

CHARACTERISATION OF ALUMINIUM-FLYASH-ALUMINA COMPOSITE FOR PISTON ANALYSIS BY CAE TOOLS

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ABSTRACT: This paper presents the piston static structural analysis for unreinforced alloy and reinforced composite with different weight percentage of reinforcements by considering the combined loading of both gas pressure force and inertia force. The force is applied on crown of piston and model is constrained for all DOF on piston pin mounting hole. In present paper the mechanical behaviour or performance of a aluminium-flyash-alumina composite is compared with the conventional material and also with zero reinforcement material.

Keywords: Catia, Ansa, Ansys, Aluminium-flyash-alumina Composite specimens, 3D-piston.

I. INTRODUCTION

Engine Piston is most complex part compared to other components in an automobile sector. Still lot of research works have been conducting on piston regarding material composition, geometry and manufacturing technique. The function of the internal combustion engine piston is to receive the energy from expanding gases after during combustion and transmit it to the crankshaft by means of connecting rod. Piston expands appreciably when it gets heated during the operation so actual clearances need to be given otherwise it will lead to engine seize. And hence to avoid this case pistons are made up of cast aluminium alloy matrix with the combination of reinforcements in different weight percentage. For better results here I am replacing conventional piston material LM13-TF with new composite [Al6061 + Al₂O₃ + FLY ASH]. The addition of Fly ash and Alumina reinforcement particles to the Aluminium matrix improves the tensile strength, compressive strength and hardness behaviour. The reinforcement material is having more factor of safety compare to unreinforced alloy material because of more yield strength due to presence of the reinforcements in the matrix alloy.

Compared to traditional aluminium alloys, aluminium alloy matrix composites reinforced with ceramic particles have better stiffness, creep resistance and wear resistance. They find application mainly in the automotive industry, aerospace industry and marine industry. The construction of vehicles is a discipline in which both economical and ecological aspects are of essential importance. [9] Among various reinforcements Fly ash is very inexpensive and also having low density available in large quantity as solid waste during the combustion of coal and hence it is economical. [3] And it not only solves the storage of waste by-product but also enhances the thermo-mechanical properties of aluminium alloy matrix composite. Similarly Alumina is also one of the most cost effective and widely used ceramic material and is readily available. It facilitates high strength and stiffness, good thermal conductivity, excellent size and shape capability and good wear resistance.

[1] One of the design criteria is the endeavor to reduce the structure's weight and thus, to reduce fuel consumption. Composites produced at an industrial scale are used for manufacturing of cylinder sleeves, pistons, brake drums and disks. [2] The Al-Si-SiC composites were used for experimentation. The SEM indicates the presence of silicon carbide in the composite. Silicon carbide occurred in the grain boundary regions associated with silicon and fragmented dendrites together with eutectic mixture. Strength, hardness and wear resistance of composite is studied increase of silicon carbide content. Specimens casting is done through stir-casting technique. To find the mechanical properties, specimens are subjected to various tests like Hardness test, EDX, Tensile test, fatigue test, SEM and Impact test. And interpretation of CAD/CAM/CAE is very helpful to design, analyze, optimize and to interpret the data.

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II CHARACTERIZATIONS OF MATERIALS AND SELECTION

The conventional materials for the pistons are LM12, LM13 and LM 26. Among them LM13-TF is suitable material for piston application. In this study LM13-TF is replaced by new composite i.e. Al6061 alloy reinforced with Fly ash and different weight percentage of Alumina (Al₂O₃).

II.A. Al6061 Alloy

Matrix phase supports the reinforcements by keeping them in their position and it also takes the load from the reinforcements to balance the load acting on the component. Low coefficient of thermal expansion, high elastic modulus, good thermal conductivity and improved resistance are the important properties.

TABLE I: Al 6061 Chemical Composition

Component	Al	Mg	Fe	Cu	Si	Cr	Mn	Ti	Others
Weight %	95.8 – 98.6	0.8 – 1.2	Max 0.7	0.15 – 0.4	0.4 – 0.8	0.04 – 0.35	Max 0.15	Max 0.15	Max 0.05

TABLE II: Mechanical Properties of Al6061 alloy

Properties	Unit	Values
Density	gm/cc	2.7
Elastic Modulus	GPa	68.9
Yield strength	MPa	276
Ultimate Tensile Strength	MPa	310
Fatigue Strength	MPa	96.5

II.B. Fly Ash

Fly ash is the waste by-product disposed during the combustion of coal, the shape of the fly ash particles are more or less spherical in shape and size ranges from 1 μm to 150 μm. The use of fly ash reduces the density and increases hardness, stiffness, wear & abrasion resistance. It also improves the machinability, it is most cost effective reinforcement.

TABLE III: Chemical Composition of Fly ash

Component	SiO ₂	Al ₂ O ₃	CaO	Fe ₂ O ₃	TiO ₂	MgO	LOI
Weight%	65.56	19.90	7.56	3.79	1.20	1.24	0.70

II.C. Alumina(Al₂O₃)

Alumina is also one of the most cost effective and widely used ceramic material and is readily available. It facilitates high strength and stiffness, good thermal conductivity, excellent size and shape capability and good wear resistance.

