International Journal of Engineering & Technology, 7 (2.33) (2018) 496-502

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Properties and behavior of squeeze pressure on aluminum molybdenum DI-supplied composite

S. Arunkumar [1] *, M. Chandrasekaran [2], T. Vinod Kumar [1], V. Muthuraman [1]

[1] *Assistant Professor, Department of Mechanical Engineering,Vels Institute of Science, Technology & Advanced Studies, Chennai,*
[2] *Professor and Director, Department of Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai,*
**Corresponding author E-mail: gct.arunkmar@gmail.com*

Abstract

To develop a metal matrix composite with lubricative properties with the help of various casting process and they are tested for their properties. Casting machine is turned ON. Furnace temperature is set to 850o C. Preheater temperature is set to 180o C. Pathway temperature is set to 550o C. The furnace is allowed to get heated up. Once it gets heated upto 600o C, the A-Si alloy is dropped into the furnace. The alloy gets melted at around 800-850o C. Molybdenum di-sulphide fine powder is preheated and then mixed with the molten metal. Molybdenum di-sulphide is a reinforcement added and it is preheated to increase the wettability. Stainless steel stirrer is used to mix the alloy and graphite well. Stirrer is rotated between 200-300rpm.Once both the alloy and reinforcement gets mixed up into a single red hot molt, it is poured. The molt now leaves from the bottom of the furnace through the pathway. Pathway is maintained at 550o C to avoid solidification of molt in the path. Pathway carries the molt to a die, where it is poured. A squeeze pressure of 30 tonnes and 60 tonnes is given on the die using a piston. Die is split up and the mould is taken out from it. The die, furnace, pathway are coated with a layer of non-stick coating to avoid the sticking of alloy in the walls. The same process is repeated in stir casting, except that, pathway is not needed. The molten alloy is poured directly into the die without any pressure being applied. The die is split and the mould is taken. Coating is done before the next casting.
Graphite powder and the Al-Si alloy materials are casted using squeeze casting process. Wear strength, tensile strength, flexural strength, impact strength and hardness test for the squeeze casted material is found out. The same materials are casted with the help of the stir casting process and they are compared with the squeeze cast material. Various testing process are to be carried out on the casted material and the results are compared.

Keywords: *Metal Matrix Composite (MMC); AL-SI alloy; squeeze casting; wear testing; Microstructure*

1. Introduction

The primary objective of this project is to prepare a metal matrix composite which consists of Al-Si alloy and molybdenum di-sulphide casted together using “Squeeze Casting” technique, which is specially made to cast alloys and reinforcements together as a composite. Alloys are then casted without any reinforcements for determining their wear behavior and other characteristics and comparing their values with the metal matrix composite casted earlier with the other parameters remaining the same.

1.1. Composite materials

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.
The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

1.2. Metal matrix composites

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet. MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminum matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminum to generate a brittle and water-soluble compound Al4C3 on the surface of the fiber. To prevent this reaction, the carbon fibers are coated with nickel or titanium boride.
The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high-

temperature applications, cobalt and cobalt–nickel alloy matrices are common.
The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging, or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD).
Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses "whiskers", short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide

1.3. AL-SI alloy

This alloy conforms to BS1490. LM6 exhibits excellent resistance to corrosion under both ordinary atmospheric and marine conditions. For the severest conditions this property can be enhanced by anodic treatment. The aluminium-silicon alloys possess exceptional casting characteristics, which enable them to be used to produce intricate castings of thick and thin sections. Fluidity and freedom from hot tearing increase with silicon content and are excellent throughout the range. The ductility of LM6 alloy enables castings to be easily rectified or modified in shape, e.g., simple components may be cast straight, and later bent to the required contour. LM6 is especially suited to castings that need to be welded although special care is needed when machining.

1.4. Molybdenum DI-sulphide

Molybdenum disulfide is the inorganic compound with the formula MoS2 .The compound is classified as a metal dichalcogenide. It is a silvery black solid that occurs as mineralmolybdenite, the principal ore for molybdenum. MoS2 is relatively unreactive. It is unaffected by the action of dilute acids and oxygen. In appearance and feel, molybdenum disulfide is similar to graphite. It is widely used as a solid lubricant because of its low friction properties and robustness.

