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Comparative Mechanical Properties of Al - Metal Matrix Connecting Rod with Various Reinforcements

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ABSTRACT

MMCs are made by dispersing a reinforcing material into a metal matrix. They are prepared by powder metallurgy and casting, although several technical challenges exist with casting technology. Achieving a homogeneous distribution of reinforcement within the matrix is one such challenge, and this affects directly on the properties and quality of composite. In this work a composite is developed by adding Boron carbide & Aluminium oxide with Aluminum Metal (6063) by mass ratio 10%. The composite has to be prepared by crucible casting technique. It is proposed to use this material for power transmitting elements such as connecting rod which are subjected to continuous loading. From the investigation the mechanical property of Al6063 metal matrix were analyzed finally found Boron carbide reinforcement enhanced the good tensile and compressive strength. Impact strength is good in Al-6063 and followed by Aluminum oxide. Boron carbide shows superior tensile and compressive strength compared than Alumina oxide metal matrix. But impact strength is more at Alumina oxide. Impact is strength is obtained at without metal matrix of Al6063.

INTRODUCTION

When building a high performance engine, great attention is paid to the connecting rods, eliminating stress risers by such techniques as grinding the edges of the rod to a smooth radius, shot peening to induce compressive surface stresses (to prevent crack initiation), balancing all connecting rod/piston assemblies to the same weight and Magnafluxings to reveal otherwise invisible small cracks which would cause the rod to fail under stress. In addition, great care is taken to torque the con rod bolts to the exact value specified; often these bolts must be replaced rather than reused. The big end of the rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell.

SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses of connecting rod made of Forged steel. Steel materials are used to design the connecting rod. In this project the material (carbon steel) of connecting rod replaced with Forged steel .Connecting rod was created in CATIAV5 R19. Model is imported in ANSYS 13.0 for analysis. After analysis a comparison is made between existing steel connecting rod viz., Forged steel in terms of weight, factor of safety, stiffens, deformation and stress.

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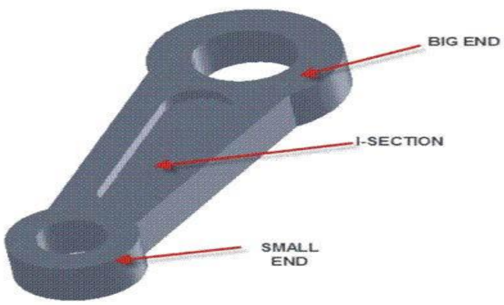

Fig: 1.1 Schematic Diagram of Connecting Rod

Fig: 1.2Aluminum Connecting Rod

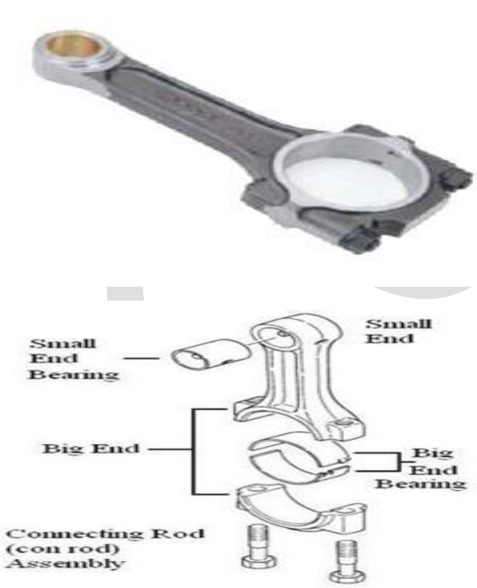

Fig: 1.3Connecting Rod assembly with press fitted brass bush, Cap, Nuts and Bolts

The connecting rod is considered as column pillar as it is subjected to cyclic compressive and tensile load which is acting in an axial direction. During the suction stroke, the rod is subjected to the partial tensile load. During the compression stroke, the rod is subjected to the partial compressive load.