TABLE IV: Chemical Composition of Alumina

Component	Al ₂ O ₃	SiO ₂	MgO	Na ₂ O	Fe ₂ O ₃	CaO	TiO ₂	B ₂ O ₃
Weight%	96	3.85	0.03	0.15	0.02	0.03	<0.01	<0.02

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TABLE V: Mechanical Properties of Alumina

Properties	Unit	Values
Colour		White
Poisson's ratio	GPa	0.21
Flexural strength	MPa	330
Hardness	Kg/mm ²	1175
Compressive strength	MPa	2100
Elastic Modulus	GPa	300
Fracture Toughness	MPa-m ^{1/2}	3.5
Shear modulus	GPa	124
Density	gm/cc	3.69

III EXPERIMENTAL DETAILS

III.A Stir Casting Technique



Fig.1 stir casting setup

The systematic procedure involved on the stir casting technique is as below.

- ❖ Heat the 3 kg of Al6061 alloy pieces in the furnace and it will get melt at 750⁰ C. and care is taken to achieve 100% melting.
- ❖ Slag is removed using scum powder to avoid the bad quality of casting.
- ❖ Measure the 15% of fly ash (reinforcement) by weight, and is pre heated to 450⁰C-600⁰C and maintained at the same temperature for about 20 minutes to remove the moisture content.
- ❖ Measure the 3% of alumina (Al₂O₃) by weight and is also preheated.
- ❖ Take less than 5% weight of solid dry hexachloro-ethane tablets to degas the molten metal at a temperature of 780⁰C..
- ❖ Now start stirring the molten metal to create a vortex. Add slowly pre heated fly ash and alumina to the molten metal with temperature maintained at more than 720⁰C.
- ❖ Add magnesium about more than 2% of weight to ensure good wettability with continuous stirring at a speed of 350-500 rpm to a time of 6-8 minutes.
- ❖ At the same time preheat the mould to avoid shrinkage of casting material.

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- ❖ Then the melted matrix with the reinforced particles is poured into the preheated moulds and the pouring temperature should be maintained at 680°C.

Finally withdraw the specimens from the mould after 3 to 4 hours. And confirm the solidification of casting before removing from the mould.

IV EXPERIMENTAL TEST RESULTS

Following figures show the shape and size of specimens which are subjected to Tension, Hardness, Impact, Fatigue, SEM and EDX tests.

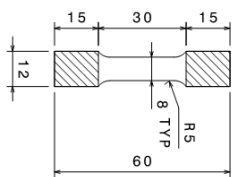


Fig 2: Specimen for Tension Test

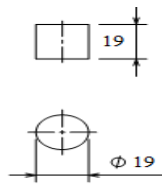


Fig 3: Specimen Hardness Test

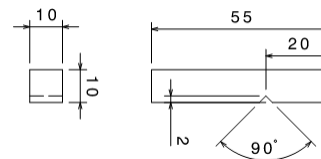


Fig 4: Specimen for Impact Test

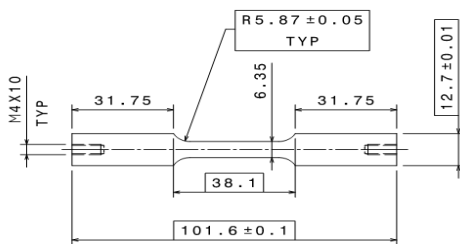


Fig 5: Specimen for Fatigue Test

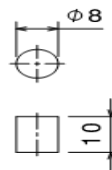


Fig 6: Specimen for SEM & EDX

IV.A. SEM Results

The figure 7 to 9 shows that uniform distribution of reinforcement particles (Al_2O_3 and fly ash) in the matrix alloy and that result in improved of the mechanical properties. SEM micrograph at the higher magnification shows the particle-matrix interfaces. And lower magnification shows that the distributions of reinforcements like Al_2O_3 and fly ash particulate

