CHARACTERIZATION AND MACHINING PERFORMANCE OF FIBRE REINFORCED CAST IRON

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ABSTRACT

This research work is carried out to manufacture fibre reinforced cast iron so that the two materials act together, each overcoming the deficits of the other. Composite materials are being tailored to meet specific needs of strength and stiffness requirements. They exhibit the best properties of the individual material and include properties that none of the individual material possesses.

Cast iron is an engineering material with a wide range of applications, including pipes, machine and automotive industry parts, such as cylinder heads, cylinder blocks, and gearbox cases. Its usage is declining in certain areas of application because it is brittle in nature and is weak under tension.

Glass fibre is the most commonly used reinforcing agent to increase strength in composite materials. They are very strong in tension but have no strength against compression.

The composite material was manufactured (FRCI) by reinforcing cast iron with glass fibre to improve its tensile strength. It was observed that its strength increases remarkably with negligible effect on hardness and its machining performance.

This research work will provide researchers and manufacturing engineers a new approach to study the application of cast iron with reinforced fibre in areas where high compressive and tensile strengths are required.

1. INTRODUCTION

We live in a materialistic society is literally true. Our whole civilization – indeed our very existence – depends upon the availability of suitable materials. An *ideal material* should be *strong*, *tough* and *light*. Metals and their alloys come close to satisfying these requirements. They are strong and tough but not very light. Some covalent materials are strong but not tough. The plastics invented in this century are light but lack stiffness, strength and toughness. An obvious approach to attaining an ideal material, therefore, would be to combine two materials with complementary properties. Composite materials are a combination of two or more distinct materials. Such combinations exhibit the best properties of the individual material and include properties that none of the individual material possesses.

2.1 LITERATURE REVIEW

Various research have carried out works to develop improved properties of composite materials. Avci Ahmet et al. (2009) studied the strengthening of gray cast iron by reinforcing with steel plates was investigated in the as-cast and normalized conditions**.** Akdemir Ahmet et al. (2009) studied the Impact toughness and microstructure of continuous steel wire-reinforced cast iron composite. In this study, improvement of impact toughness of gray cast iron by reinforcing steel wire was investigated. The composite material was produced by sand mould casting technique. Alper Cerit A. et al. (2008) studied the effect of reinforcement particle size and volume fraction on wear behaviour of metal matrix composites. Funaki Katsuyuki et al. (2005) studied the internal stress behavior of the short ceramic fiber reinforced aluminum alloy under tensile deformation. Reinicke R. et al. (1999) studied the tribological properties of SiC and C-fiber reinforced glass matrix composites. The findings proved that the addition of SiC-fibers has a positive influence on the wear performance of the glass matrix composites. It has been observed that Composites of aluminium and magnesium have been developed by using fibres and particulates. Carbon fibres are also being used to improve the strength of materials. It is felt that a composite of cast iron with glass fibres may improve its strength properties. There has been no work reported in the available literature using glass fibres.

2.2 CAST IRON

Grey cast iron is named after its grey fractured surface, which occurs because the graphitic flakes deflect a passing crack and initiate countless new cracks as the material breaks. Iron (Fe) accounts for more than 95% by weight of the alloy material, while the main alloying elements are carbon (C) and silicon (Si). The amount of carbon in cast irons is 2.1 to 4 wt%. Cast irons contain appreciable amounts of silicon, normally 1 to 3 wt%.

With its low melting point, good fluidity, cast ability, excellent machinability, resistance to deformation, and wear resistance, cast irons have become an engineering material with a wide range of applications, including pipes, machine and automotive industry parts, such as cylinder heads, cylinder blocks, and gearbox cases. It is resistant to destruction and weakening by oxidisation. Cast iron tends to be brittle, except for malleable cast irons. It has low tensile strength but has high compressive strength.

2.3 GLASS FIBRES

Glass Fibre, also called as fiberglass, is material made from extremely fine fibers of glass. The main advantages of glass fibres are high tensile strength and strain to failure. However, heat and fire resistance, chemical resistance, moisture resistance and thermal & electrical properties are also cited as reasons for their use. There are several types of glass fibres with different compositions. The most commonly used type of glass fibre is E-glass because it is of relatively low cost and has high strength properties.

