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Design and analysis of Aluminum Metal Matrix (Al-Cu) + Fly ash Material and comparison with pure Aluminum

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Abstract
This research offers an analysis of the Aluminum matrix (Al-Cu) and the addition of fly ash with different combinations such as 0%, 1%, 2%, 3% & 4% of aluminum. Now a day's application of composites spreads widely as it fulfills the need of applications such as aerospace industries, shipbuilding, propeller shafts, transportation, etc. All above-mentioned applications need a high weight-to-strength ratio, hence conventional materials like steel, and cast iron need to be replaced by composite materials such as aluminum matrix. Wear resistance of material and tensile strength shows the usefulness of composites over ordinary materials. Aluminum matrix with different combinations of fly ash is analyzed in this project. Chemical composition of the composite matrix, wear of the composite matrix, and tensile strength of the composite matrix (Al-cu + different combinations of fly ash) is measured. The wear test of different combinations of the aluminum matrix is tested on the wear test setup and compared different combinations of fly ash reinforcement of 0%, 1%, 2%, 3% & 4%. The tensile strength of the Aluminum matrix is measured on a universal testing machine and this measured tensile strength is compared with a standard tensile strength of pure Aluminium.
Keywords: *Aluminum metal matrix, Fly ash, Tensile strength, Universal Testing Machine*

1. Introduction
Nowadays, it has been seen that the use of composite materials is increasing widely in many fields of engineering applications such as aerospace industries, railways, drones, shipbuilding, etc. These applications need a more weight-toweight-to-strength ratio. A composite material satisfies demand like lightweight material, less cost-effective, low production cost, higher flexibility with major strength, etc. Aluminum alloys are extensively used in the above-mentioned fields. In the transportation system, the Propeller shaft plays a crucial role in transferring torque from one location to another. Fly ash is a waste product of coal. The use of fly ash in the composite as a reinforcing agent is not only increases the strength of the material but also it helps to decrease environmental pollution. The addition of Copper maximum of 2% of aluminum and fly ash used as reinforcement gives a more stable composite with enhanced material properties Metal Matrix Composite (AMMC) is also used in newer applications where the need for light weight, high strength, high stiffness, and required properties. The aluminum helps in reducing the wear rate, however, the friction coefficient increases with the addition of aluminum in the matrix of the aluminum. The fly ash presents in the aluminum matrix resists the destruction action in turn wear resistance of the composites considerably increased. Wear resistance is the change in conditions caused by friction and the result obtained from deformation, scratches, and indentations on the interacting surfaces. Friction occurs between moving parts and is commonly analyzed in parts that come into contact with one another during operation, such as power trains in automobiles. Aluminum metal matrix with different reinforcing agents such as fly ash, copper, manganese, etc. gives different enhanced mechanical properties of material for optimum utilization of material for various applications of the aluminium.

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2. Methodology

In this project, the stir casting process is used for making Al-Cu and fly ash composites. The stir-casting refers to the process of stirring molten metal is used for continuously stirring particles into metal alloy to melt and immediately pour into the sand mold then cooled and allowed to solidify. In stir casting, particles are of equal size and are homogeneous, which can be achieved only by dissolving by stirring at high speed and at high temperature. Stir casting is a method in which liquid state of composite materials fabrication is done, in which a dispersed phase is mixed with a molten matrix metal by mechanical stirring. The mixing is typically enhanced by a motor-driven stirring mechanism or an ultrasonic transducer. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technology. Stir casting is a suitable for processing technique to fabricate aluminum matrix composites and hybrid aluminum matrix composites as it is an economical process and preferred for mass production first step of stir casting involves the melting of aluminum, during melting, aluminum melts reacts with the atmosphere and moisture and forms a layer of aluminum oxide. This layer shields the surface of the melt from further reaction with the atmosphere. Stir casting process involves stirring of melt, in which the melt is stirred continuously with help of a motor. When exposed the melt surface to the atmosphere which tends to continuously oxidation of aluminum melt. As a result of continuous oxidation, the weight ability of the aluminum reduces and the reinforcement particles remain unmixed. Al2O3 is a very stable chemical compound, which cannot be reduced under normal conditions and the weight ability of melt remains unchanged. an invert environment To stop the oxidation completely, an invert environment has to be created, which involves lots of complications. Therefore, adding wetting agents such as borax, magnesium in the melt is an alternate solution of this problem and widely used for the fabrication of Aluminum Metal Composites. Melt should be homogeneous to get uniform mechanical properties that are desirable but the homogeneous distribution of particles in the melt is another problem faced in the stir casting process, which is controlled by stirring parameters play a major role in the stir casting process. Stirring speed, stirring time, impeller blade angle, size of impeller, and position of the impeller are major parameters, affecting the distribution of the reinforcements in the matrix. Stir casting is a type of casting process in which a mechanical stirrer is introduced to form a vortex to mix reinforcement in the metal matrix.