Fig. 1: Molybdenum Di-Sulfide.

2. Experimental procedure

2.1. Structure

In MoS_2 each Mo (IV) center occupies a trigonal prismatic coordination sphere, being bound to six sulfide ligands. Each sulfur centre is pyramidal, being connected to three Mo centres. In this way, the trigonal prisms are interconnected to give a layered structure, wherein molybdenum atoms are sandwiched between layers of sulfur atoms. Because of the weak van der Waals interactions between the sheets of sulfide atoms, MoS_2 has a low coefficient of friction, resulting in its lubricating properties. Other layered inorganic materials exhibitlubricating properties (collectively known as solid lubricants (or dry lubricants)) including graphite, which requires volatile additives, and hexagonal boron nitride.

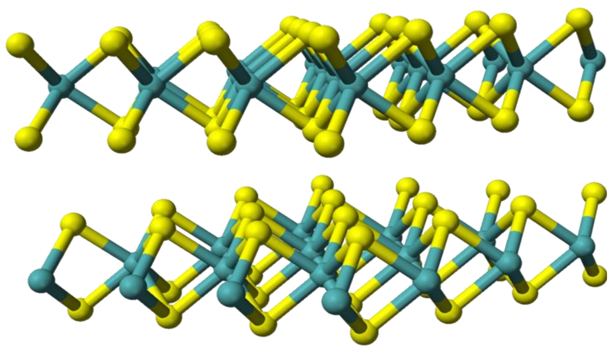

Fig. 2: Molecular Structure of Mos_2.

While bulk material forms a layered structure, nanoparticulate MoS_2 forms fullerene and nanotubular microstructures.Bulk MoS_2 is a diamagnetic, indirect bandgap semiconductor similar to silicon, with a gap of 1.2 eV.

2.2. Properties

Table 1: Properties of MoS_2

Molecular formula	MoS_2
Molar mass	160.07 g/mol
Appearance	black/lead-gray solid
Density	5.06 g/cm^3
Melting point	1185 °C decomp.
Solubility in water	Insoluble
Solubility	Decomposed only by aquaregia, hot sulfuric acid, and nitric acid insoluble in dilute acids.

2.3. Squeeze casting

Squeeze casting as liquid-metal forging, is a process by which molten metal solidifies under pressure within closed dies positioned between the plates of a hydraulic press.
The applied pressure and instant contact of the molten metal with the die surface produce a rapid heat transfer condition that yields a pore-free fine-Graphiteain casting with mechanical properties approaching those of a wrought product. The squeeze casting process is easily automated to produce near-net to net shape high-quality components.

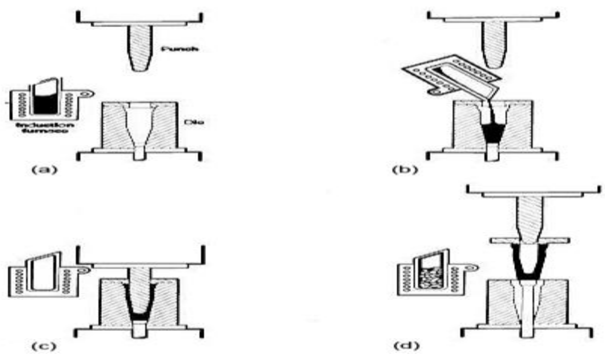

Fig. 3: Schematic Illustrating Squeeze-Casting Process.

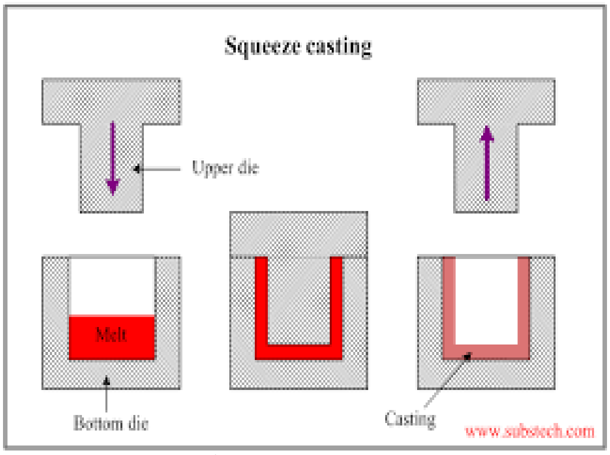

Fig. 4: Squeeze Casting.

a) Melt charge, preheat, and lubricate tooling.
b) Transfer melts into die cavity.
c) Close tooling, solidify melt under pressure.
d) Eject casting, clean dies, charge melt stock.