3. MANUFACTURING OF FRCI

Cast iron is made by re-melting pig iron, often along with substantial quantities of scrap iron and scrap steel, and taking various steps to remove undesirable contaminants such as phosphorus and sulfur. Iron is sometimes melted in a special type of blast furnace known as a cupola, but more often melted in electric induction furnaces. After melting is complete, the molten iron is poured into a holding furnace or ladle and this molten metal is further poured into the moulds to get desired casting.

The manufacturing of FRCI was done with the use of a wooden pattern. The mould was prepared by hand moulding process using molasses sand as shown in fig 3.1(a). Fig 3.1 (b) & (c) shows that the fibre layer was placed at the parting line of the cope and drag mould with use of

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chaplets to support the fibre layer. Molten metal of grade IS: 210 Gr 25 melted from an Induction Furnace was poured in the mould as shown in Fig 3.1 (d). When the mould was fettled after one hour, it was found that the fibre did not fuse in the molten metal as it can be seen in Fig 3.3(e) and it got reinforced. Fig 3.1 (f) & (g) show a clearer and closer view of the fibres attached along the parting line of the FRCI block. Another block was casted from the same molten metal and the same pattern without using the fibre to compare their properties.


Fig 3.1(a): Mould Preparation

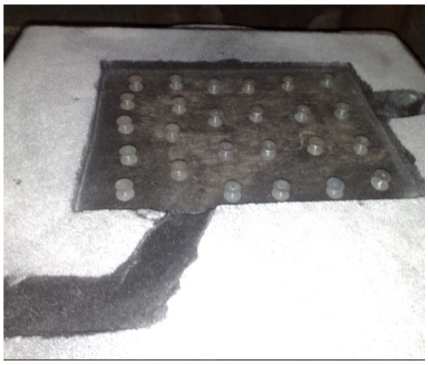


Fig 3.1(b): Placing of chaplets

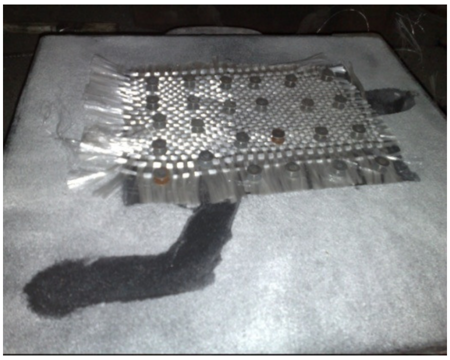


Fig 3.1(c): Placing of fibre


Fig 3.1(d): Metal Poured

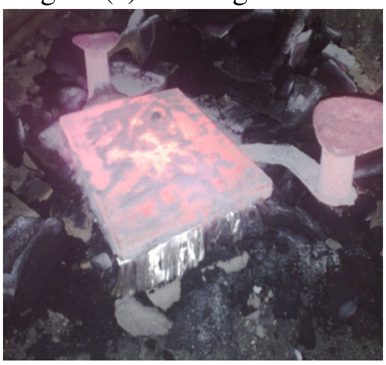


Fig 3.1(e):Fettled mould


Fig 3.1(f):FRCI block


Fig 3.1(g):Close view of FRCI block

4. TESTING FOR MECHANICAL PROPERTIES

Two categories of specimens were made, one with reinforced fibre (FRCI) and the other without fibre (C.I). Further both the specimens were cut into ten smaller rectangular strips of 120X10X10mm dimension. Following tests were conducted to compare the mechanical properties of the specimens:

1) Tensile Test: The main objective of this research work is to increase the tensile strength of cast iron by reinforcing fibre. This test was conducted to check for the tensile strength of both the specimens.

