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Effect of Different Proportions of Magnesium reinforced Carbon Steel for Excavator Bucket Teeth

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Abstract

Effects of carbon steel with different proportions of magnesium were studied through mechanical properties for escavator bucket teeth applications. In this study, micron-sized magnesium particles were used as reinforcement to fabricate the carbon steel - Mg composites at two casting temperatures (650 and 830 °C) and stirring periods (3 and 6 min). In this regard, escavator bucket teeth are replaced by Magnesium based carbon steel material and it also describes the modeling and analysis of escavator bucket teeth. Tensile strength, bending strength and hardness of Caron steel with magnesium was improved in all proportions when compared to virgin carbon steel and existing chromium steel. These results indicated that, failure can be minimize by improving bucket tooth with fabrication of carbon steel and Magnesium alloy for more efficient digging and ground leveling. The project concludes that, usage of carbon steel-magnesium composites in the place of Excavator teeth; it can achieve reliability with less weight and high strength.

Keywords: *Excavator; Bucket teeth; Mechanical properties; Carbon steel; Analysis.*

INTRODUCTION

An excavator is a typical hydraulic heavy duty human operated machine used such a s digging, ground leveling,carrying loads, dumping loads and straight action loads. Also, these machines are used to remove soil for various purposes including road construction, building and structural construction or mining. An excavator uses mainly hydraulics or a wire rope pulley system to dig holes or trenches, therefore, often called a digger. Excavators are also called backhoes. An excavator has a long boom arm and a cab that is mounted on a pivot. The boom is connected at an elbow to a stick that holds the bucket [1].The bucket design can be replaced with a different attachment depending on the requirements of the work. They come in different shapes and sizes depending on the requirements. The main advantage of excavators is to improve efficiency and productivity by reducing operating expenses and also they are used where large scale excavation of soil is needed [2]. Excavators can be used in any space that requires equipment superior than hoes and spades. As the use of excavator in day to day life is increasing for many purposes but the applicable site is not inspected properly due urgency of work by the client and the tooth point of the bucket gets damage due to some improper handling by the operator, which leads to the damage of tip of teeth and hence decrease the performances [3].Generally alloy steel is used to make an excavator bucket teeth and hard facing of some wear resistant materials can be applied on the material of bucket teeth, so that its life will improve against abrasive wear [4]. The main attention is focused on the influence of Boron carbide and chromium variations on analysis of bucket teeth [5]. The finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians [6]. Therefore, it has important practical significance to research work on new excavator teeth material, improve the relieving under the condition of service life and reduce the economic loss caused by wear [7]. These teeth assembly is either welded or mounted to the base edge of the loader bucket. When the loader bucket is in action bucket teeth may get deform due to heavy load. So, design with new material is spot of interest in this scenario[8].Nowadays, an excavator tooth has to be replaced after approximately a working week, causing an elevated cost which represents an important economic factor in the mining industry[9].The materials / composite materials plays vital role in the place of getting good performance of escavator bucket teeth. This research work focuses on to fabricate and analyze the escavator bucket teeth with carbon steel in different proportions of magnesium and also compare the performance with existing excavator teeth.

MATERIALS AND METHODS

Materials

Carbon steel is composed of iron with confines of under two percentage points of carbon, there is huge variance in phyMg.al characteristics—especially hardness. It is the most widely-used alloy steels. It is a high-purity alloy with excellent corrosion resistance, excellent strength. chemical composition of carbon steel as shown in the following table 1.

Table 1: *Chemical Composition of Carbon steel*

Elements	C	Mn	Ni	Si	Cr	S	P	Fe
Wt%	1.3-1.6	2-10	3.5-22	1-2	16-26	0.5-0.8	0.3-0.6	Rest

Modeling

The dimensions of the selected bucket teeth are found using vernier calliper, screw gauge. According to the dimensions the model of the bucket teeth is developed using *CATIA.* The modeled bucket teeth and it is imported in to design modeller of *Hyperworks 11.0.* The next stage of the modeling is to create meshing of the created model. For the finite element analysis 3.2 Mpa of pressure was used. The analysis was carried out using CATIA and hyper works software. The pressure is applied at the every tooth of escavator bucket. The maximum and minimum von-misses stresses and strains were noted. The model of Escavator bucket with teeth is as shown in Fig 1.