2.1 Process of stir casting

The flow chart of the stir casting process is shown in below figure 1

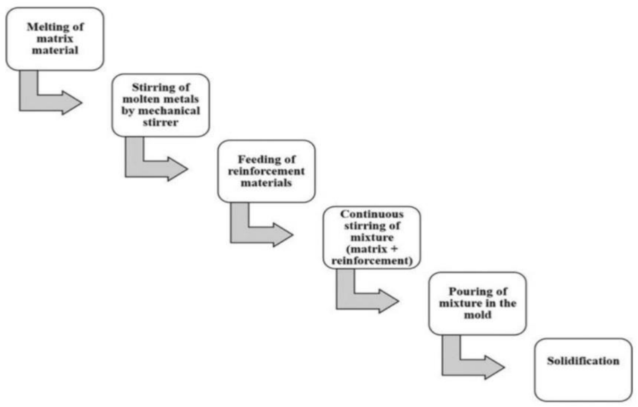

Figure 1 Flow Chart of Stir Casting

2.2 The flow structure is outlined as follows

- Melting of matrix material in an induction furnace in the crucible.
- Preheating of die and reinforcement.
- Pouring of particles in to the crucible.
- Running the stirrer with optimum speed for the mixing of matrix and reinforcement.
- Pouring the mixed liquid into the preheated die.
- Allow the mold to solidify
- Removing the component into the die.

Figure 1 shows the entire process, with each step seamlessly leading to the next, forming a cast product of aluminum,2% of copper, and different percentages of fly ash. There is various impeller blade geometry are available, melting of the matrix

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material is the very first step that has been done during this casting process. The molten mixture is then poured into the preheated mold and kept for natural cooling and solidification, further post-casting processes such as heat treatment, machining, testing inspection, etc.

3. Raw Materials of composites

3.1 Aluminum Strap

Raw materials used for this research are Aluminum, copper powder, and fly ash. Aluminum 6061 is used as a strap material and is melted at 900ºC. 12 Kg of Aluminum is used for the whole process, and 2 kg of Aluminum is used for each step. The aluminum strap is shown in Figure 2.

Figure 2 Aluminum Strap

3.2 Copper Alloy

According to the literature, a maximum of 2% copper can be used for most applications. Hence, 2% of Copper powder is used in this project. A size between 75-100µm of copper powder is used with the help of a sieve shaker machine shown below. The brownish copper powder is used, which is preheated at 300º as shown in Figure 3.

Figure 3 Copper Powder

3.3 Fly Ash

Fly ash is obtained from the thermal plant. It is a waste for many industries. Fly ash in composition must be of equal size; otherwise, the material's non-uniform properties will fail the component for use. It is useful for engineering applications. In this project, fly ash is used below 100µm, andconfigurations0%, 1%, 2%, 3%, and 4% are used in that process shown in Figure 4.

Figure 4 Fly Ash Particles

3.4 Final Product

Hexachloro-ethane is used to remove impurities, and Magnesium is used to improve the weight ability and the quality of fabricated composites. Magnesium is used to reduce the surface tension of molten Aluminum of proper wetting and Improve the wetting between Aluminum, Copper, and fly ash particles; in turn, mechanical properties are enhanced. Products are formed with 12kg of Aluminum, 2% of Copper, and (0%,1%,2%,3%,4%) of fly ash configuration is shown in below Figure 5. Finished components are ready for testing for various mechanical properties such as wear of material tensile strength.

