strength and creep resistance. Despite this interest, they regards still niche applications, about the industrial world, cause to their cost does not allow a wider use. Major applications are in the aerospace and aeronautical field, where the material costs are not so limited and where it is researched continuous improvement about the specific performance. The fact remains that an ever greater interest are taking MMC applications regarding the automotive areas, with particular attention to be fields of engine and brake system.

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Table 3.1 CHEMICAL COMPOSITION

ELEMENT	COMOPOSITION
Si	7.5-9.5%
Fe	1.30%
Cu	3-4%
Mn	0.5%
Mg	0.3%
Zn	3%
Ni	0.5%
Pb	0.3%

Table 3.2 MECHANICAL PROPERTIES

PROPERTIES	CHILL CAST
Ultimate Tensile Strength(N/mm²)	180
Elongation (%)	1.5
Brinell hardness	85
Modulus of elasticity($\times 10^3$ N/mm²)	71
0.2% Proof Stress (N/mm²)	100 – 200
Density(g/cc)	2.79

PROPERTIES:

- Aluminium LM 24 is the base metal for our metal matrix composite.
- Alumina (Al_2O_3) and graphite are the selected ceramics for reinforcement in the metal matrix.
- Aluminium is the most abundant metal available in earth's crust, the most abundant element after Oxygen and silicon.
- Aluminium is mostly used for its high strength to low weight ratio.
- Aluminium has high electrical and thermal conductivity along with good corrosion property.
- Aluminium can also be anodized as it is corrosion resistant
- Typical applications for Aluminium alloy LM24 include
- Aircraft and aerospace components
- Marine fittings Transport
- Bicycle frames
- Camera lenses
- Drive shafts & Valves
- Electrical fittings and connectors
- Brake components & Couplings

Table 3.3 PHYSICAL PROPERTIES

Coefficient of Thermal Expansion (per°C at 20100°C)	0.000021
Thermal Conductivity (cal/cm 2 /cm/°C at 25°C)	0.23
Electrical Conductivity (% copper standard at 20°C)	24
Density (g/cm 3)	2.79
Freezing Range (°C) approx.	580-520

Table 3.4 THERMAL PROPERTIES

Grade	Thermal Expansion Co-efficient 10^{-6} L/K	Specific heat J/gK	Enthalphy from 25^{0}c J/Kg	Thermal Conductivity W/mK
A1	5.4	0.775	0	30 – 40
A2	5.4	0.775	0	30 – 40
A3	5.4	0.775	0	30 – 40
A4	5.4	0.775	0	25 – 35
A5	5.4	0.780	0	30 – 40
A6	5.1 – 5.4	0.780	0	25 – 30
A7	5.1 – 5.4	0.760 – 0.780	0	20 – 30
A8	4.9 – 5.5	0.755 – 0.785	0	15 – 20
A9	4.5 – 5.5	0.750 – 0.785	0	15 – 20

IV. PREPARATION SAMPLES

GRAPHITE STRUCTURE:

The effect of graphite powder with respect to the performance of final Plastic Metallurgy parts is not fully understood yet. The same is valid for the interaction of graphite with other additives, especially lubricants, which plays a major role for flow ability and agglomeration. For the latter, the selection of raw materials and the many processing options available, result in a wide range of property variation.

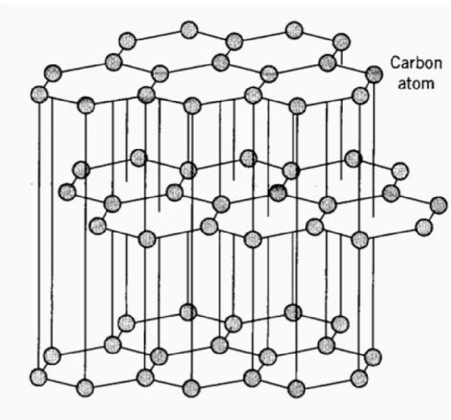

Fig 4.1 : Structure of Graphite

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STIRRING MECHANISM:

These both degrade the final property of the composition and rises viscosity of slurry, making subsequent casting difficult. The rate of reaction reduced and become zero. If the melt is Si-rich either by prior alloying or as a result of the reaction. These both degrade the final property of the composition and rises viscosity of slurry, making subsequent casting difficult. The rate of reaction reduced and become zero. If the melt is Si-rich either by prior alloying or as a result of the reaction.

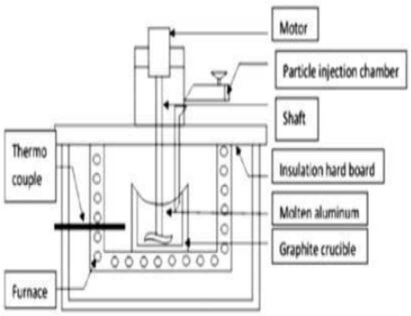

Fig 4.2: Stirring Mechanism

STIR CASTING:

This two-step mixing process has been used in the fabrication of aluminum LM24 matrix composite reinforced with graphite and alumina particles. The resulting microstructure has been found to be more uniform than that processed with conventional stirring. Compared with conventional stirring, the mixing of the particles in the semi-solid state can more effectively break the gas layer because the high melt viscosity produces a more abrasive action in the particle surface.