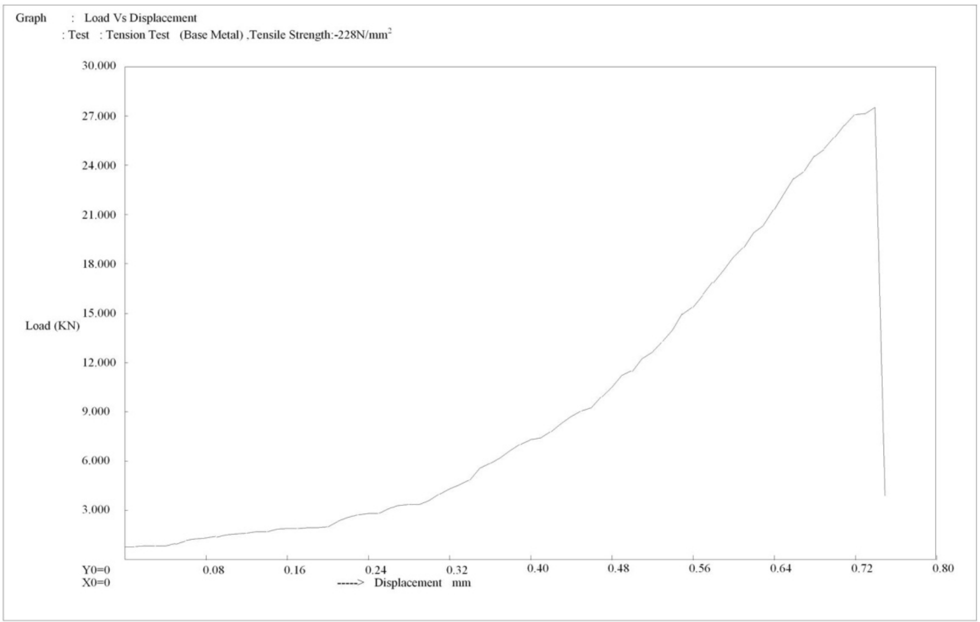
2) Microstructure Observation: Images were taken to see what changes have taken place in the microstructure of cast iron by reinforcing fibre.

3) Hardness Test: This test was done to check the effect of reinforcement of fibre on hardness to see whether the machining performance is also affected or not.

4.1 TENSILE TEST

The specimens were tested on FIE Make Universal Testing Machine, UTE – 60. Milling was done on both the specimens to create a dumbbell shape. The specimens were gripped by using flat grips

TENSILE TEST FOR FRCI



Fig

4.1(a): Load-Displacement graph for FRCI

In this test maximum force applied on the specimen was 28000 N. At this force the fracture of the specimen took place. The tensile strength of the specimen was observed to be **228 N/mm²**.

Following is the observed data for the specimen:
Maximum Force (Fm): 28000N
Displacement at Fm : 0.73 mm
Tensile Strength : 228Mpa or 228 N/mm²

<u>TENSILE TEST FOR CAST IRON</u>
In this test maximum force applied on the specimen was 10230 N. The tensile strength of the specimen was observed to be 170.5N/mm².
Following is the observed data for the specimen:
Maximum Force (Fm): 10230N
Displacement at Fm : 3.1 mm
Tensile Strength : 170.5Mpa or 170.5 N/mm²