2.4. Casting parameters

Casting temperatures depend on the alloy and the part geometry. The starting point is normally 6 to 55°C above the liquidus temperature.
Tooling temperatures ranging from 190 to 315°C are normally used.
Time delay is the duration between the actual pouring of the metal and the instant the punch contacts the molten pool and starts the pressurization of thin webs that are incorporated into the die cavity.
Pressure levels of 50 to 140 Map are normally used.
Pressure duration varying from 30 to 120s has been found to be satisfactory for castings weighing 9 kg.
Lubrication for aluminum, magnesium, and copper alloys, a good Graphiteade of colloidal Graphite spray lubricant has proved satisfactory when sprayed on the warm dies prior to casting.

3. Experimental process

3.1. Casting defects

Extensive efforts have been made to investigate how heat transfer characteristics affect the solidification behavior of aluminum alloys in squeeze casting. Some qualitative explanations on the foundation of channel macro graphite have been made in the squeeze casting of an Al-4.5 wt pct Cu alloy. Attention has also been given to the exploration of practical methods of eliminating casting defects in squeeze castings. However, it is generally considered difficult to prevent the foundation of macro graphite in squeeze casting, since the condition for producing sound castings without the foundation of macro graphite and shrinkage defects is very limited. No quantitative work has reported on the control of solidification characteristics to prevent the formation of macro graphite in the squeeze casting process.
An Al-4.5 wt pct Cu alloy was used as the casting material. After melting in a high frequency induction furnace, liquid metal with a certain superheat was poured into the preheated tool steel die with a cylindrical cavity of an internal diameter of 50 mm. After pouring the melt into the die cavity, pressurization was achieved using a 30 T hydraulic press. The delay time, which is necessary for the pressurization of the melt after pouring, could be kept below 4 seconds in order to prevent the start of solidification prior to pressurization. Degassing of the melt was not performed to investigate the effects of humidity on the formation of macro defects.
In order to investigate the conditions of the formation of macro graphite in correlation with the formation of shrinkage defects, the effects of the process parameters, such as pouring temperature (Tp), die temperature (TD), delay time (tD), applied pressure (P), and humidity (Hd), were examined.
The die temperature was in the range of 50°C to 300°C, and the pouring temperature was in the range of 650°C to 810°C. The average humidity was in the range of 20 to 80 pct RH, and the relevant air temperature was in the range of 15°C to 30°C.

3.2. Process parameter

For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there are various process parameters if they properly controlled can lead to the improved characteristic in composite material.
Stirring speed
Stirring speed is the important process parameter as stirring is necessary to help in promoting wetability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In our project we kept speed from 300-600 rpm. As solidifying rate is faster it will increase the percentage of wettability.
Stirring temperature
It is an important process parameter. It is related to the melting temperature of matrix i.e. aluminium. Aluminium generally melts at 650◦C. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature with increasing holding time stirring time. It also accelerates the chemical reaction b/w matrix and reinforcement. In our project in order to promote good wetability we had kept operating temperature at 630°C which keeps Al (6061) in semisolid state.
Reinforcement preheat temperature
Reinforcement was preheated at a specified 500◦C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wetability of reinforcement with matrix.
Addition of Molybdenum di-sulphide
Addition of molybdenum di-sulphide enhances the wetability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult.
Stirring time
Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The stirring time b/w matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

3.3. Wear testing

This method is used to test the wear of a material. The material is placed on a rotating disk. A measured load is applied on the material through a pin from the top. The initial mass of the pin is measured. After a particular time, the sliding distance and the mass of the pin is measured. The difference in the mass of the pin gives the wear rate.

