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FEA Analysis of Connecting Rod with Aluminium - Fly Ash Zirconia Metal Matrix Composite for Automotive Engine by using ANSYS

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ABSTRACT: The connecting rod is the central part of an IC engine, together with the piston cylinder, crank, connecting rod, crankshaft, and so on. The connecting rod is the most heavily loaded part of an internal combustion engine. The primary motivation for this study is to find a way to replace steel with a composite material made of aluminium fly ash, thereby reducing the weight of connecting rods without compromising their strength or hardness. By acting as a lever arm, a connecting rod transfers force from the piston to the crankshaft. By experimenting with different ratios of aluminium, fly ash, and zirconia in three different compositions (90%-5%-5%, 94%-3%-3%, and 96%-2%-2%), we analyzed the connecting rod's failure and strain under extreme loading conditions in an effort to find a superior material and to modernize the same old material, which is used to make connecting rods in all engines. To explain this under typical load and strain conditions, ANSYS is used to conduct a sophisticated stress and deformation analysis. Therefore, the purpose of this research is to conduct a stress, strain, and deformation analysis of a selection of connecting rod materials. On the basis of this, we can obtain an improved connecting rod material. In order to find an answer, a geometric model of a connecting rod was developed in a computer programme (Solidworks), and a dynamic analysis was performed to determine the equivalent stress, maximum principle elastic strain, and total deformation under loading conditions of compression on the connecting rod. It is possible to lower the weight of aluminium-fly ash-zirconia composite material by as much as 40 per cent without sacrificing its strength or hardness. In the end, Ansys is used to examine aluminium and steel connecting rods, and the FEA findings are compared to those of the current materials.

KEYWORDS: Aluminium, Flyash, Zirconia, FEA analysis, Connecting rod

I. INTRODUCTION

Connecting rods link pistons to crankshafts in internal combustion engines. Modern engines have steel connecting rods. Most current autos have these engines. Cast iron is strong and cheap enough for motor scooter frames, whereas aluminium and titanium are ideal for connecting rods in high-performance engines due to their low weight and impact absorption. Cast iron's affordability and durability make it versatile[1]. Cast iron is used when durability and cost matter. Cast-iron connecting rods have several uses. The narrowest end (gudgeon pin or wrist pin) needs piston pin access. A "floating wrist pin" is used when the piston pin must move freely within the piston. Most engines press-fit the piston pin into the connecting rod. The connecting rod delivers tension to the piston by spinning a load. While the engine runs, the connecting rod moves between stretching and compressing. Engine speed triples connecting rod stress. When a car engine's connecting rod breaks, it "throws a rod," causing a catastrophic failure. Connecting rod failure can be caused by fatigue near a rod defect, insufficient bearing lubrication (due to poor engine maintenance), or faulty, incorrectly tightened, or reused rod nuts. Mass-produced cars rarely break down [2,3]. A larger buffer and improved quality control at each stage of car component production are the main reasons. Mass manufacturing is now more precise and reliable. High-performance engines include many moving parts, including connecting rods. Shot preened rods are magnafluxed to find minute fractures that could fail under stress. We also inspect for equivalent weight and smooth, rounded edges on pistons and connecting rods. The magnafluxings indicate rod defects that could shatter under load. Magnafluxings reveal rod defects that are undetectable under pressure. The con rod bolts must be torqued to the exact amount measured during magnafluxing, which usually means replacing them. Any development requires it. The