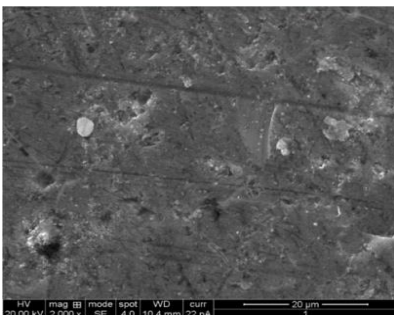


Fig 7: 3% Al_2O_3 + 15% Fly ash at 2000X

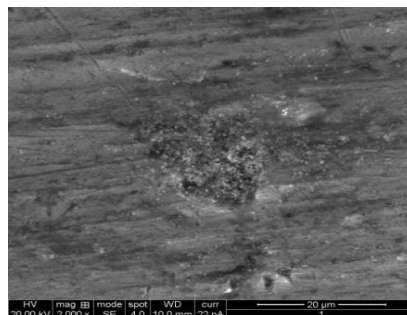


Fig 8: 6% Al_2O_3 + 15% Fly ash at 2000X

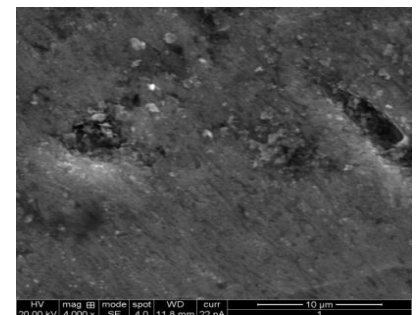


Fig 9: 9% Al_2O_3 + 15% Fly ash at 2000X

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IV.B.EDT Testing

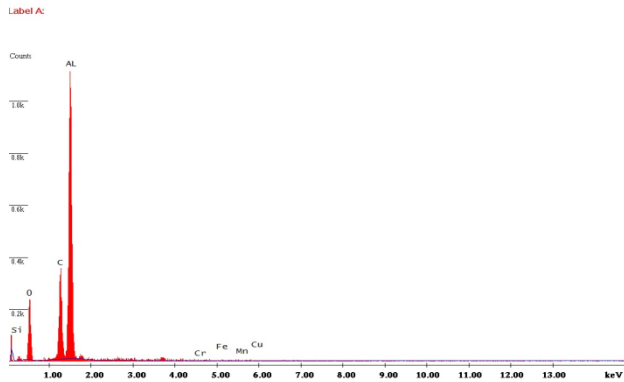


Fig 10: Energy dispersive x-ray spectroscopy of Al 6061 alloy with 3%Al₂O₃ + 15%

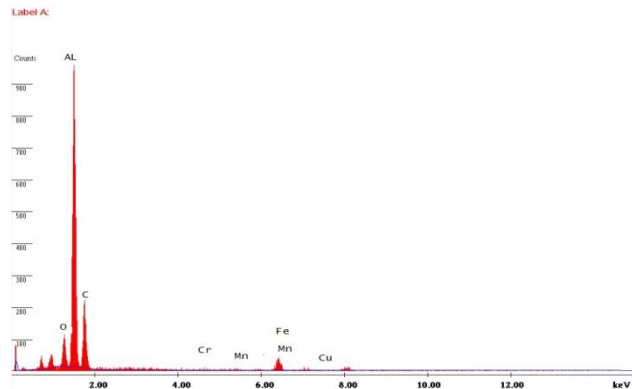


Fig 11: Energy dispersive x-ray spectroscopy of Al 6061 alloy with 9%Al₂O₃ + 15%

Elements	Z-scale	Wt %
AL	0.876	83.4
AL ₂ O ₃	0.074	2.3
Fly ash	0.073	13.6
Mg, Si and others	0.0511	0.7

TABLE VI: Energy dispersive x-ray spectroscopy report of Al 6061 alloy Reinforced with 3% Al₂O₃ + 15% Fly ash reinforcements.

Elements	Z-scale	Wt %
AL	0.876	78.8
AL ₂ O ₃	0.074	8.2
Fly ash	0.073	12.3
Mg,Si and others	0.0511	0.7

Table VII: Energy dispersive x-ray spectroscopy report of Al 6061 alloy Reinforced with 9% Al₂O₃ + 15% Fly ash reinforcements.

The above figures 10 and 11 and Tables VI and VII of Energy dispersive x-ray spectroscopy report of prepared composites indicate the physical composition of specimens and it is clear that the prepared composite specimens are having mixture of different compounds.

IV.C. TENSION TEST

The tension test is conducted at a velocity of 0.05 mm/min in the Universal Tensile test machine of capacity 10KN. The ultimate tensile strength of a material is calculated by dividing the amount of the load at its failure point by the original area, which is expressed in Mpa.

The addition of reinforcements (fly ash and alumina) to Al6061 increases the tensile strength of the specimen. These reinforcement particles in the metal matrix Al6061 acts as barrier to the deformation of a macrostructure by importing strength to the metal matrix. Hence specimen with 9 % of Al₂O₃ and 15% of fly ash shows better tensile strength behaviour than those of previous composition.

For Al6061, the results without the reinforcements and with wt% variation of different reinforcement (Al₂O₃), keeping 15% Fly ash as constant are shown below.

TABLE VIII: Ultimate Tensile Strength of composites for different wt% of Al₂O₃ reinforcement

Sample No	Nomenclature	Ultimate Load (KN)	Ultimate Tensile Stress (Mpa)	% Elongation
1	Al6061 + 0% reinforcement	16.08	319.90	16.00
2	Al6061 + 3% Al ₂ O ₃ + 15% FLY ASH	19.45	386.99	12.70
3	Al6061 + 6% Al ₂ O ₃ + 15% FLY ASH	19.91	396	11.5
4	Al6061 + 9% Al ₂ O ₃ + 15% FLY ASH	20.16	400.99	10.6

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TABLE IX: % Change in UTS of composites for different wt% of Al₂O₃ reinforcements.