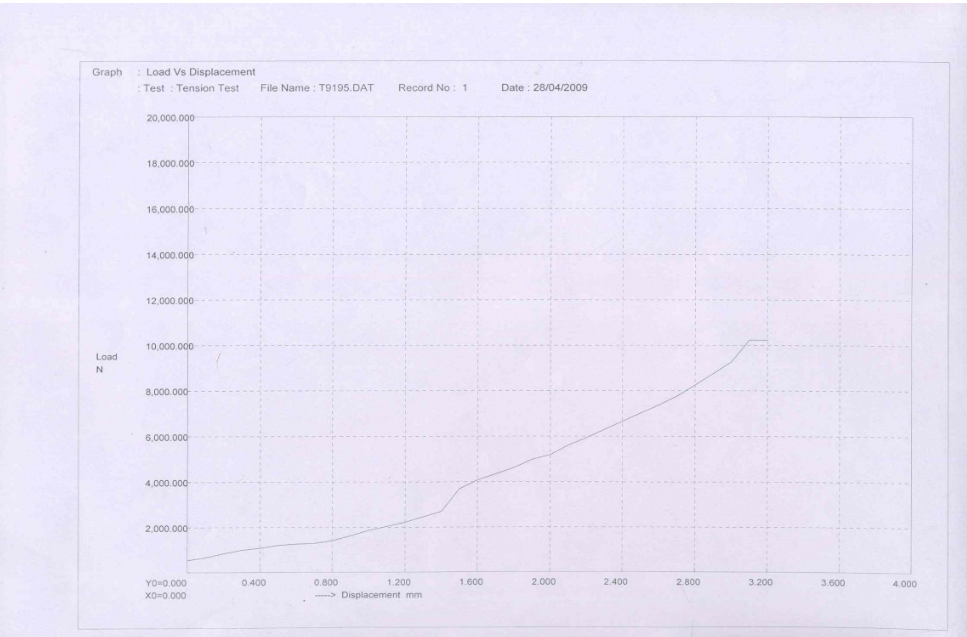


Fig 4.1 (b): Load-Displacement graph for C.I.

4.2 MICROSTRUCTURE OBSERVATIONS

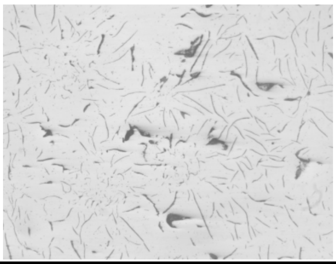
Metallurgical Microscope with an image analyzer was used at a magnification of 100X to take the microstructure of both the specimens. Three images were taken for each sample with and without etchant.

The specimens were polished using double disc polishing machine. First they were polished by using an emery Paper No. 1200 and to create a mirror like finish the specimens were later polished using a muslin cloth and diamond paste.

Further the specimens were washed again by using an organic solvent. Acetone was used as an organic solvent in this experiment. The etchant when required was applied after the specimens were washed by the organic solvent. After applying the etchant the specimens were again washed by the organic solvent. 4% Nital was used as an etchant in this experiment.

Microstructure Observations of C.I.

(i) Microstructure without using Etchant



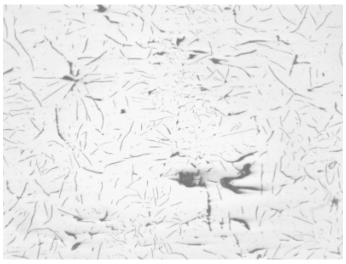


Fig 4.2(a) Fig 4.2(b) Fig 4.2(c)

Observation:

With reference to the above figures i.e. Fig 4.2(a), (b) &(c) we can imply that there is mostly ‘A’ and ‘B’ Type Graphite flakes present and in almost equal proportions. The size of the flakes is Size 4. Approximately 10% of ‘C’ Type flakes are also present. To conclude the distribution is fairly uniform throughout the surface.

(ii) Microstructure using an Etchant

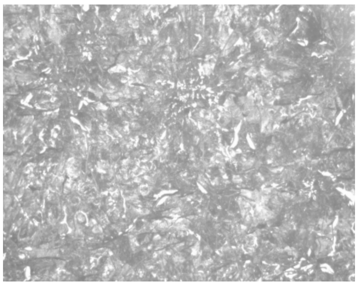
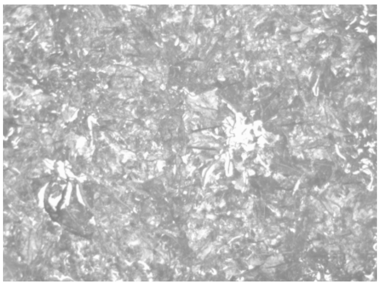
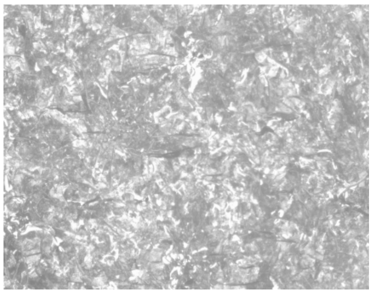




Fig 4.3(a) Fig 4.3(b) Fig 4.3(c)

Matrix:

With reference to the above figures, i.e. Fig 4.3(a), (b) &(c) we can conclude that the matrix contains medium and slightly coarse lamellar pearlite with approx. 10% free ferrite. P.E. is fine and in even distribution.