enormous end-bearing shell requires integral construction. This step precedes sawing the rod in half through its widest part. We guarantee success with our precise procedures. Modern engines like the Ford 4.6-liter and Chrysler 2.0-liter require less machining due to powder metallurgy advances, allowing for better weight and dimension control[4-6]. Balancers remove less mass. Powder metallurgy also cuts machine time for bulk removal. Powder metallurgy is used to make these engines' connecting rods for better component size and weight control. Snap off the rod cap. The powdered metal's grain will create an uneven mating joint. Since the mating surfaces are not flat, no assembly misalignment is allowed. The cap will stay on the rod. The cap's convexity and concavity cause this. Avoid them by making mating surfaces rough. Slower ageing delays wrinkle formation. The crankshaft bears the engine's highest load to transfer the flywheel's lateral force to the piston through the connecting rod. The crankshaft powers the connecting rods. An oval cylinder wall compresses a piston ring, increasing its force. Although oval cross sections are harder to seal than circular ones, this is true. Pressure speeds piston ring wear. Larger connecting rods reduce lateral load, improving engine durability. Longer connecting rods lessen side forces. The piston stroke, connecting rod length, and engine block dimensions are set. Every power plant layout has the defect. This maintains the connecting rod's length[7]. Calculate the horizontal distance between the cylinder block's top and the crankshaft's centre hub. The cylinder block's last element, the cylinder head, is attached. Increased stroke requires a shorter connecting rod or a piston with a lower compression height, which accelerates cylinder wear. Increase the piston's compression height to increase stroke length and use a shorter connecting rod. A piston with a lower compression height requires a shorter connecting rod to facilitate a longer stroke. H-beams, I-beams, or a mix can be used to form connecting rods. Multipurpose items can be used in numerous situations. I-beams' load capacity depends exclusively on their material strength, notwithstanding their portability and longevity. H-beams are strongest. This allows its use in strong motors. The connecting rod is under significant strain due to erratic loading. It's susceptible to cyclic loads of 108 to 109 cycles and tensile and compressive strains owing to combustion and inertia. Its rapid cyclic stresses (108-109 cycles per second) cause this. Its high pressure cycle frequency (108-109 cycles) causes this. It's crucial that the part can tolerate regular tension and wear[8-10]. Thus, several investigations have examined connecting rods. Scientists must study finite element modelling, optimisation, manufacturing technology advances, novel material creation, fatigue modelling, and manufacturing cost estimates. Every internal combustion engine has cylinders, pistons, connecting rods, a crank, and a crank shaft. Covered are I.C. motor components. Engines need connecting rods. Connecting rods deliver piston force to the crank pin. Pins or cranks end connecting rods. Pistons are joined by pins. Crank pins attach the crank end of a crankshaft to the rest of the shaft. Crankshafts transform piston reciprocation into engine rotation. Rotating crankshafts propel vehicles. Under high-cycle stress and strain, the connecting rod's stiffness is essential. A connecting rod has a small "shank," long "pin end," and crank end at halfway. Connecting rods have three parts. Square, round, tube, I, and H shanks are possible. These examples should have shown that this is only the beginning of what is achievable. Low-speed engines use circular cross-sections for stability. High-speed engines use I-sections[11].

II. AIM & OBJECTIVE

- ◆ To design the connecting rod for a petrol engine so as to determine the section thickness of connecting rod.
- ◆ To apply the metal matrix materials in below composition for numerical investigations.
 - 90% Aluminium, 5% Fly ash, 5% Zirconia
 - 94% Aluminium, 3% Fly ash, 3% Zirconia
 - 96% Aluminium, 2% Fly ash, 2% Zirconia
- ◆ To perform analysis on the connecting rod design with the above metal matrix composition.
- ◆ To find out the best material from different metal matrix compositions through the analysis results.
- ◆ Cast the best one composition and conduct the Impact, Hardness and Microstructural characterization.