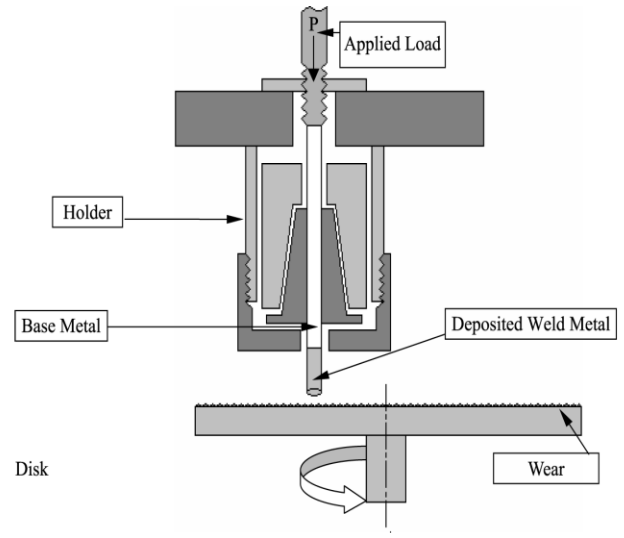

Fig. 5: Wear Testing.

3.4. Stages of wear

Under normal mechanical and practical procedures, the wear-rate normally changes through three different stages (ref.4):
Primary stage or early run-in period, where surfaces adapt to each other and the wear-rate might vary between high and low.
Secondary stage or mid-age process, where a steady rate of ageing is in motion. Most of the components operational life is comprised in this stage.
Tertiary stage or old-age period, where the components are subjected to rapid failure due to a high rate of ageing.

3.5. Types

The study of the processes of wear is part of the discipline of tribology. The complex nature of wear has delayed its investigations and resulted in isolated studies towards specific wear mechanisms or processes. Some commonly referred to wear mechanisms (or processes) include:
Adhesive wear, Abrasive wear, Surface fatigue. Fretting wear, Erosive wear
Adhesive wear can be found between surfaces during frictional contact and generally refers to unwanted displacement and attachment of wear debris and material compounds from one surface to another. Two separate mechanisms operate between the surfaces.
Friccohesity defines actual changes in cohesive forces and their reproduction in form of kinetic or frictional forces in liquid when the clustering of the nano-particles scatter in medium for making smaller cluster or agGraphiteegates of different manometer levels.

3.6. 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 (which can be broadly classified into metallic, polymeric, ceramic and composite) 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

Fig. 6: Microstructure Testing Machine.

3.6.1. Specimen

Tensile specimens made from an aluminum alloy. The left two specimens have a round cross-section and threaded shoulders. The right two is flat specimen designed to be used with serrated Graphiteips.

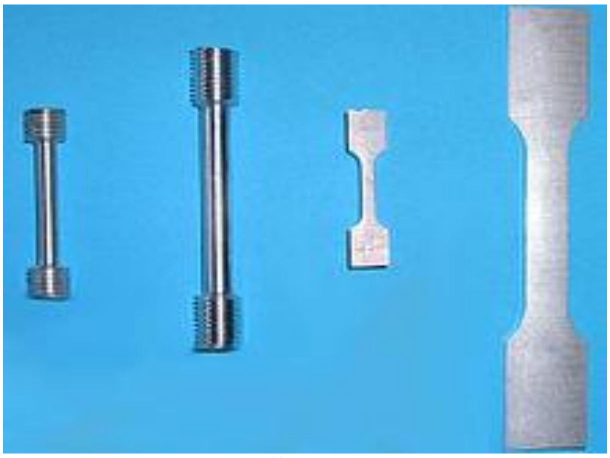

Fig. 6: Different Specimens.

3.7. Types of flexural tests

Flexure testing is often done on relatively flexible materials such as polymers, wood and composites. There are two test types; 3-point flex and 4-point flex. In a 3-point test the area of uniform stress is quite small and concentrated under the center loading point. In a 4-point test, the area of uniform stress exists between the inner span loading points.