1. The connecting rod is subjected to alternating direct compressive and tensile forces.
2. Compressive forces are much higher than tensile forces; so cross section of connecting rod is designed as strut and Rankin’s formula is used.

Due to axial load, the rod may buckle as shown in Fig. 6.2 and Fig. 6.3. Consider, the connecting rod as both the ends hinged about X axis for buckling and both ends are fixed about Y axis for buckling.

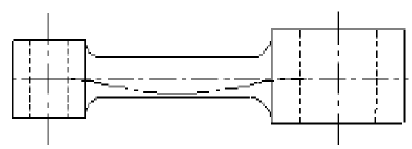

Fig: 1.4Buckling of Connecting Rod about Y-axis (Both ends fixed Leq = *l*/2)

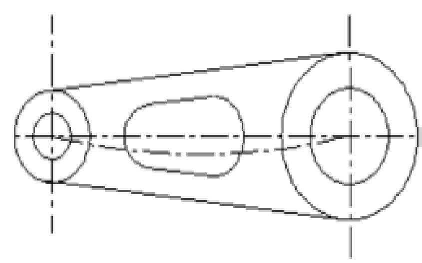

Fig: 1.5Buckling of Connecting Rod about X-axis (Both ends hinged Leq = *l)*

According to Rankin’s formula,

WB about X axis =[σc x A] / [1 + a { Lequ / Kxx }2] , for Leq = *l* ; both ends hinged. (1)

WB about Y axis = [σc x A] / [1 + a { Lequ / Kyy }2], for Leq = *l/2* ; both ends fixed. (2)

Where, L_{eq} = Equivalent length of connecting rod.

a= Rankine's constant

= 1/1600for C.I.

= 1/7500 for M.S.

= 1/9000for Wrought Iron

To have an equal strength of connecting rod in buckling about both axis, the buckling load must be equal.

LITERATURE REVIEW

A.Prem kumar [1] et.al Connecting rod is one of the important components of the whole engine assembly as it acts as a mediator between piston assembly and crankshaft. It's converting the reciprocating motion of the piston to rotary motion of the crank. Also it faces a lot of tensile and compressive loads during its life time. Generally connecting rods are manufactured using carbon steel and in recent days aluminium alloys are finding its application in connecting rod. In this work connecting rod is replaced by aluminium based composite material reinforced with Boron carbide. And it also describes the modelling and analysis of connecting rod.

COMPOSITES

1.MATRIX PHASE

1. The primary phase, having a continuous character,
2. Usually more ductile and less hard phase,
3. Holds the reinforcing phase and shares a load with it.

2. REINFORCING PHASE

1. Second phase (or phases) is imbedded in the matrix in a discontinuous form,
2. Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

2.1 CLASSIFICATION OF COMPOSITES

A. Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

B. Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibers of other ceramic material (dispersed phase).

C. Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated polyester (UP), Epoxy) or thermoplastic (PVC, Nylon, Polysterene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

(b) On the basis of Material Structure:

1. Particulate Composites
2. Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.
3. Composites with random orientation of particles.
4. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets.
5. Fibrous Composites

ALUMINUM USE IN THE AUTO INDUSTRY

Automakers lightened average car weights by about 25 percent, to about 3,000 pounds during 1978-80, doubling fuel economy and improving performance. Some industry analysts think that the average automobile will have to be lightened further, by 500 to 700 pounds (16 to 22 percent), to meet upcoming fuel efficiency and emissions requirements.Alcoa produced the Audi A8 model in 1994, featuring an aluminum space frame, floor pan, body panels, and a cast-aluminum engine.