III. METHODOLOGY



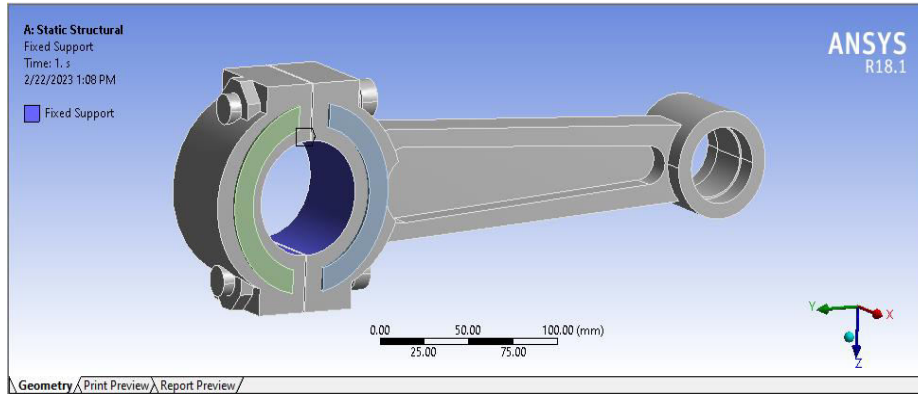


Fig.(4.4) Boundary Condition - Fixed Support

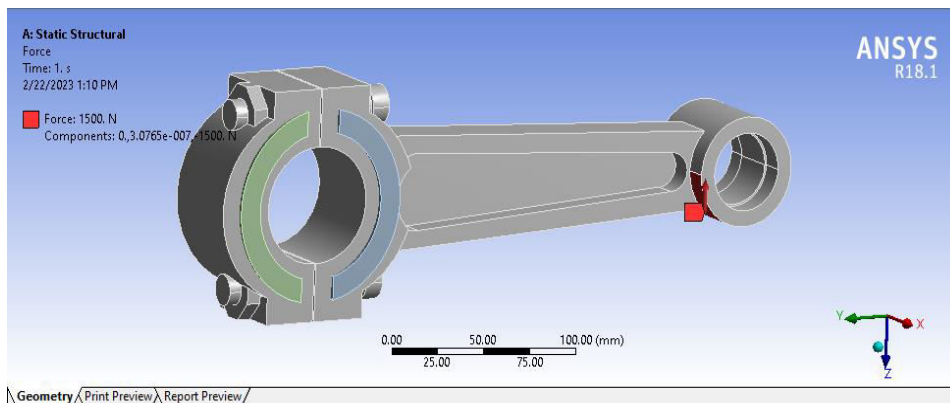


Fig.(4.5) Boundary Condition - Force

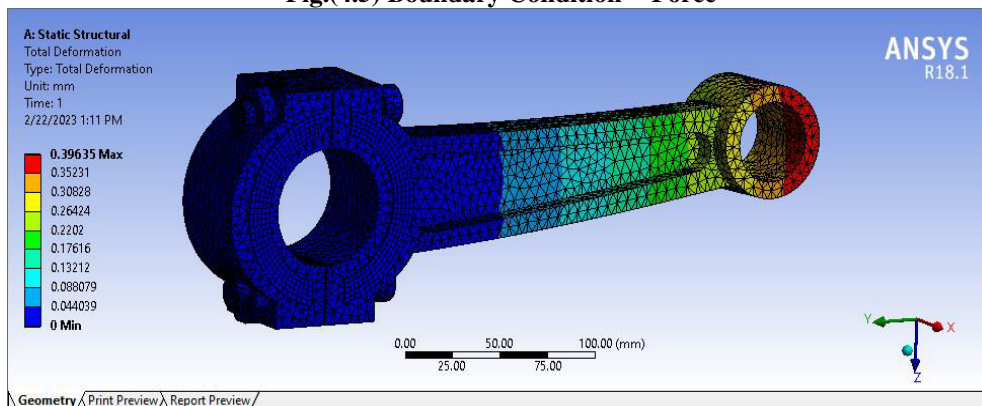


Fig. (4.6) Total Deformation

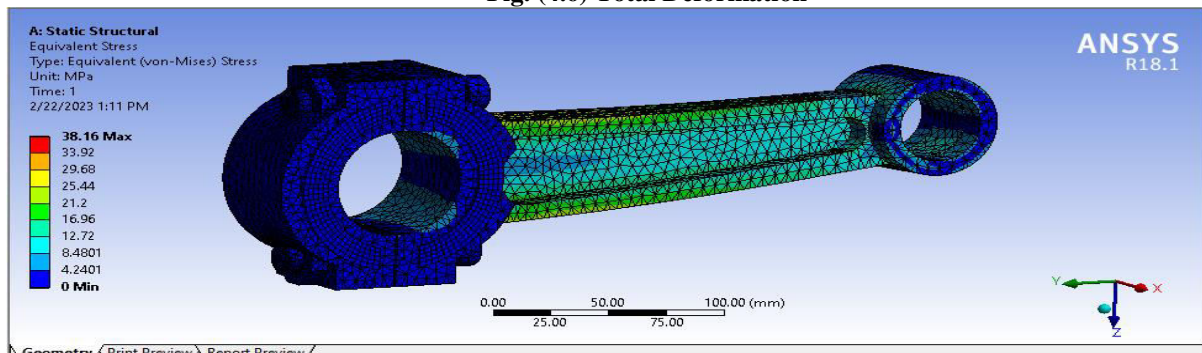


Fig. (4.7) Equivalent stress

Sample 2 – 94% Aluminium, 3% Flyash, 3% Zirconia

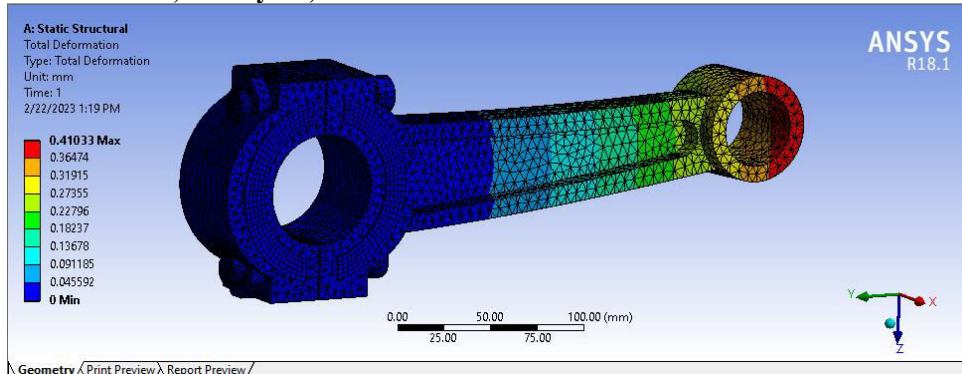