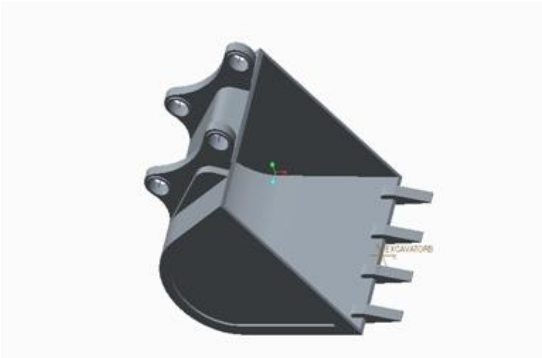

Fig.1 *Modeling of escavator bucket teeth*

Bucket Teeth Preparation

Stir casting process used as process for the fabrication of the testing specimen. Stir casting is the process in which mechanical stir is used for the mixing of the particles. The speed controller maintained a constant speed of the stirrer, as the stirrer speed got reduced by 50-60 rpm due to increase in viscosity of the melt when particulates were added into the melt. After the addition of reinforcement, stirring is continued for 18 to 25 minutes for proper mixing of the prepared particles in the matrix. After this the stir is replaced by an ultrasonic probe for the proper dispersion of particulates in the matrix. Before the system the horn is preheated to higher than 5500 ^{o}C, the system frequency 21.40 KHz about. The melt was kept in the crucible for approximate one minute in static condition and then it was poured in the mould. However, cast bucket teeth are made in the condition of high temperature molten metal and then injected in the casting molds, final cast bucket teeth are thus formed after cooling. Machining operations were carried out for perfect finishing op bucket teeth.

RESULT AND DISCUSSION

The important mechanical tests were performed such as Tensile strength, Bending strength and Hardness Test. Those tests are performed to investigate the mechanical properties by the effect of different weight percentage of reinforcement of Magnesium in carbon steel.

***Table 2** Mechanical Properties of various types of steel*

Property	**Chromium Steel**	**Carbon steel**	**Carbon steel +1%Mg**	**Carbon steel +3%Mg**	**Carbon steel +5%Mg**
	Graph representation				
	0	**1-0**	**1-1**	**1-3**	**1-5**
Bending strength (Mpa)	405	418	421	425	426
Hardness (BHN)	197	215	221	239	243
Tensile Strength (Mpa)	655	670	680	686	687
Young's Modulus (Gpa)	64.7	77.2	79.5	82.1	82.0

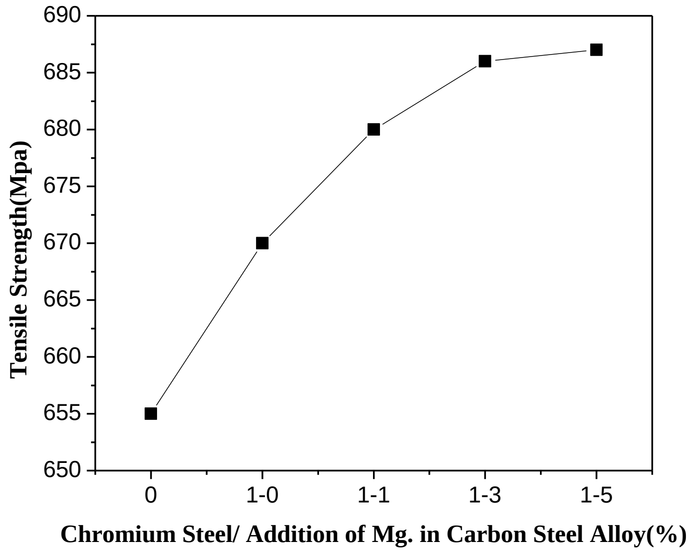

***Fig. 2** Effect of tensile strength of carbon steel-Mg. composites*

Figure 2 shows that, the tensile strength of carbon steel reinforced with Mg. particles. It was observed that tensile modulus gradually increased with addition of Mg. particles. It was due to the fine grain size of carbon and Mg., both together considered to be inhibited with improvement of the tensile strength. Also, the grain size and the local strain of Mg are very small. Hence fine grain structure was formed the carbon steel-Mg. matrix which leads to tensile strengthincrement.

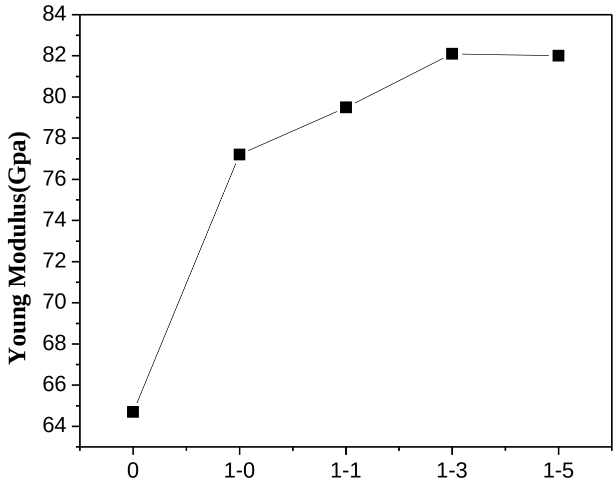

Fig. 3 *Effect of Young modulus of carbon steel-Mg. composites*

Figure 3 shows that, the tensile/young modulus of carbon steel alloy reinforced with Mg. particles. It was observed that tensile modulus gradually increased with addition of Mg. particles. It was due to the fine grain size of carbon with fine powder of Mg., both together were facilitate to increase the tensile modulus.