Sample No	Nomenclature	Ultimate Load (KN)	Ultimate Tensile Stress (Mpa)	% Change UTS
1	Al6061 + 0% reinforcement	16.080	319.901	
2	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	19.452	386.985	20.97
3	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	20.156	400.991	25.35
4	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	20.407	405.984	26.91

IV.D. **HARDNESS**

The hardness testing of specimens are carried out in a Leitz hardness tester. And specimens are prepared as per ASTM standard D105 with 19*19 dimensions. The calibrated specimens are polished with the polishing grade paper before the test.

TABLE X: Hardness of composites for different wt% of Al₂O₃reinforcement

Sample No	Nomenclature	LOAD (N)	BHN
1	Al6061 + 0% reinforcement	250	50
2	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	250	77
3	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	250	79
4	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	250	84

TABLE XI: % Change in Hardness of composites for different wt% reinforcements

Sample No	Nomenclature	LOAD (Kgf)	BHN	% Change in Hardness
1	Al6061 + 0% reinforcement	250	50	
2	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	250	77	34.77
3	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	250	79	36.47
4	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	250	84	38.56

Here the hardness of the composite material increases monotonically by significant amounts as the reinforcement's particles content increases. Table 8.4 indicates that, the Al₂O₃ reinforcement contents increased from 0% to 3% by weight with fly ash 15% constant will result in the percentage change in hardness of a specimen by 34.77%. And for 3% to 6% increase of Al₂O₃ will result in 36.47%, finally for 6% to 9% increase in Alumina reinforcement, percentage change in hardness of a specimen will show 38.56%.

IV.E. **Impact Strength**

It is necessary to test the specimens to check its energy absorption capability to avoid the failure of composite under working conditions. The test is carried out in charpy impact tester because it is cheap and faster. The Specimen is prepared as per ASTM standard E23, The Specimen is cut into 10*10*55 mm dimensions.

TABLE XII: Impact strength as a variation of Al₂O₃ reinforcement

Sample No	Nomenclature	Impact Strength (J/mm ²)
1	Al6061 + 0% reinforcement	0.60
2	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	0.64
3	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	0.65
4	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	0.68

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TABLE XIII: % Change in impact strength of composites for different wt% Al₂O₃ reinforcement

Sample No	Nomenclature	Impact Strength (J/mm ²)	% Change in Impact Strength
1	Al6061 + 0% reinforcement	0.60	
2	Al6061 + 3% Al ₂ O ₃ + 15% FLY ASH	0.64	6.67
3	Al6061 + 6% Al ₂ O ₃ + 15% FLY ASH	0.65	8.33
4	Al6061 + 9% Al ₂ O ₃ + 15% FLY ASH	0.68	13.33

Table XII indicates that the test specimen shows the 6.67% change in impact strength at 3% increment of Al₂O₃ with 15% fly ash constant. And 8.33% change in impact strength at 3% to 6% increase in Al₂O₃ for the last specimen of 6% to 9% increase in Al₂O₃ result in 13.33% of change in impact strength.

IV.F. Fatigue Test

The results of fatigue strength and fatigue life for alloy Al6061 without reinforcements and the Wt. % variation of different reinforcements of Al₂O₃ and keeping Fly ash as constant are shown in the Table XIV.

TABLE XIV: Fatigue life of composites for different wt% of Al₂O₃ reinforcement

Material	Ultimate tensile Strength UTS (Mpa)	Load Selected	Applied load in N	Stress (MPa)	No of Cycles
Al6061 + 0% reinforcements	320	0.9UTS	90	288	778038
	320	0.7UTS	70	224	853310
	320	0.5UTS	50	160	928551
Al6061 +3% Al ₂ O ₃ + 15% Fly ash reinforcements	386.98	0.9UTS	90	350	787374
	386.98	0.7UTS	70	272	863550
	386.98	0.5UTS	50	195	939694
Al6061 +6% Al ₂ O ₃ + 15% Fly ash reinforcements	400.99	0.9UTS	90	361	795933
	400.99	0.7UTS	70	281	872936
	400.99	0.5UTS	50	201	949908
Al6061 +9% Al ₂ O ₃ + 15% Fly ash reinforcements	405.98	0.9UTS	90	365	799823
	405.98	0.7UTS	70	284	877203
	405.98	0.5UTS	50	203	954550

V. FINITE ELEMENT METHOD

Finite element analysis is a way to solve the numerical problems using computer interface and mainly it is used for calculating the thermo mechanical behaviour of engineering components. It has been applied to a number of physical problems, where the governing differential equations are available. With the rapid advancement of technology, the complexity of the problem to be dealt by a design engineer is also increasing. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. This scenario demand speedy, efficient and optimal design from an engineer. Finite element analysis is one of such numerical procedure for analyzing and solving wide range of complex engineering problems which are complicated to be solved satisfactorily by any of the available classical analytical method. Here the 2D piston drawing is converted to 3D with a help of

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CATIA V5. The mesh generation is done in ANSA 13.2.1 as per the standard. Static structural analysis is carried out in ANSYS APDL V13.1.