Fig. (4.8) Total deformation

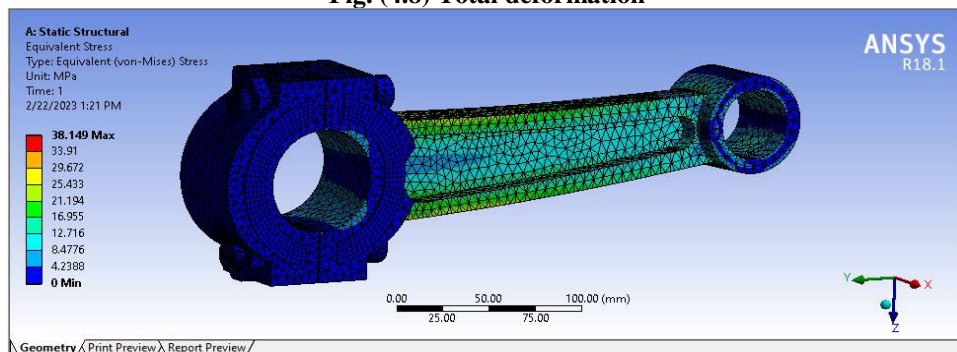


Fig.(4.9) Equivalent stress

Sample 3 - 96% Aluminium, 2% Flyash, 2% Zirconia

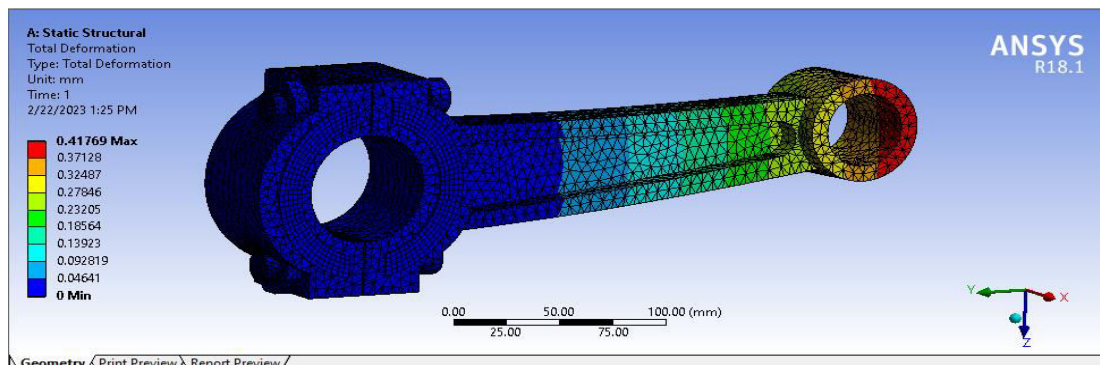


Fig. (4.10) Total Deformation

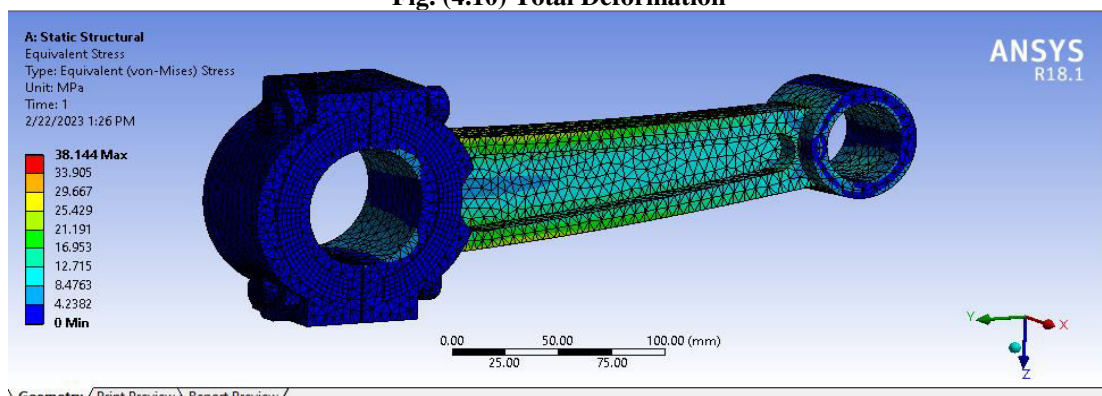


Fig. (4.11) Equivalent stress

5.Results & Discussion

Sample 1 – 90% Aluminium, 5% Flyash, 5% Zirconia

Sample 2 – 94% Aluminium, 3% Flyash, 3% Zirconia