1) Calculation of the flexural stress σ_f

$\sigma_f = \frac{FL}{\pi R^3}$ (Circular cross section)

2) Calculation of the flexural strain ϵ_f

$$\epsilon_f = \frac{6Dd}{L^2}$$

3) Calculation of flexural modulus E_f

$$E_f = \frac{L^3 m}{4bd^3}$$

In these formulas the following parameters are used:

- σ_f = Stress in outer fibers at midpoint, (MPa)
- ϵ_f = Strain in the outer surface, (mm/mm)
- E_f = flexural Modulus of elasticity,(MPa)
- F = load at a given point on the load deflection curve,(N)
- L = Support span, (mm)
- b = Width of test beam, (mm)
- d = Depth of tested beam, (mm)

- D = maximum deflection of the center of the beam, (mm)
- m = The gradient (i.e., slope) of the initial straight-line portion of the load deflection
- Curve,(P/D), (N/mm)
- R = The radius of the beam, (mm)

Fig. 7: Al-Si Alloy Materials.

Fig. 8: Molybdenum Di-Supplied.

Fig. 9: Squeezing Machine.

Fig. 10: Cast with the Piston Ram (Vertical).

Fig. 10: Squeeze Casted Material.

4. Results and discussion

MICRO STRUCTURE TEST REPORT
Sample No: 30 tonnes (MoS_2)

Photo-1 As Etched Magnification: 150x

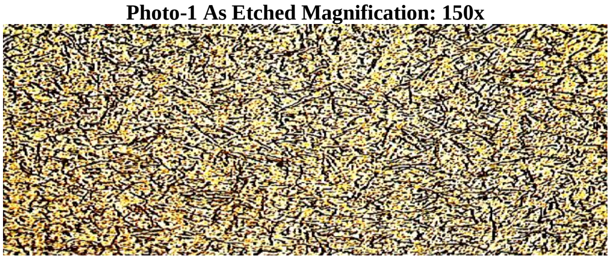

Photo 2 As Etched250X. Etchant: H.F Solution & Kellar's Reagent

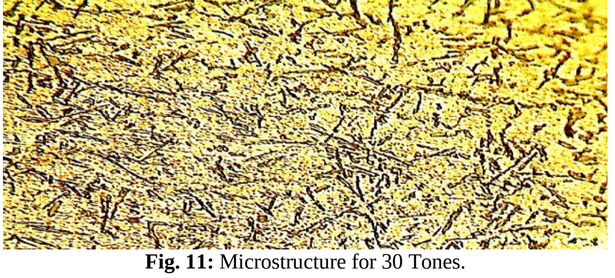

Fig. 11: Microstructure for 30 Tones.

The matrix shows the distribution of Al-Si eutectic particles in spike like appearance in aluminium solid solution. The presence of MoS2 is isolated in the matrix.
Sample No: 60 tonnes (MoS2)

Photo-1 As Etched Magnification: 150x

Photo-2 As Etched 250X Etchant: H.F Solution & Kellar's Reagent

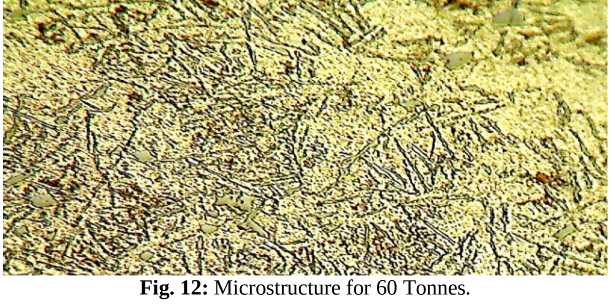

Fig. 12: Microstructure for 60 Tonnes.

The matrix shows the distribution of Al-Si eutectic particles in spike like appearance in aluminium solid solution. The presence of MoS2 is more leading the presence of it in the matrix. The particles appear red particles in white aluminium matrix.

Table 2: Test Report

Sl .no	Test parameters	Observation	
		30 Tonnes	60 Tonnes
1	Tensile Strength	147 N/mm²	151.3 N/mm²
2	Hardness	76 BHN	87 BHN
3	Flexural Strength	100 N/mm²	158.4 N/mm²
4	Impact Strength	11 joules	14 joules

Table 3: Wear Test Report

SAMPLE DESRIPTION : Aluminium - MOS2.

30 tonnes.