Microstructure Observations of FRCI

(i) Microstructure without using etchant

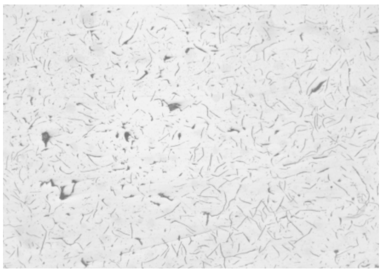


Fig 4.4(a)

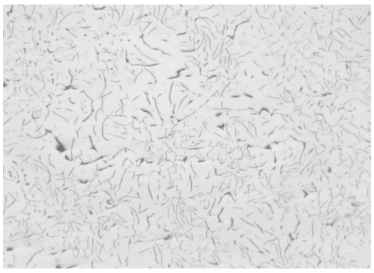


Fig 4.4(b)


Fig 4.4(c)

Observation:
With reference to the above figures i.e. Fig 4.4(a), (b) &(c) we can imply that there is mostly 'A' Type Graphite flakes present with approx. 20% of 'B' Type flakes. 'C' Type flakes are also present upto an extent of approx 10%. The size of the flakes varies in between Size 5 and 6 and evenly distributed. To conclude major area is covered by 'A' Type Graphite flakes.
(ii) Microstructure using an Etchant

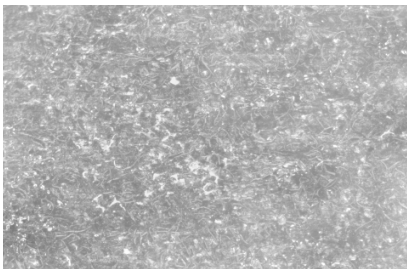


Fig 4.5(a)

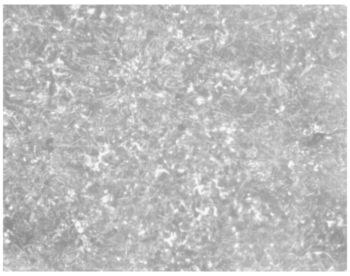


Fig 4.5(b)

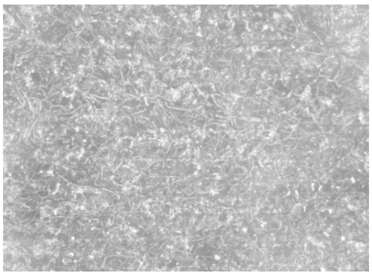


Fig 4.5(c)

Matrix:
With reference to the above figures, i.e. Fig 4.5(a), (b) &(c) we can conclude that the matrix contains medium and fine lamellar pearlite with aprox. 5% free ferrite. P.E is fine and in even distribution.

Result & Discussion

It is observed that there is clear difference between the microstructures of C.I. and FRCI. In C.I. there is even distribution of 'A' and 'B' type graphite flakes whereas in FRCI it is mostly 'A' type with only 20% 'B' type graphite flakes. The size of the flakes in C.I. is size4 whereas in FRCI it varies between size5&6. C.I. contains medium and slightly coarse lamellar pearlite whereas FRCI contains medium and fine lamellar pearlite. Only 5% free ferrite is present in FRCI as compared to 10% in C.I. Thus it can be concluded that by reinforcing cast iron with fibre there is improvement in its microstructure which improves the tensile strength of the material.