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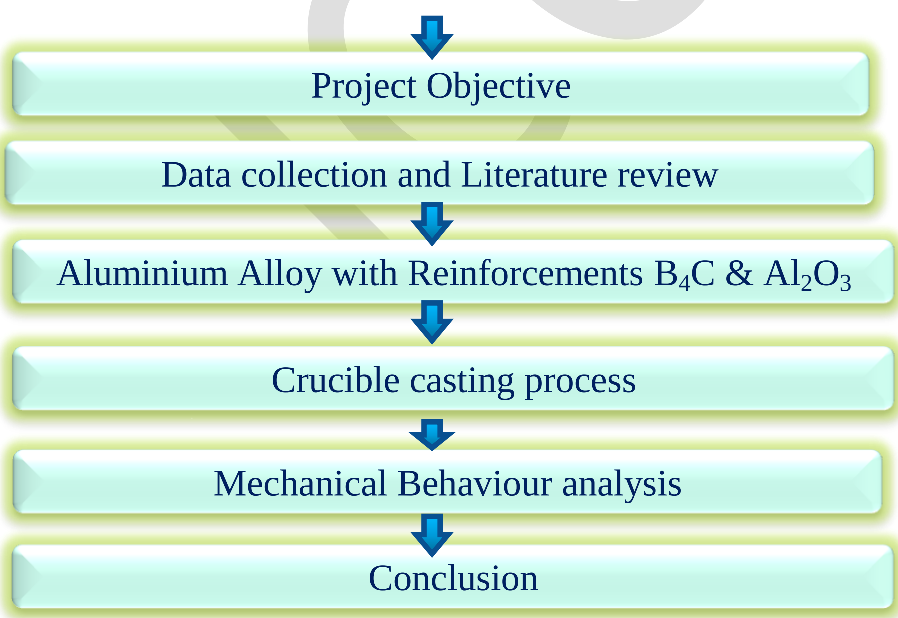
OBJECTIVES

The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Boron carbide&Alumina oxide is one of the least expensive and low density reinforcement available in huge quantities as solid waste by-product in ceramic plant. The Hardness strength will also be taken into consideration. For the achievement of the above, an experimental set up is prepared where all the necessary inputs will be made. In this work a composite is developed by adding silicon nitride in Aluminum metal by weight ratio with various percentages.

MATERIALS AND METHODS-6063

AL 6063 Aluminium alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions.

It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.



Chemical composition of Al-6063

Table: 5.1 Chemical properties

	Chemical Composition (weigh					
Weight (%)	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**M**
Min.	Bal	0.20	0.0	0.0	0.0	0.4
Max.	Bal	0.60	0.35	0.10	0.10	0.9

BORON CARBIDE

Boron Carbide is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities. Originally discovered in mid-19th century as a by-product in the production of metal borides, boron carbide was only studied in detail since 1930.Boron carbide powder (see figure 1) is mainly produced by reacting carbon with B_2O_3 in an electric arc furnace, through carbothermal reduction or by gas phase reactions. For commercial use B_4C powders usually need to be milled and purified to remove metallic impurities.

Table 5.2 Typical properties of boron carbide.

Property	**Value**
Density ($g.cm^{-3}$)	2.70

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Melting Point (°C)	655
Hardness (Knoop 100g) ($kg.mm^{-2}$)	75HB
Fracture Toughness ($MPa.m^{-½}$)	2.9 - 3.7
Young's Modulus (GPa)	69.5Gpa
Electrical Conductivity (at 25°C) (S)	140
Thermal Conductivity (at 25°C) (W/m.K)	201 W/m.K
Thermal Expansion Co-eff. $x10^{-6}$ (°C)	23.5 x10^-6 /K
Thermal neutron capture cross section (barn)	600

ALUMINIUM OXIDE

Alumina is one of the most cost effective and widely used materials in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. Elevated temperature attack occurs in the presence of alkali metal vapors particularly at lower purity levels.

EXPERIMENTAL SET UP

SL.NO	EQUIPMENT USED
1	Power Hacksaw
2	Graphite crucible mould
3	Graphite stirrer
4	Crucible Furnace
5	Stainless steel

PIT FURNACE

PIT furnace was used to heat the material to desired temperatures by conduction,convection, or blackbody radiation from electrical resistance heating elements..