Sample 3 – 96% Aluminium, 2% Flyash, 2% Zirconia

Total Deformation

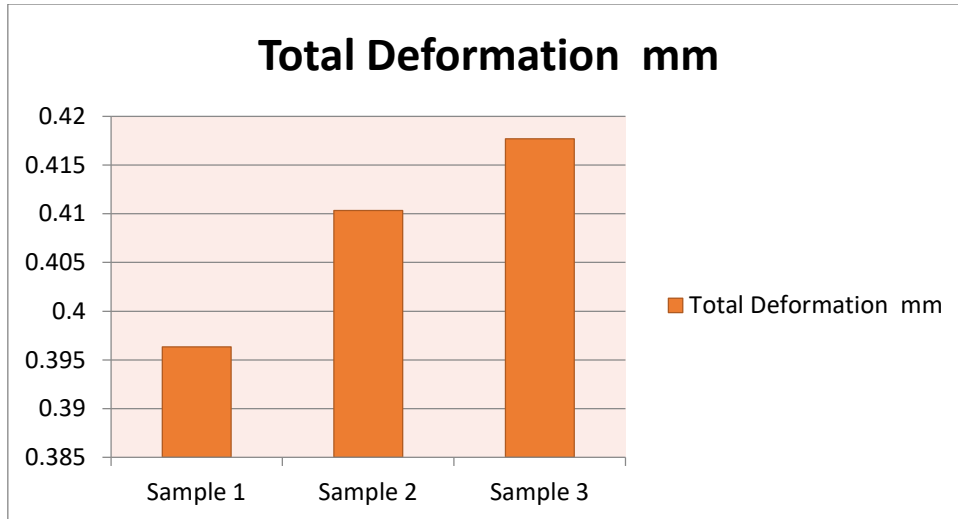


Fig.(5.1) Total deformation graph

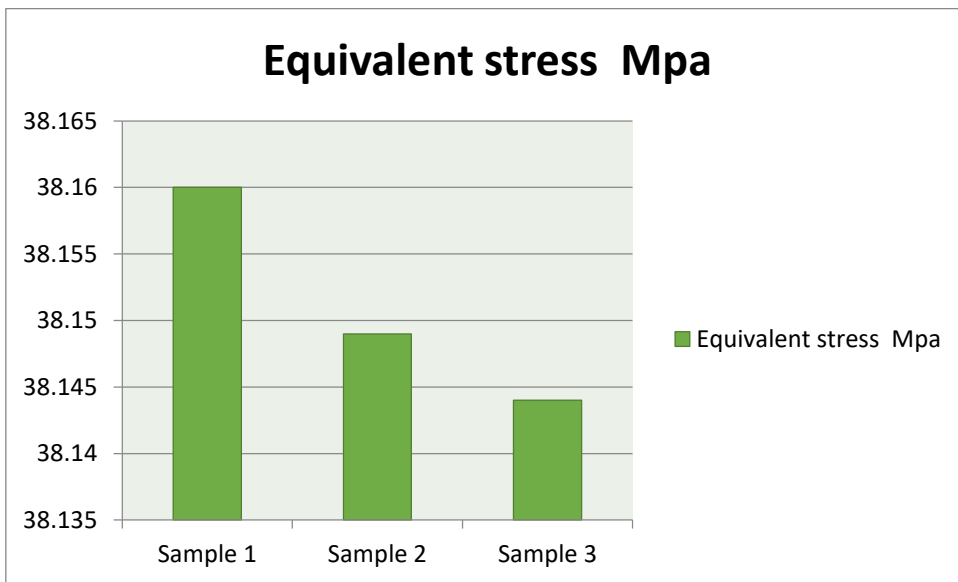


Fig.(5.2) Equivalent stress graph

V. EXPERIMENTAL INVESTIGATIONS

Based on the numerical investigation, it was found that the sample 3, which consists of 96% aluminium, 3% flyash, and 3% zirconia was the best compositions to performs the other two samples statistically. Sample 3 causes greater deformation than the other samples subjected to the identical boundary conditions, but it causes less stress. Sample 2 causes the least stress. This demonstrates that less stress is created, which in turn increases product longevity. The third sample may be used for connecting rods since it provides the best overall performance. The identified composition is casted and tested as below:-