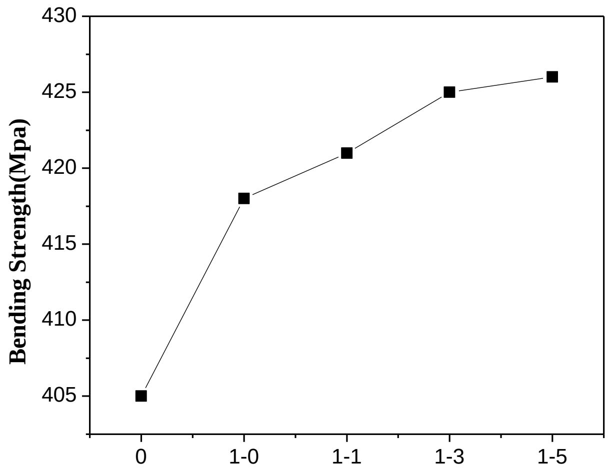

Fig. 4 *Effect of Bending strength of carbon steel-Mg. composites*

Figure 4 shows that, the bending strength of carbon steel reinforced with Mg. particles. It was observed that bending strength gradually increased with addition of Mg. particles. It was due to Mg. powder made vital role along with carbon steel contents in the composition, it expressed as mass percent rather than Volume percent, which leads to increase of density with steel alloy composites and hence bending strength increases with increment of Mg.

Figure 5 shows that the hardness of carbon steel reinforced with Mg. particles. It was observed that the hardness deeply increased by addition of wt. % of Mg. It was due to hardness of alloy depends on reinforcement and the matrix formation, which relates to coefficient of thermal expansion of Mg. (7.103μm/m ^{o}C) is less than that of carbon steel alloy 5083 (24.3μm/m^{o}C), an enormous amount of dislocations are generated at the particle-matrix interface during solidification process. It leads to further increases of the matrix hardness.

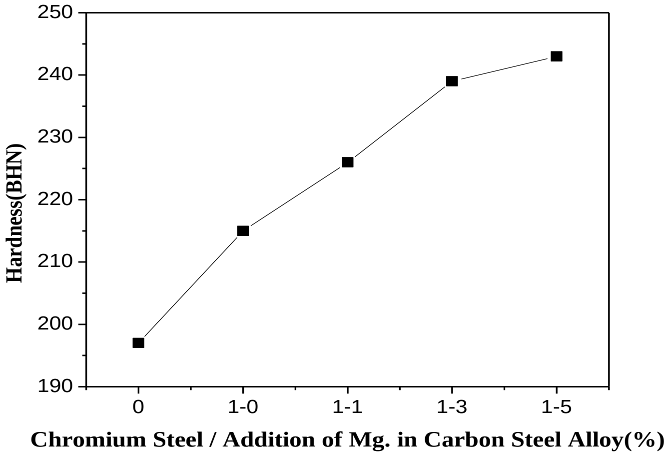

Fig. 5 *Effect of Hardness of carbon steel-Mg. composites*

ANALYSIS OF BUCKET TEETH

The von-mises stress and strain were noted for all the composites of magnesium alloy with different proportions of Mg. powders are shown in the following figures 6-8.