MIXINGRATIO

In this project Aluminum and Boron carbide& alumina oxide mixed below mentioned weight categories -

Sample1: Boron Carbide-10%--Remaining-90%

Sample2: Alumina oxide -10%--Remaining-90%

MATERIAL REQUIREMENT FINDING METHOD

Cylindrical Specimen size-2.5cm dia-&Length-30cm

Rectangular Specimen:10x3.5x1.6 Cm

Volume-3.14/4*25^2*320*percentage of composite*density*percentage of excess of material

<u>MODEL CALCULATION FOR RATIO:1</u>

$= \pi d^2 *L$

$= \pi/4*2.5^2*30$---vol 147.26

VolumeX Density X pecentage of Contribution

147.26 X 2.7 X 0.95-377 gram+30 % 113=490 gram-ALUMINIUM

Plate: L*B*H

=10*3.5*1.6=56

Al=56*2.7*0.95---- 143.64 =387g

Gear-500g

Total-800 gram

Table:6.2 Weight percentage of Reinforcement

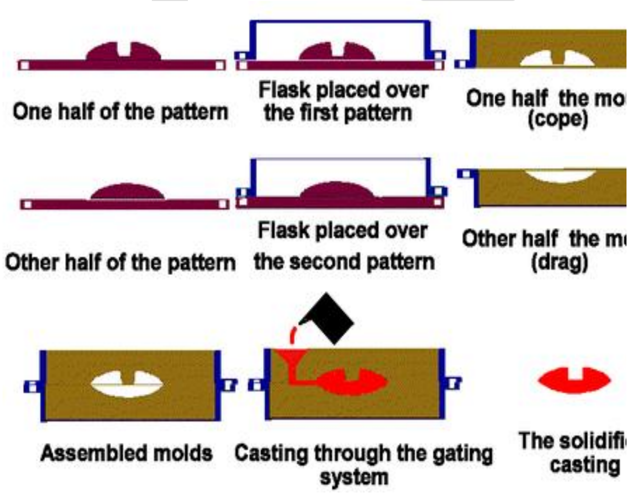
Ratio	AL 6063 grams	B_4C & Al_2O_3 weight percentage	Required weight gms
Al-6063	800	0	0
I	800	10	80
II	800	10	80

CASTNG

There are six steps in this process:

1. Place a pattern in sand to create a mold.
2. Incorporate the pattern and sand in a gating system.
3. Remove the pattern.
4. Fill the mold cavity with molten metal.
5. Allow the metal to cool.
6. Break away the sand mold and remove the casting.

STEPS



MECHANICAL TEST

ROCKWELL HARDNESS TEST

Rockwell Hardness systems use a direct readout machine determining the hardness number based upon the depth of penetration of either a diamond point or a steel ball. Deep penetration indicated a material having a low Rockwell Hardness number.

Using the “B” Scale;

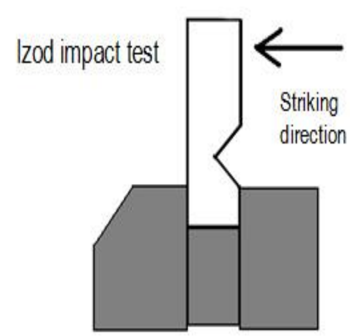
a. Use a Diamond indenter

b. Major load: 100 Kgf, Minor load: 10 Kg

c. Use for alloy metal.

d. Do not use on hardened steel

IMPACT TEST



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Izod impact strength testing is an ASTM standard method of determining impact strength. A notched sample is generally used to determine impact strength. Impact is a very important phenomenon in governing the life of a structure. In the case of aircraft, impact can take place by the bird hitting the plane. **TENSILE TEST&ELONGATION**

Elongation

Deformation in continuum mechanics is the transformation of a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body.