V.A. Loading Condition

In general the piston will be designed for high fatigue life cycles usually $> 10^8$ cycles life. In this project work we are considered the effect of pressure force and inertia force and it is assumed that side thrust force is negligible but in reality this may have some influence on stress and deformation of piston. Also the temperature effect is neglected and assumed that temperature is uniform. The pressure force and inertia force is applied on crown (i.e. top face) of the piston as shown in the red colour in figure 7.3.5

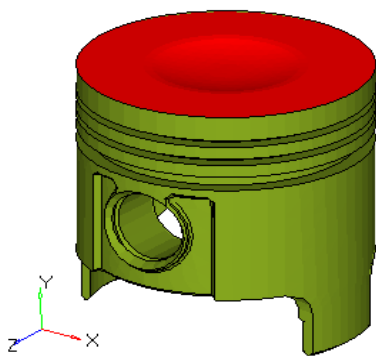


Fig 12: Loading Condition on Piston

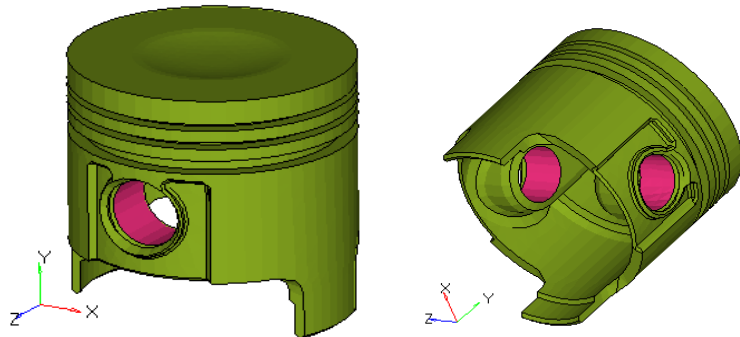


Fig 13: Boundary Conditions on Piston

V.B. Boundary Conditions

The piston and connecting rod is connected with positive lock by piston pin, there will be no relative motion between piston and piston pin. Hence the piston pin holes are constrained for all degrees of freedom (DOF) as shown by pink colour in figure 13.

VI. DESIGN CALCULATIONS OF PISTON

Kirloskar Rex Engine Specifications:

- ❖ Ideal gas constant $R = 8.3143 \text{ J/mol.k}$
- ❖ Molecular weight $M = 114.228 \text{ g/mole}$
- ❖ Density of petrol at $288.855 \text{ K} = 737.22 \times 10^{-9} \text{ kg/mm}^3$

Engine type liquid cooled 4-stroke.

Maximum Power = 13.8bhp at 8500rpm; Displacement = 149.5CC

Bore \times Stroke (mm) = 57 \times 58.6

Compression Ratio = 9.35/1

Maximum Torque = 13.4Nm at 6000rpm

From gas equation,

$$PV = m \cdot R_{\text{specific}} \cdot T$$

Where,

Specific = Specific gas constant

V = Volume

P = Pressure

m = Mass

T = Temperature

But,

$$\text{Mass} = \text{density} \times \text{volume}$$

$$m = 0.11 \text{ kg}$$

$$m = 737.22 \times 10^{-9} \times 150 \text{ E}3$$

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$P = m \cdot R_{\text{specific}} \cdot T / V$
 $P = 0.11 \cdot 72.786 \cdot 288.85 / 150E3$
 $P = 15.4177 \text{ MPa}$
 $P \sim 16 \text{ MPa}$
 $R_{\text{specific}} = 72.76$
 $R_{\text{specific}} = 8.3143 / 0.114228$
 $R_{\text{specific}} = R / M$

VII. DESIGN AND MESHING OF PISTON MODELS

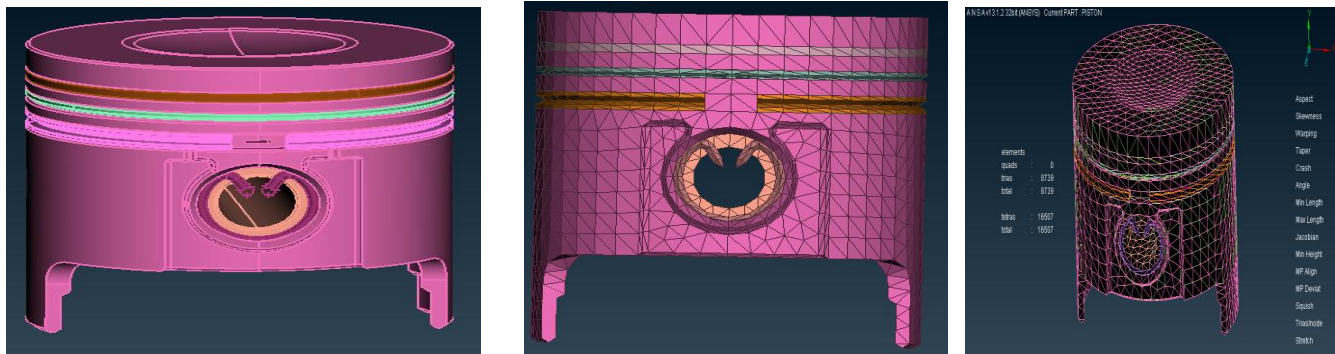


Fig 14: Piston model before and after meshing

Here the 2D piston drawing is converted to 3D with a help of CATIA V5. The mesh generation is done in ANSA 13.2.1 as per the standard. Static structural analysis is carried out in ANSYS APDL V13.1.