5. HARDNESS TEST

A Brinell hardness tester was used to conduct the hardness test at a load of 3000Kgf for both C.I. and FRC specimens. The indent formed on both the specimens was then seen through

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brinell microscope.
Observations:

1) C.I.
   Diameter of indent = 4.2mm
   Hardness = 187BHN
2) FRCI
   Diameter of indent = 4.1mm
   Hardness = 197BHN

Increase in Hardness = 10BHN
Percentage Increase in Hardness = 5.34%

6. MACHINING PERFORMANCE

The term machinability refers to the ease with which a metal can be machined to an acceptable surface finish. Machinability can be difficult to predict because machining has so many variables. The ease with which a material can be machined can be related to the term machining performance. It can be related to any one parameter which affects the machinability e.g. tool life, cutting time, surface finish etc. Thus machining performance can be described as the performance of a material while machining when only one of these parameters is considered. Drill test is one such method in which machining performance can be measured considering cutting time as the performance parameter.

Drill Test

Cutting time is taken as the performance criterion. Thus lesser the cutting time better is the machining performance of the material. In this test a drill of a particular diameter is used at a fixed speed and feed for a fixed depth of cut. The time taken to make the drill of a fixed depth is recorded.

The experiment was performed using the following parameters:
Drill Diameter = 6mm
Depth of Cut = 10mm
Speed = 280, 450 & 710 RPM
Feed = 0.032, 0.05 & 0.08 mm/rev

C.I. and FRCI plates were drilled at three different speeds and feeds and the time was recorded for a fixed depth of cut.

Table 5.1: Machining time of FRCI and C.I.

MATERIAL	SPEED (RPM)	FEED (MM/REV)	MACHINING TIME(SECS)
C.I.	280	0.032	40.8
FRCI	280	0.032	43

C.I.	280	0.05	27.5
FRCI	280	0.05	28.8
C.I.	280	0.08	17.8
FRCI	280	0.08	18.5
C.I.	450	0.032	27.7
FRCI	450	0.032	28.5
C.I.	450	0.05	16.9
FRCI	450	0.05	17.6
C.I.	450	0.08	11.6
FRCI	450	0.08	12.1
C.I.	710	0.032	17.3
FRCI	710	0.032	18.3
C.I.	710	0.05	10.7
FRCI	710	0.05	11
C.I.	710	0.08	7.2
FRCI	710	0.08	7.6

Test of Hypothesis

Hypothesis testing determines the validity of the assumption with a view to choose between two conflicting hypothesis about the value of a population parameter. Hypothesis testing helps to decide on the basis of a sample data, whether a hypothesis about the population is likely to be true or false.

t-test

It is based on t-distribution and is considered an appropriate test for judging the significance of a sample mean or judging the significance of difference between the means of two samples in case of same sample when population variance is not known. In case two samples are related, we use *paired t-test* for judging the significance of the mean of difference between two related samples.

Conducting a paired t-test

Following is the observed machining time of FRCI and C.I at three different speeds and feeds.

0.05 level of significance has been used to test whether there is any significant difference in the machining time of FRCI and C.I.

Table 5.2: Paired t-test chart

S.No.	Speed (rpm)	Feed (mm/rev)	FRCI X_1	C.I. X_2	d_i (x_1-x_2)	$(d_i-d)^2$
1	280	0.032	43	40.8	2.2	1.768
2	450	0.032	28.5	27.7	0.8	0.004
3	710	0.032	18.3	17.3	1.0	0.016

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4	280	0.05	28.8	27.5	1.3	0.184
5	450	0.05	17.6	16.9	0.7	0.028
6	710	0.05	11.0	10.7	0.3	0.324
7	280	0.08	18.5	17.8	0.7	0.028
8	450	0.08	12.1	11.6	0.5	0.136
9	710	0.08	7.6	7.2	0.4	0.220
TOTAL			185.4	177.5	7.9	2.708

$$\bar{x}_1 = \frac{185.4}{9} = 20.6$$

$$\bar{x}_2 = \frac{177.5}{9} = 19.722$$

$$\bar{d}_i = \frac{7.9}{9} = 0.877$$

Null hypothesis: $\mu_d = 1$
Alterative hypothesis: $\mu_d > 1$
Level of significance: x = 0.05
Degrees of freedom = n -1 = 9-1=8
Criterion: Reject the null hypotheses if t > 1.860