The major merit of stir casting is its applicability to large quantity production. Among all the well-established metal matrix composite fabrication method, stir casting is the most economical compared to other methods, stir casting costs as little as one third to one tenth for mass production. For that reason stir casting is currently the most popular commercial method.

- Stirring speed: 700 rpm
- Stirring time: 2 min
- Crucible preheating temp: 400oC
- Pattern material: PVC Pipe (35mm dia)
- Stirring rod material: mild steel (304 grade)
- Stirring blade: mild steel (304 grade

Table 4.1 HYBRID RATIO OF THE REINFORCEMENT

ITERATIONS	P1(g)	P2 (%)	P3 (%)
1	300	4	3
2	300	8	6
3	300	12	9
4	320	4	6
5	320	8	9
6	320	12	3
7	340	4	9
8	340	8	3
9	340	12	6

Table 4.2 HYBRID RATIO OF ALUMINIUM ALLOY LM24 WITH REINFORCEMENT MATERIAL

VARIABLE	LEVEL 1	LEVEL 2	LEVEL 3
ALUMINIUM LM24	300	320	340
ALUMINA	4%	8%	12%
GRAPHITE	3%	6%	9%

V. RESULTS

The Nine Iterations are carried out and the results are given below:

Table 5.1 : ANOVA FOR HARDNESS

Experiment	LM 24 (g)	Alumina (%)	Graphite (%)	Hardness
1	300	4	3	57.26
2	300	8	6	66.10
3	300	12	9	66.26
4	320	4	6	57.30
5	320	8	9	65.03
6	320	12	3	62.76
7	320	4	9	57.53
8	320	8	3	63.63
9	320	12	6	68.20

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Table 5.2 GREY RELATION ANALYSIS

Iterations	LM 24 (g)	Alumina (%)	Graphite (%)	Grade
1	300	4	3	0.333
2	300	8	6	0.868
3	300	12	9	0.720
4	320	4	6	0.615
5	320	8	9	0.740
6	320	12	3	0.715
7	340	4	9	0.560
8	340	8	3	0.618
9	340	12	6	0.774

SIMULATION:

With the solution completed simulation automatically creates Results folder with several new folders in the study Manager Window like Stress, Displacement, and Strain & Deformation. Each folder holds an automatically created plot with its respective type of results. The solution can be executed with different properties.

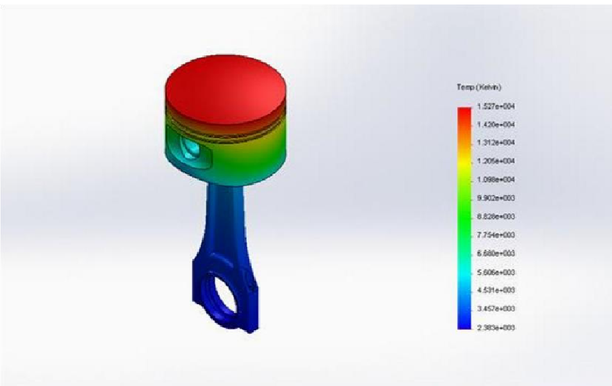

Figure 5.1 Aluminium composite material

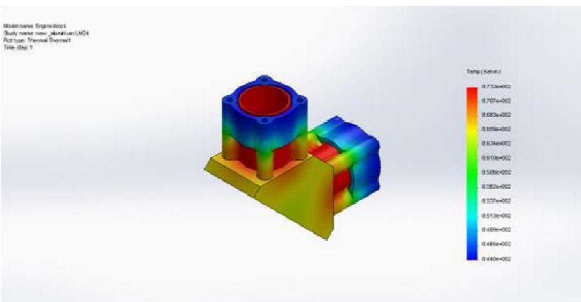

Figure 5.2 Engine block - AluminiumLM24 – Thermal

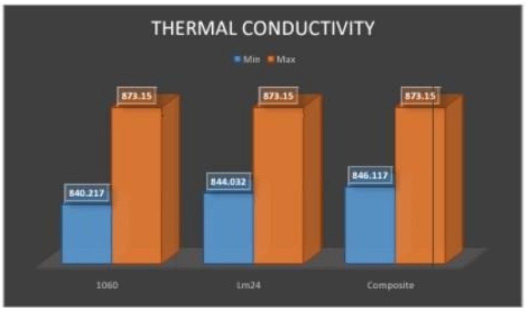

Fig 5.3: Thermal Conductivity Histogram

TABLE 5.1 : TEMPERATURE DISTRIBUTION

Material	Min	Max
Aluminium 1060	840.217	873.15
LM 24	844.023	873.15
LM 24 Composite	846.117	873.15

VI. CONCLUSION

Thus the metal matrix composite was carried out successfully by carrying out in various percentages of iterations. For proper mixing of the composite added to the crucible in the furnace, the stir casting setup was made to fabricate. This was fabricated mainly to make the proper mixing of the composition added to the furnace in such a way it should not stick at any side walls of the crucible. In our project work we carried stir for two minutes which is very much enough for magnesium composites.

- The density of the material was made to measure, which was better than actual magnesium value. This will increase the weight ratio.
- The analysis of variance was calculated for the various iterations involved in the project in which we found that factor (Al2O3) was responsible for increasing the hardness of the material.
- Wear testing was conducted for the material and it has identified that there is 6.7% of wear subjected.
- The reinforcement was made to analyse by means of seeing the chemical composition in the material. And which was made to result by means of percentage involved in it.

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