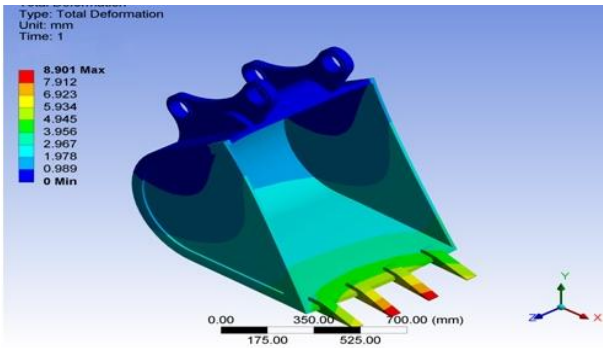

Fig. 6 *Von Mises stress on Escavator Bucket Teeth for Carbon steel*

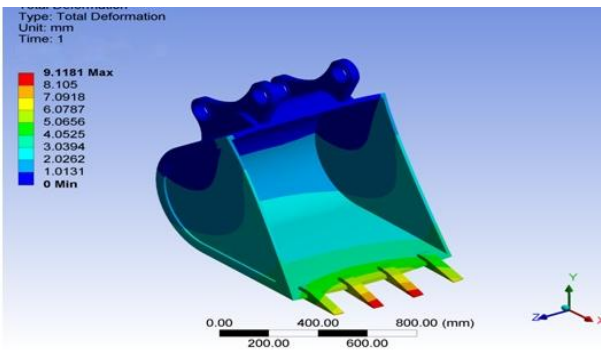

Fig. 7 *Von Mises stress Escavator Bucket Teeth for Carbon steel with 1% Mg..*

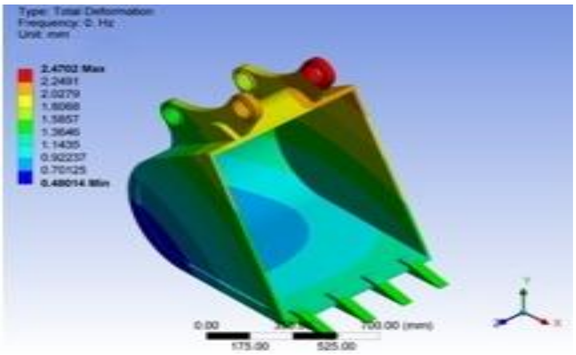

Fig. 8 *Von Mises stress on Escavator Bucket Teeth for Carbon steel with 5% Mg.*

Figure 9 and 10 shows that, von mises stress and strain were observed as decreasing order as increase of Mg. It was due to fine form of Mg. powder are uniformly distributed in the steel alloy matrix and good bonding with carbon steel alloy which influences the mechanical properties. If addition of more than 5% Mg. with carbon steel alloy it loosens its bonding, which due to speroidal shape of Mg. not having good adhesion with steel alloy. Hence, 5% of Mg. reinforced with Carbon steel, itself it maintains the mechanical property of the bucket teeth.

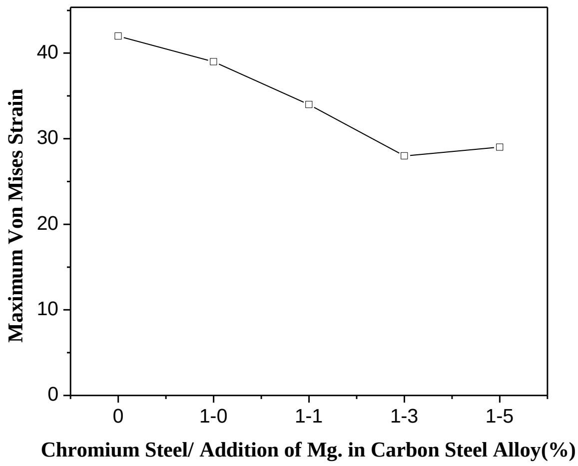

Fig. 9 *Effect of Max. Von Mises Strain of carbon steel with variation of Mg.*

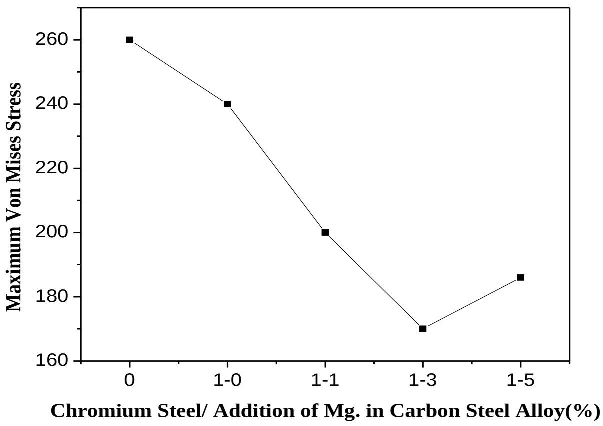

Fig. 10 *Effect of Max. Von Mises Stress of carbon steel alloy with variation of Mg.*

Maximum von mises stress and maximum von mises strain are minimum in bucket teeth made of carbon steel with 4%Mg. More than 5%Mg. addition with carbon steel appeared as von stresses higher, which leads to lesser working life/durability and hence the maximum tensile stress developed in 5% Mg. in carbon steel. Also, this analysis study found that, carbon steel with 4%Mg. is the best suited for applications of bucket teeth.

CONCLUSION

Use of Magnesium with carbon steel alloy composites causes enhancement in the properties. From this study, the following conclusions can be drawn:

- The tensile strength and tensile modulus gradually increased with addition of Mg. with carbon steel alloy composites.
- The bending strength and hardness increased by increasing addition of Magnesium.
- Von mises stress and von mises strain are minimum in bucket teeth made of magnesium alloy with 4%SiC.
- Using of carbon steel with 4% of Mg., minimizes failure of bucket teeth and improve the performance of digging and ground leveling.

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