$d_o = 1$

$$t = \frac{d_i - d_o}{s_d / \sqrt{n}}$$

$$= \frac{0.877 - 1}{.58/\sqrt{9}}$$

$$= \frac{0.877 - 1}{.58/3}$$

$$= \frac{0.123}{0.193}$$

t= -0.637

Decision: Since t= -0.637 which is less than 1.860, the null hypothesis is accepted. We conclude that the difference in the machining time if FRCI and C.I. is not more than 1 second

7. CONCLUSIONS

In this study a fibre reinforced composite of cast iron using glass fibre was manufactured and mechanical tests were performed on the new material. Its machining performance was also studied. Based on the results of the mechanical tests and machining performance following conclusion have been drawn:

1. Reinforcement of cast iron using glass fibres is possible.

2. Tensile Strength of cast iron is increases when it is reinforced with fibre.

3. Microstructure of FRCI is evident that there is an increase in its tensile strength.

4. With an increase in tensile strength of cast iron by reinforcing it with fibre there is insignificant effect on the hardness of the material.

5. The machining performance of Fibre reinforced cast iron is similar to that of cast iron. There is insignificant difference in the machining time of both the materials.

6. Fibre reinforced cast iron can find its application where, along with high compressive strength, high tensile strength is needed.

Future Scope

With the increasing thirst for developing materials that are light and strong, fibre reinforced cast iron can be thought of as a material which is strong and can be made light. The future scope in this field is to increase the ratio of fibre to make the material light and carry out subsequent studies.

REFRENCES

1. Akdemir Ahmet, Kus Recai and Simsir Mehmet; (2009), "Impact toughness and microstructure of continuous steel wire-reinforced cast iron composite", *Journal of Materials Science & Engineering: Vol. 516, 1-2, pp 119-125..*

2. Avci Ahmet, İlkaya Nevzat, Şimşir Mehmet, Akdemir Ahmet; (2009), "Mechanical and microstructural properties of low-carbon steel-plate-reinforced gray cast iron", *Journal of Materials Processing Technology*, *Vol. 209, 3*, *pp 1410-1416.*

3. ASTM E10 - 08 Standard Test Method for Brinell Hardness of Metallic Materials.

4. Cerit Alper A., Karamis Baki M., Nair Fehmi, Yildizli Kemal Cerita A. Alper, Karamis Baki M., Fehmi Nair, Kemal Yildiz; (2008), "Effect of reinforcement particle size and volume fraction on wear behavior of metal matrix composites", Tribology in Industry, Vol. 30, pp. 3 & 4, pp. 31-36.

5. Clyne T.W.; Series editors: Kelly A., Zweben C. and Pergamon; (2000), "Comprehensive Composite Materials", *Volume 3: Metal Matrix Composites.*

6. Jayamathy M, Seshan S, Kailas S. V, Kumar K and Srivatsan T. S; (2005), "Influence of Reinforcement and Processing on the Wear Response of Two Magnesium Alloys", In: Materials and Manufacturing Processes, Vol. 20 (2), pp. 255-271.

7. Kalpakjian Serope, Schmid Steven R; (2001), "Manufacturing Engineering and Technology", International edition. 4th Ed. Prentice Hall, ISBN 0-13-017440-8.

8. Reinicke R., Friedrich K., Beier W., Liebald R.; (1999), "Tribological properties of SiC and C-fiber reinforced glass matrix composites", *Vol. 225-229, Part 2, pp 1315-1321.*

9. Waterman, Pamela J.; (2007), "The Life of Composite Materials", *Desktop Engineering Magazine* April 2007

10. Pavlina E.J. and Tyne C.J. Van; (2008), "Correlation of yield strength and tensile strength with hardness for steels", Journal of Materials Engineering and Performance, Vol. 17(6), pp 888-893.