Applied Load (kN)	2	2	2	2	2
Sliding distance (meter)	1000	2000	3000	4000	5000
Weight Loss(gm)	0.0004806	0.0009963	0.0016092	0.0016956	0.0024192
Wear Volume Loss (mm3)	0.178	0.369	0.596	0.628	0.896
Wear Volume Loss (cm3)	0.000178	0.000369	0.000596	0.000628	0.000896
Wear rate(cm3/Nm)	0.000000089	9.225E-08	9.93333E-08	7.85E-08	8.96E-08
Wear rate(m2/N)	8.9E-14	9.225E-14	9.93333E-14	7.85E-14	8.96E-14

Applied Load (kN)	1	2	3	4	5
Sliding distance (meter)	2000	2000	2000	2000	2000
Weight Loss(gm)	0.0007533	0.0015822	0.0016578	0.0022707	0.0024975
Wear Volume Loss (mm3)	0.279	0.586	0.614	0.841	0.925
Wear Volume Loss (cm3)	0.000279	0.000586	0.000614	0.000841	0.000925
Wear rate(cm3/Nm)	1.395E-07	1.465E-07	1.02333E-07	1.05125E-07	9.25E-08
Wear rate(m2/N)	1.395E-13	1.465E-13	1.02333E-13	1.05125E-13	9.25E-14

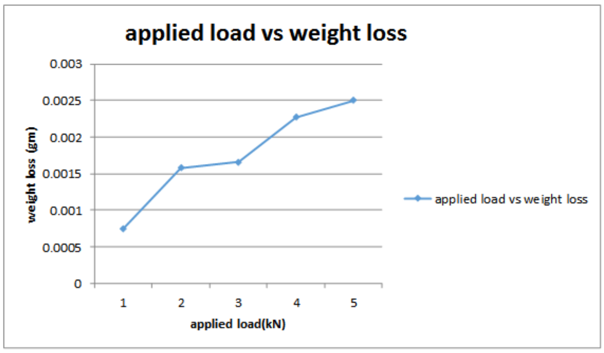

Fig. 13: Applied Load vs. Weight Loss.

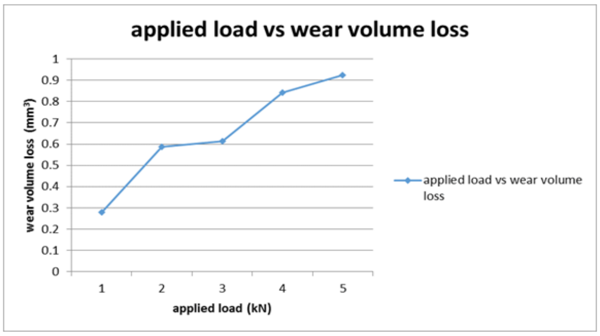

Fig. 14: Applied Load vs. Wear Volume Loss.

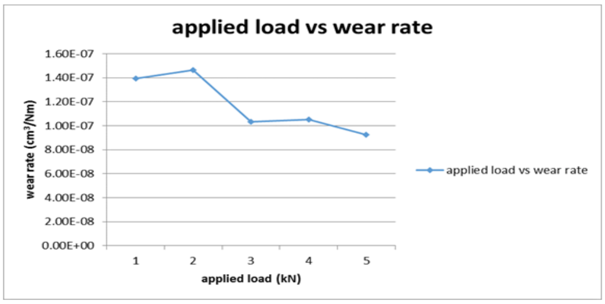

Fig. 15: Applied Load vs. Wear Rate.

Fig. 16: Sliding Distance vs Weight Loss.

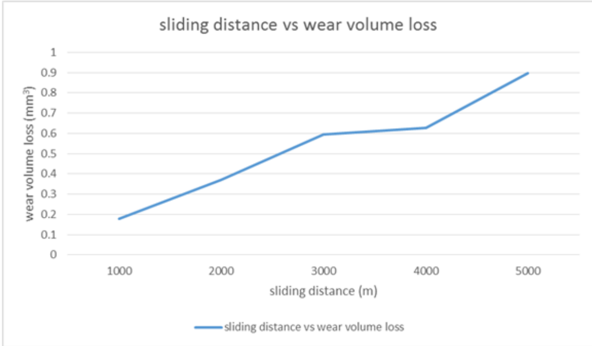

Fig. 17: Sliding Distance vs Wear Volume Loss.

Fig. 18: Sliding Distance vs Wear Rate.