COMPRESSION TEST

A compression test is any test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, **"squashed"**, crushed, or flattened.

RESULT

HARDNESS VALUE

Table:Hardness value

S.No	Material	HRB
R1	Al6063%	37
R2	BoronCarbide 10% & Remaining Al-6063	41
R3	Alumina oxide 10% & Remaining Al-6063	51

S.No	COMPOSITION	Impact Strength (Joules)
R1	Al-6063%	11
R2	BoronCarbide 10% & Remaining Al-6063	7
R3	Alumina oxide 10% & Remaining Al-6063	9

Fig: Before Hardness Strength Specimen Image

Fig: After Hardness Strength Specimen Image

HARDNESS TEST GRAPH

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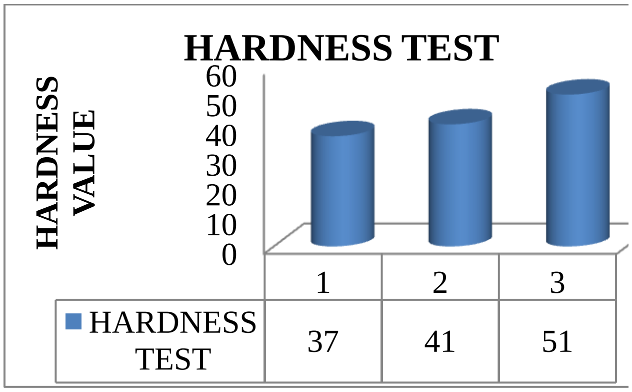

Fig: 8.3Hardness Strength

IMPACT STRENGTH VALUES

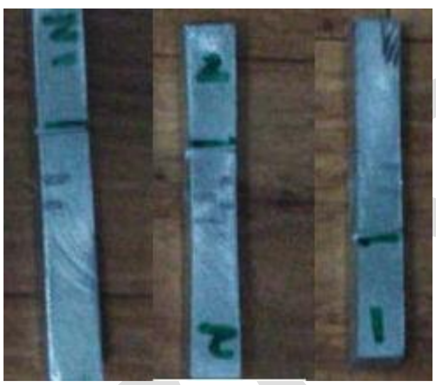

Fig: Before Impact Strength Specimen Image

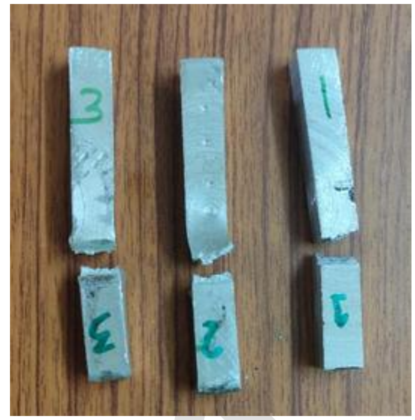

Fig: 8.5 After Impact Strength Specimen Image

IMPACT STRENGTH GRAPH

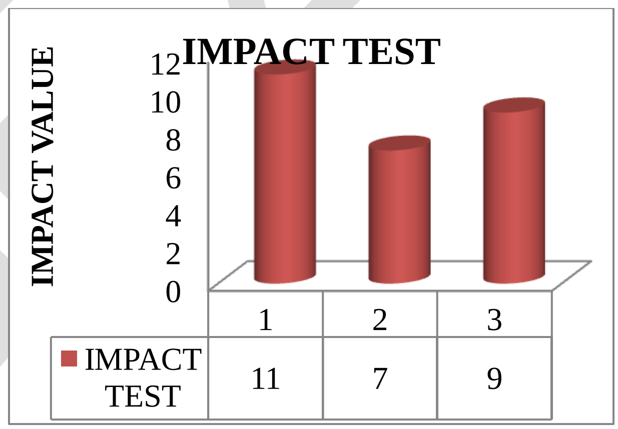

Fig: Impact strength

TENSILE STRENGTH VALUES

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Fig: Tensile Strength

Ratio	Dia mm	CSA mm^2	YL KN	YS N/mm^2	TL KN	TS N/mm^2	IGL mm	FGL mm	%E	FD	%RA
Ratio 1	16.34	209.78	10.08	48.05	13.86	66.07	50.00	51.16	2.32	14.93	16.51
Ratio 2	15.97	200.39	11.24	56.09	16.48	82.24	50.00	51.24	2.48	14.89	13.07
Ratio 3	16.02	201.65	10.37	51.43	15.29	75.83	50.00	51.06	2.12	14.95	12.91