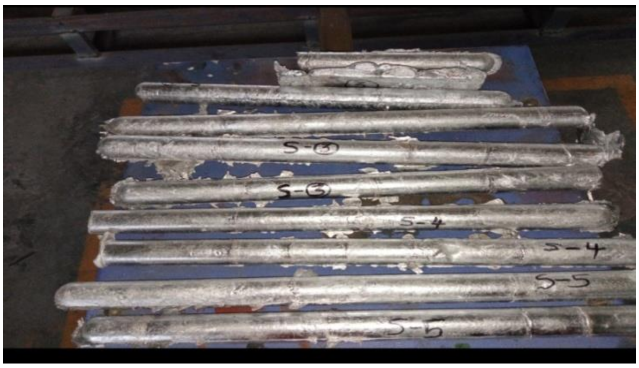

Figure 5 Final Product

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4. Result And Discussion

The research results show the chemical composition of metal composites, wear of different combinations of aluminum matrix with different percentages of fly ash, and tensile strength of components as discussed below.

4.1 Chemical Composition

The following describes the chemical composition of composite alloy; different chemical composition values are achieved for different combinations of composites. The term "chemical composition" describes the kinds and quantities of chemical constituents that go into creating a given substance. The proportions of the constituent elements in the material determine a pure substance's composition. The arrangement, kind, and ratio of atoms in chemical compounds' molecules are called their chemical composition. When chemicals are added to or removed from substances, their chemical composition changes. The chemical composition is displayed in Table 2 below.

Table 1 Chemical Composition

S.No	Sample Id	Chemical Composition										
		Si	Cu	Fe	Mn	Mg	Zn	Pb	Sn	Ti	Cr	Al
1	Sample 1	0.305	1.320	0.106	0.077	0.932	0.132	0.018	0.014	0.023	0.034	96.04
2	Sample 2	0.327	1.466	0.34	0.099	0.050	0.169	0.014	0.008	0.020	0.023	97.494
3	Sample 3	0.320	1.695	0.06	0.086	0.323	0.139	0.017	0.012	0.020	0.027	97.299
4	Sample 4	0.348	1.029	0.047	0.082	0.156	0.192	0.015	0.008	0.019	0.022	98.081
5	Sample 5	0.347	1.288	0.119	0.084	0.772	0.080	0.014	0.009	0.018	0.018	97.252

4.2 Wear Test Result

The percentage of fly ash is increased, and then the wear value is up to 4% of fly ash. At 4% of fly ash wear, the value is high up to 0.0151, and at 0%, the value is 0.0057, respectively. The following graph shows wear variation relative to fly ash percentage variation. In addition to fly ash in composite, which clusters are formed because of that fly ash, the wear value is increased. Some particles remain on the grain boundary; because of that, improper mixing of particles is done, and the weight ability and wear value are increased. Suitable utilization of fly ash in Aluminum Metal Matrix is reducing the damage to the environment. Different percentage of fly ash is used for better strength of material. Different of configurations of fly ash will be used for future experimentation. Different materials should be used for different results. The efforts should be made with different materials and percentages of fly ash along with various testing methods. Solutions for optimizing weld strength in multi-spot welding scenarios. which is more than pure Aluminum. Pure Aluminium has tensile strength of 90 to 140 (N/mm2). Fly ash is accommodated at the grain boundaries of the matrix hence it increases the tensile strength of the material. healthy also we will get enhanced mechanical properties of composites. Hence the addition of fly ash helps. tincrease

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Table 3 Wear Test Report

S.No.	Sample ID	Initial weight	After weight	Wear
1.	Sample 1:0%fly ash,Al-2kg, Cu-2%	13.9640	13.9632	0.0057
2.	Sample 2:1% fly ash	15.8443	15.8425	0.0114
3.	Sample 3:2% fly ash	16.6030	16.6010	0.0129
4.	Sample 4:3% fly ash	15.7433	15.7411	0.0140
5.	Sample 5:4% fly ash	17.0878	17.0867	0.0151

The graph of wear of components at different combinations of fly ash is shown in the graph below. From the graph, it is concluded that as the fly percentage increased, wear also increased.