VIII. RESULT AND DISCUSSION

VIII.A. Structural Analysis Using Unreinforced Material Properties

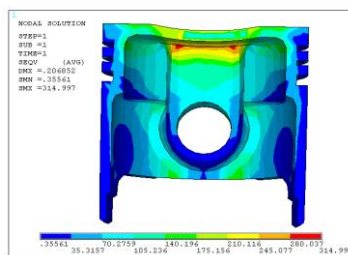


Fig 15

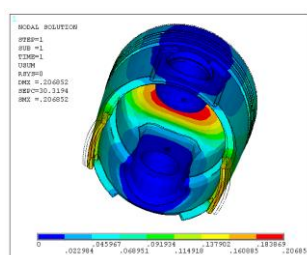


Fig 16

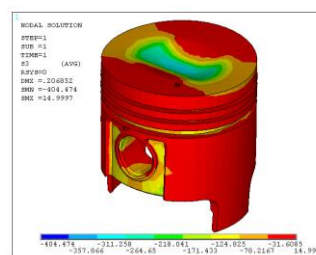


Fig 17

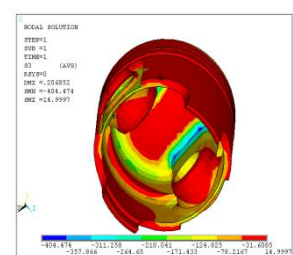


Fig 18

Fig 15: Von mises stress distribution along thickness of Piston wall. Fig 16: Zoom In view of Total deformation Fig 17: Minor Principle Stress plot, Fig 18: Zoomed view of Minor Principle stress.

The maximum von mises stress induced in the piston is 315 Mpa, at the inner boss fillet area which is due to stress concentration effect and pressure application on top face of the piston. The stress at piston ring grooves is approximately 140 MPa. The stress distribution is shown in the figure 16. The maximum displacement is 0.206 mm is observed at the centre of the piston as shown in fig 18.

VIII.B. Static Analysis for 3% Alumina + 15 % Fly ash Material Properties

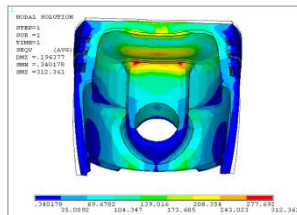


Fig 19

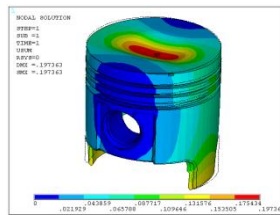


Fig 20

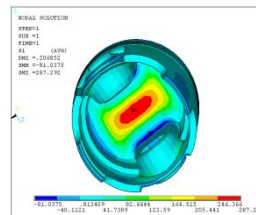


Fig 21

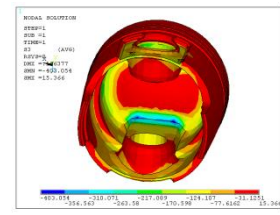


Fig 22

Figure 19: Von mises stress distribution along thickness of Piston wall, Figure 20: Zoom In view of Total deformation, Figure21: Zoomed view of Major Principle stress, Figure22: Minor Principle Stress plot

The maximum von mises stress induced in the piston is 312 Mpa, at the inner boss fillet area which due to stress concentration effect and pressure application on top face of the piston. The stress at piston ring grooves is approximately 135 MPa. The stress distribution is shown in the figure 19. The maximum displacement is 0.197mm is observed at the centre of the piston due to applied pressure force and the deformation pattern of the piston is shown in figure 20. The maximum and minimum stress is observed at inner side of the piston pin boss fillet region.

VIII.C. Static Analysis for 6% Alumina + 15 % Fly ash Material Properties

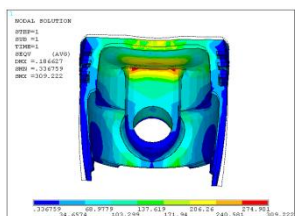


Fig 23

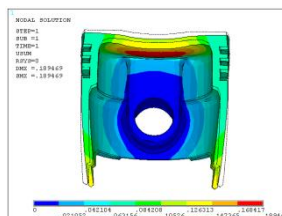


Fig 24

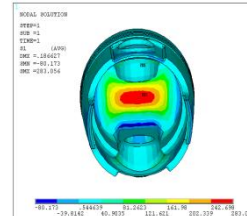


Fig 25

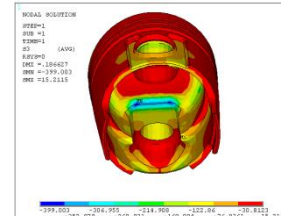


Fig 26

Figure 23: Von mises stress distribution along thickness of Piston wall, Figure 24: Cut section view of deformation, Figure 25: Zoomed view Major Principle Stress plot, Figure 26: Zoomed view of Minor Principle Stress plot.