TEST RESULTS

6.1 MICRO STRUCTURE

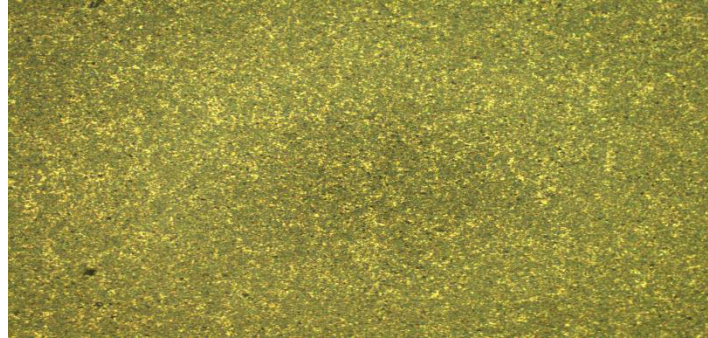


Fig. (6.1) Microstructure Image with scale of 200x

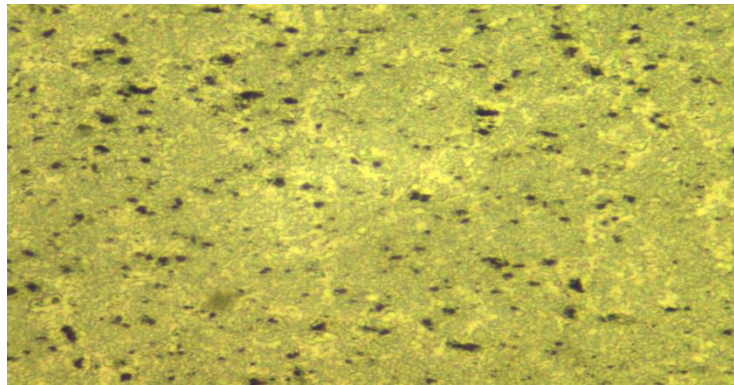


Fig. (6.2) Microstructure Image with scale of 1000x

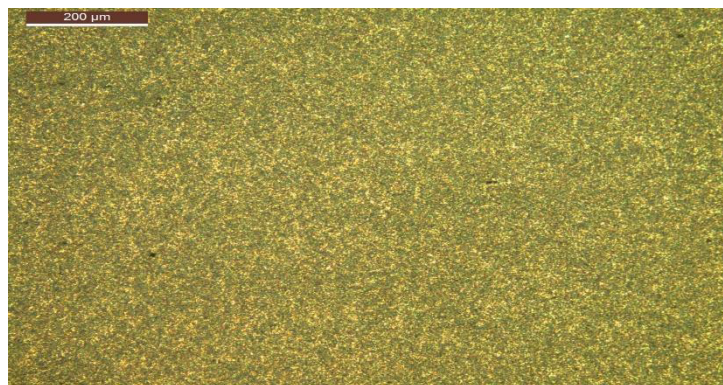


Fig. (6.3) Microstructure Image with scale of 100x

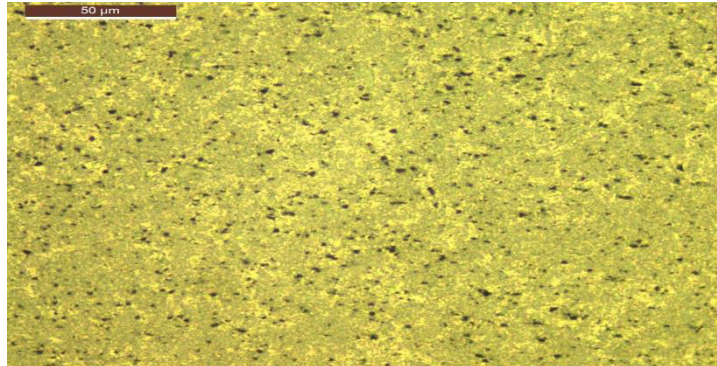


Fig. (6.4) Microstructure Image with scale of 500x

6.1.1 Inference of Microstructure

Composition, production conditions, and environmental influences shape composite material microstructure. From the data, the composite of 96% aluminium, 3% fly ash, and 3% zirconia will have a specific microstructure. Aluminum's thermal and electrical conductivity make it versatile. When aluminium is mixed with other elements, numerous phases and compounds can form, depending on the alloy's chemical composition and production conditions. Coal combustion releases microscopic particles of fly ash into the air. Its oxides include silica, alumina, and iron. Zirconia is a tough, heat-resistant ceramic. Fly ash and zirconia can substantially change the microstructure of an aluminium composite. Fly ash particles can nucleate new phases and alter composite solidification. Zirconia particles can modify thermal expansion characteristics and reinforce the microstructure. The composite's microstructure can be studied using optical, scanning electron, and X-ray microscopy. An optical microscope can reveal composite defects and grain structure. SEM photographs of the microstructure can reveal particle distribution and shape. 96% aluminium, 3% fly ash, and 3% zirconia composites have complex microstructures. Characterization can disclose valuable microstructure data regarding the composite's composition, production circumstances, and characteristics.

6.2 VICKER HARDNESS TEST (ASTM E92)

Test Parameters	Observed Values
	50.1, 50.6, 50.3

6.3 Charpy Impact Test (ASTM E23)

	Absorbed Energy (Joules)
Sample1	14
Sample2	12
Sample3	12

VI. CONCLUSION

After applying the metal matrix composition to the design, static structural analysis was performed on the structure. An analysis was performed on three samples that were each 90% aluminium. The analysis revealed the following findings: 94% of the aluminium is comprised of 3% zirconia; 5% of the fly ash is composed of 5% zirconia; and 96% of the aluminium is composed of 2% zirconia and 5% fly ash. According to the data, sample 3 displays the most effective and efficient performance when exposed to similar border circumstances. This is the case even if all of the boundary conditions were the same. The performance of this recommended sample was verified in Ansys, and it has the potential to one day replace the place of the material that is used to build the connecting rods. From the obtained experiemntal investigation such as hardness and impact behaviour of proposed composition for connecting rod is increased the mechanical strength due to its addition of flyash and zirconia. Also, the uniform grain structure was attained with microstructural characterization.



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