Fig: Before Tensile Strength Specimen Image

Fig:After Tensile Strength Specimen Image

TENSILE STRENGTH GRAPH

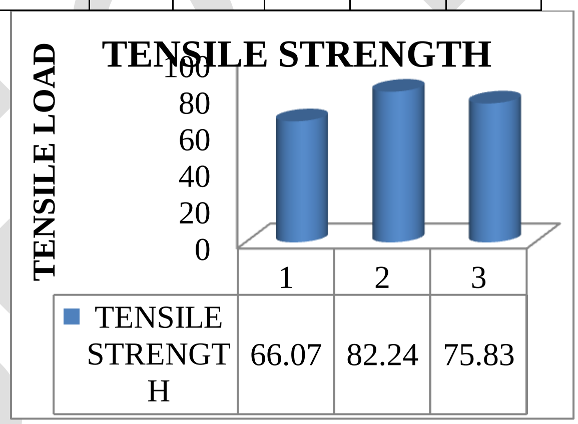

Fig: Tensile strength

ELONGATION

Sample 1 Composite 1-**1.16 mm**

Sample 2 Composite 2-:1.24 mm

Sample 3 Composite 3-**1.06 mm**

8.4 COMPRESSIVE STRENGTH VALUES

Table: 8.4 Compression Strength

Identification	Dia mm	CSA mm^2	Compression Load kN	Compression Strength N/mm^2
Ratio 1	16.34	209.78	51.02	243.20
Ratio 2	15.	200.1	59.67	298.14

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	96	4		
Ratio3	17.06	228.68	54.26	237.28

Fig: Before Compression Strength Specimen Image

After Compression Strength Specimen Image

COMPRESSIVE STRENGTH GRAPH

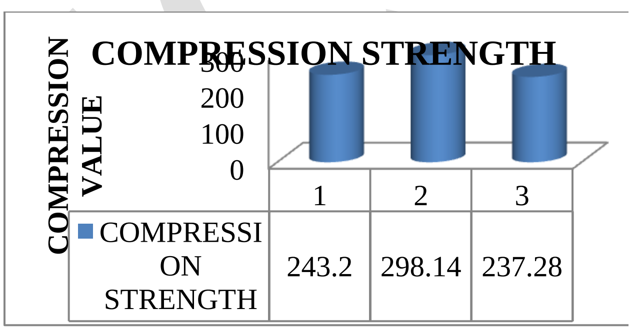

Fig: 8.12Compression Strength

RESULT &CONCLUSION

Composite materials especially Aluminum 6063 boron carbide and Alumina oxide composites having good mechanical properties compared with the conventional materials. It is used in various industrial applications these materials having light weight along with high hardness for automobile industries. The present work was based on the development of aluminum alloy with the additions of different reinforcements in terms of constant volume percentages. Developed composites were characterized by mechanical testing in terms of hardness and tensile strength, and impact. Following points can be concluded from the work carried out.From the investigation the mechanical property of Al-6063 metal matrix were analyzed finally found Boron carbide reinforcement enhanced the good tensile and compressive strength. Impact strength is good in Al-6063 and followed by Aluminina oxide. Boron carbide shows superior tensile and compressive strength compared than Alumina oxide metal matrix. But impact strength is more at Alumina oxide. Impact is strength is obtained at without metal matrix of Al-6063.

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