The maximum von mises stress induced in the piston is 309 Mpa, at the inner boss fillet area which due to stress concentration effect and pressure application on top face of the piston. The stress at piston ring grooves is approximately 130 MPa. The stress distribution is shown in the figure 23. The maximum displacement is 0.189 mm is observed at the centre of the piston due to applied pressure force and the deformation pattern of the piston is shown in figure 24. The maximum and minimum stress is observed at inner side of the piston pin boss fillet region.

VIII.D. Static Analysis for 9% Alumina + 15 % Fly ash Material Properties

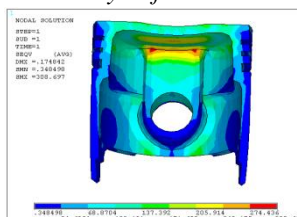


Fig 27

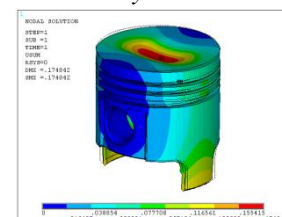


Fig 28

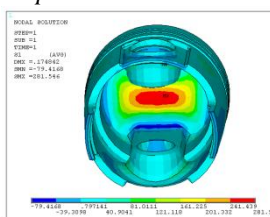


Fig 29

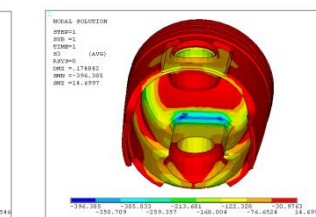


Fig 30

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Figure 27: Von mises stress distribution along thickness of Piston wall, Figure 28: Total deformation on piston with deformed and unreformed edge, Figure 29: Zoomed view Major Principle Stress plot, Figure 30: Zoomed view of Minor Principle Stress plot.

The maximum von mises stress induced in the piston is 308 Mpa, at the inner boss fillet area which due to stress concentration effect and pressure application on top face of the piston. The stress at piston ring grooves is approximately 128 MPa. The stress distribution is shown in the figure 27. The maximum displacement is 0.174 mm is observed at the center of the piston due to applied pressure force and the deformation pattern of the piston is shown in figure 28. The maximum and minimum stress is observed at inner side of the piston pin boss fillet region.

VIII.E. Comparison Between Conventional Material, Zero Reinforcement Material and Reinforcement Materials.

Iteration No	Material	Load applied in MPa	Yield strength in Mpa	Induced Stress in Mpa	Factor of safety
1	LM 13 TF	16	240	323	0.75
2	Al6061 + 0% reinforcement	16	280	314	0.90
3	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	16	325	312	1.04
4	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	16	330	309	1.06
5	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	16	335	308	1.08

TABLE XV: FOS for maximum loading condition

Iteration No	Material	Displacement in mm
1	LM 13 TF	0.230
1	Al6061 + 0% reinforcement	0.206
2	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	0.197
3	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	0.188
4	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	0.174

TABLE XVI: displacement induced on the piston

Iteration No	Material	Von-Mises stress
1	LM 13 TF	323
2	Al6061 + 0% reinforcement	315
3	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	312
4	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	309
5	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	308

TABLE XVII: stress induced in piston

Sl No	Material	Young's Modulus, E (Gpa)	Poisson's ratio μ	Yield Strength, σ_y (Mpa)	Ultimate strength, σ_{ut} (Mpa)
1	LM 13 TF	73	0.33	170	210
2	Al6061 + 0% reinforcement	69	0.3	280	320
3	Al6061 + 3% Al ₂ O ₃ + 15%FLY ASH	75	0.3	325	387
4	Al6061 + 6% Al ₂ O ₃ + 15%FLY ASH	80	0.3	330	401
5	Al6061 + 9% Al ₂ O ₃ + 15%FLY ASH	82	0.3	335	406