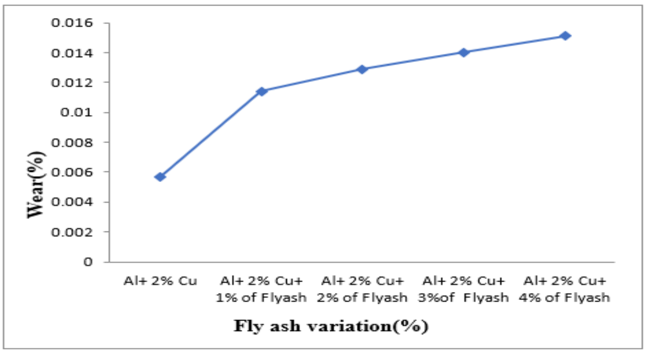

Figure 6 Wear Test Results Graph

4.3 Tensile Strength of Composites

The tensile strength of pure Aluminum ranges from 90 to 140 N/mm2. It has been found that the tensile strength of (Aluminum + 2% Cu) + 4% fly ash gives 141.489 N/mm2.The maximum load carried by each component is shown in table no.3 below. Different materials should be used for different results. The efforts should be made with different materials and percentages of fly ash along with various testing methods. Solutions for optimizing weld strength in multi-spot welding scenarios. The successful application of these optimization techniques holds great promise for improving the efficiency and reliability of resistance spot welding in diverse industrial applications.

Table 4 Tensile Strength of Various Components

S.No.	Sample Id	Tensile strength (N/mm^2)	Maximum load applied (N)	Tensile strength of Aluminum(N/mm^2)
1	**Al +2% cu**	129.369	38150	90 to 140
2	**Al +2% cu+ 1% fly ash**	133.528	38950	
3	**Al +2% cu+ 2% fly ash**	135.524	39450	
4	**Al +2% cu+ 3% fly ash**	138.033	40250	
5	**Al +2% cu+ 4% fly ash**	141.489	44450	

The following graph shows the tensile strength of different combinations. It clearly shows that (Al +2% u) and 4% fly ash tensile strength is 141.489 N/mm2, which is more than pure Aluminum. Pure Aluminium has tensile strength of 90 to 140

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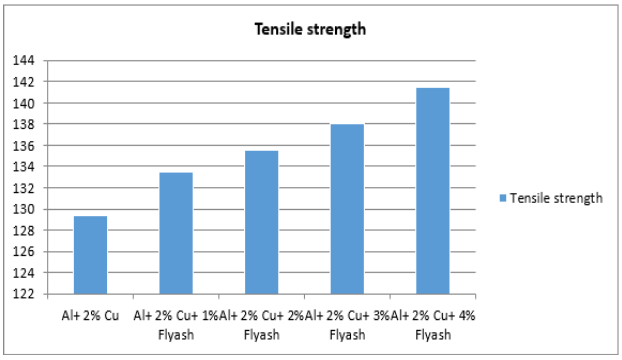

Figure 7 Tensile Strength of Components (N/mm2)

Conclusion And Future Scope

In conclusion, different compositions such as (Al+ 2% Cu) and 0%, 1%, 2%, 3%, and 4% of fly ash gave different results of wear test and tensile strength. At 4% of fly ash wear value is maximum up to 0.0151. The wear of aluminum metal matrix increases with the increase in fly ash. (Al + 2% Cu) + 4% fly ash gave a maximum tensile strength of 141.489 N/mm^2, whereas the tensile strength of pure aluminum is 90 to 140 N/mm^2. Hence we concluded that the addition of fly ash into the aluminum metal matrix gives more tensile strength. Tensile strength with 0% of fly ash is 129.369 N/mm^2 and for 4% of fly ash addition tensile strength is 141.489 N/mm^2. Fly ash is a waste of coal and it is a reason for air pollution hence use of fly ash will be environmentally healthy also we will get enhanced mechanical properties of composites. Hence addition of fly ash helps to increase mechanical properties as well as it reduces pollution. Research shows that Aluminum Metal Matrix (AMM) with the addition of fly ash can replace pure aluminum in various applications such as utensils, aero planes, shipbuilding, etc. Suitable utilization of fly ash in Aluminum Metal Matrix is reducing the damage to the environment. Different percentage of fly ash is used for better strength of material. Different configurations of fly ash will be used for future experimentation. Different materials should be used for different results. The efforts should be made with different materials and percentages of fly ash along with various testing methods. Solutions for optimizing weld strength in multi-spot welding scenarios. The successful application of these optimization techniques holds great promise for improving thefficiencyreliability of resistance spot welding in diverse industrial applications.

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