Table 4: For 60 Tonnes Squeez Pressure

Applied Load (kN)	1	2	3	4	5
Mass Loss (gm)	0.000699	0.001314	0.001431	0.001987	0.002144
Sliding Dis-tance (m)	2000	2000	2000	2000	2000

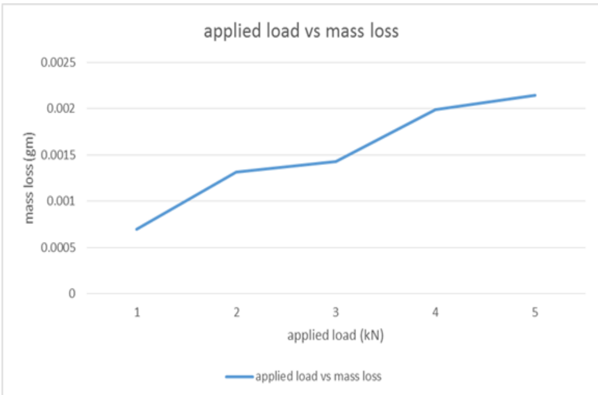

Fig. 19: Applied Load vs Mass Loss.

5. Conclusion

In this project the micro structure reveals that in 30 tonnes squeeze pressure, the MoS2 dispersion is not closely packed compared to the one with 60 tonnes squeeze pressure. The addition of MoS2 provides better wear resistance for the composite material.
The tensile test, hardness test, flexural strength and wear test reports reveals that the 60 tonnes squeeze pressure is more reliable than 30 tonnes squeeze pressure.

References

[1] T.W.CLYNE and P.J.WITHERS. “An introduction to metal matrix composites”, 1st ed., Cambridge University Press, Cambridge, 1993, pp 1-10.
[2] “Effect of applied pressure on the microstructure and mechanical properties of squeeze- cast aluminium AA6061 alloy”, S.SKOLIANOS, DRIOURTSIDIS, THOMAS, XATZIFOTIOU, materials science and engineering, 1997, vol231 A, pp 17-24.
[3] KARNEZIS P.A. “Microstructure and tensile properties of squeeze cast Sic particulate reinforced Al-7si alloy”, materials science and technology, 1998, vol. 17, pp 97-107.
[4] S.A.PELASEYYED. “Characterization of aluminium/graphite particulate composites synthesized using novel method termed – in situ powder metallurgy”, Mater. Sci.Eng. A, 2004, 385, pp 258-266.
[5] S. RAY, “Review Synthesis of Cast Metal Matrix Particulate Composites”, J. Mater. Sci., 1993, 28(20), pp5397–5413.
[6] SARAVANABHAVAN. “Synthesis, Characterization and Mechanical Behavior of Nickel Coated Graphite on Aluminum Matrix Composite”, International Journal of Research in Engineering and Technology, 2013 vol 02, pp. 749 -755.
[7] YOUNG– HO SEO, CHUNG GIL KANG. “ The effect of applied pressure on particle dispersion characteristics and mechanical properties in melt stirring squeeze cast Sicp / Al composite, Journal of materials processing technique”,1995 vol 55,pp. 370 – 379.
[8] MENEZES P L, ROHATGI LOVELL P.K,Self-Lubricating Behavior of Graphite Reinforced Metal Matrix Composites, in: Nosonovsky. N, Bhushan .B (Eds.), Green Tribology, Springer, Berlin Heidelberg 2012, 445–480.
[9] SURAPPA M.K, ROHATGI P.K, Preparation and properties of cast aluminium-ceramic particle composites, Journal of Materials Science, 16 (1981), 983–993.
[10] ROHATGI .P, Cast Metal Matrix Composites: Past, Present and Future, Transactions of the American Foundry Society, 109 (2001), 1–25.
[11] RUCH P.W, O. BEFFORT, KLEINER.S, WEBER.L Selective interfacial bonding in Al(Si)–diamond composites and its effect on thermal conductivity, Composites Science and Technology, 66 (2006), 2677–2685.
[12] BAI B.N.P, E. S. DWARAKADASS, S. K. BISWAS, Scanning electron microscopy studies of wear in LM13 and LM13-graphite particulate composite, Wear, 76 (1982), 211Author,”Title of the Paper”, Journal name, Vol.X, No.X, (200X), pp.XX-XX, available online: http://xxx, last visit:28.02.2013.