TABLE XVIII: The material properties

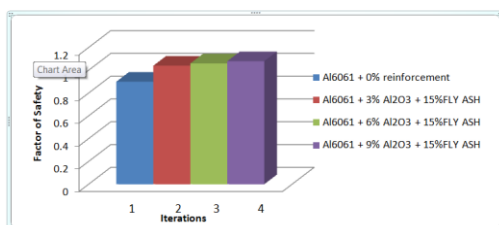


Fig 31: Graph showing FOS

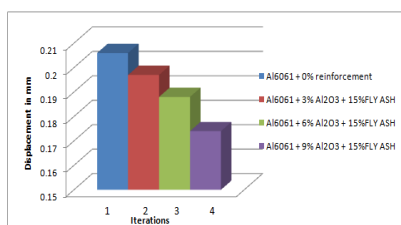


Fig 32: graph showing displacement

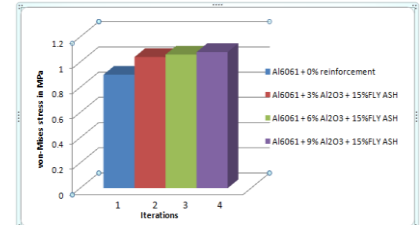


Fig 33: graph showing von-mises stress

The reinforcement material is having more factor of safety compare to unreinforced alloy material because of more yield strength due to presence of the reinforcements in the matrix alloy. From the table is clear that the resistance to the deformation of the material is increases with increase in reinforcement particles. The composites are showing better results compare to unreinforced alloy. Hence for static application, the composites materials can be replaced with unreinforced alloy without affecting the performance of a part.

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The addition of reinforcement particles enhances the mechanical properties like modulus of elasticity and yield strength, this result in decrease in displacement of the component. A reinforced composite is showed better results compare to unreinforced alloy.

IX.CONCLUSIONS

From the results and discussion of this project work reveals the flowing conclusions.

- ❖ The Stir casting technique produces good quality of composite specimen with the better distribution of reinforcements in the matrix.
- ❖ The addition of Fly ash and Alumina reinforcement particles to the Aluminum matrix improves the tensile strength, compressive strength and hardness behavior. And also addition of these reinforcements enhances the effective bonding between reinforcements and matrix by allowing the larger interfacial area of contact, and thereby increasing the mechanical properties of the composite.
- ❖ The effective utilization of fly ash (which is the waste by product during combustion of coal) as reinforcement in the Aluminum Alloy metal matrix composites, and it is less costly compared to other reinforcements. And utilization of fly ash is environmental friendly. Because it solve the storage problem and disposal of waste product.
- ❖ The fatigue behavior of the composite increases with increase in reinforcements but at higher reinforcements there will not be much difference in fatigue behavior.
- ❖ It has been observed and analyzed that the Fly ash and Alumina particulates are the best suitable reinforcement materials to the Aluminum alloy 6061 matrix for better mechanical properties of the composite.
- ❖ FOS of the prepared composite is greater compared to conventional material LM13-TF and unreinforced alloy.
- ❖ SEM images shown in the previous chapter clearly shows that the reinforcement particulates are fairly distributed in Al 6061 alloy matrix.
- ❖ EDX results showed the presence of uniformly dispersed Alumina and fly ash particles in aluminum alloy matrix.
- ❖ And the only drawback is, as the wt% of reinforcements increases the impact strength of the composite decreases due to the presence ceramic particles.
- ❖ The static structural analysis is carried out for unreinforced alloy and reinforced alloy with different weight percentage of reinforcements by considering the combined loading of both gas pressure force and inertia force of 16 bar. The force is applied on crown of piston and model is constrained for all DOF on piston ping mounting hole.
- ❖ For unreinforced Al 6061 alloy, the maximum von mises stress induced in the inner boss fillet area of the piston is 315 Mpa, The stress at piston ring grooves is approximately 140 MPa. And the maximum displacement is 0.206 mm is observed at the center of the piston.
- ❖ The analysis is carried out for 2nd specimen made up of 3% Alumina and 15% of Fly ash with Al 6061 alloy. The maximum von mises stress induced in the piston is 312 Mpa, The stress at piston ring grooves is approximately 135 MPa. The maximum displacement is 0.197mm is observed at the center of the piston.
- ❖ The analysis is carried out for 3rd specimen made up of 6% Alumina and 15% of Fly ash with Al 6061 alloy. The maximum von mises stress induced in the piston is 309 Mpa, The stress at piston ring grooves is approximately 130 MPa. The maximum displacement is 0.189 mm is observed at the center of the piston.
- ❖ The analysis is carried out for 4th specimen made up of 9% Alumina and 15% of Fly ash with Al 6061 alloy. The maximum von mises stress induced in the piston is 308 Mpa, The stress at piston ring grooves is approximately 128 MPa. The maximum displacement is 0.174 mm is observed at the center of the piston.
- ❖ The stresses induced in the piston reduced as the percentage of reinforcements (Alumina and Fly ash) in the composites increases. And hence the prepared piston composite specimens show better results than those of unreinforced alloy.
- ❖ The reinforcement material is having more factor of safety compare to unreinforced alloy material because of more yield strength due to presence of the reinforcements in the matrix alloy. And it is clear that the resistance to the deformation of the material is increases with increase in reinforcement particles. The composites are showing better results compare to unreinforced alloy.
- ❖ The displacement induced in the piston crown is decreased for the reinforced composite material. The addition of reinforcement particles enhances the mechanical properties like modulus of elasticity and yield strength, this result in decrease in displacement of the component. A reinforced composite is showed better results compare to unreinforced alloy

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