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Manufacturing of Gray Cast Iron Automotive Disc Brake

KEYWORDS: Gray cast iron, disc brake, automotive industry and microstructure

Masoud I. M.	Al-Jarrah J. A	Abu Mansour T
Chemical and Material Engineering Department, Faculty of Engineering, Northern Border University, KSA	Mechanical Engineering Department, Faculty of Engineering, Northern Border University, KSA	Mechanical Engineering Department, Faculty of Engineering, Northern Border University, KSA

ABSTRACT *The wear behavior of four to two different types of gray cast iron (with different carbon and silicon content) was studied. The materials were cast in controlled sand molds with Y block from each type for wear and hardness tests and microscopic investigation. The wear tests were carried out in a pin-on-ring wear-testing machine. The wear was measured by weight loss after 30min at different loads and speeds. The results showed lower weight loss for gray iron of high carbon content and lower silicon content compared with the three to other gray iron at any applied pressure. In addition, better hardness was obtained for the same gray iron.*

1. Introduction:

The braking system of most modern cars is based on brake discs, which uses gray cast iron brake discs as the braking surfaces. The metallurgical properties of the gray cast iron determine the strength, noise, wear and braking characteristics of the brake discs. If a brake disc is too soft, it will wear rapidly. On the contrary, if a brake disc is too hard, it is more likely to crack [1]. Disc brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A disc brake (or rotor) is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon-carbon or ceramic-matrix composites [2-5]. Friction causes the disc and attached wheel to slow or stop. Brakes (both disc and drum) convert motion to heat, but if the brakes get too hot, they will become less effective because they cannot dissipate enough heat. This condition of failure is known as brake fade [2]. The friction and wear of disc brake materials have been widely studied by numerous researchers for many decades [2-5]. Gray cast irons are widely used for automotive parts such as vibration resistant casings, clutch plates, brake discs and flywheels [6-8]. They are attractive due to low cost, good mechanical, wear and thermal properties along with vibration damping capabilities [2, 3]. The mechanical properties of brake disc casting are function of composition and microstructure[9, 10].

This project is a trail to improve the properties of the disc brake and to increase its life time by increasing its resistance to wear. For this purpose the team-work decided to manufacture disc brakes using sand casting process with changing the disc brakes' chemical composition, then testing the produced disc and comparing them with an original disc brake.

Standard specification for various grades of most automotive grey iron castings according to ASTM A159 is shown in **Table 1**. [10]

Table 1 Typical base composition % of various grades of most automotive grey iron castings according to standard Specification for automotive grey iron castings ASTM A159

Grade	C%	Si%	Mn%	S%	P%
G1800	3.4-3.7	2.3-2.6	0.5-0.8	0.15	0.25
G2500	3.2-3.5	2.0-2.4	0.6-0.9	0.15	0.20
G3000	3.1-3.4	1.9-2.3	0.6-0.9	0.15	0.15
G3500	3.0-3.3	1.8-2.2	0.6-0.9	0.15	0.12

Experimental Work

2.1 The original disc brake

Specimens were cut off from original disc brake to investigate the microstructure and chemical composition. Other original one used for preparing the pattern for producing disk brake of proper dimensions and surface quality.

Table 2 and Figure 1 show the microstructure and chemical composition of the original disk brake.

2.2. Manufactured disc brake

The original disc brake was used to design pattern to be used in the casting process. Two green sand molds were prepared to have disk brake and Y block in each one. Then the casting process was applied to produce two new parts of disc brakes with different chemical compositions, Y block from each one of the new disc brakes were made under the same conditions with dimensions (12 x 6 x 1.5cm) for the destructive tests.

Electric resistance melting furnace of 100kg and 100kW was used to produce different types of gray cast irons in sand molds. According to ASTM A159 standard for gray cast iron used in automotive industries, the carbon content changes from 3.0 to 3.7% while, silicon changes from 1.8 to 2.6 and Mn is about 0.7%. Different compositions for such alloy were produced based on changing the weight percentage of carbon from 3.44 to 3.54% while, silicon changes from 2.08 to 2.44 and Mn is 0.85%, producing 2 types of gray cast iron (D1 and D2) considering the carbon equivalent.

Specimens for hardness and wear test were cut out from as cast Y block. Wear test was carried out using pin-on-ring TNO Tribometer with Stainless Steel ring-diameter of 73mm; Hardness of 63 HRC. Cylindrical pins of 9mm in diameter and15mm in height were made from the as-cast alloy. The wear loss was recorded for 0.1, 0.2 and 0.3bar normal load at three speeds of 100, 200, and 300rpm and specific wear rate was calculated for each alloys. Vickers hardness test (5kg) and microscopic investigation were carried out for the different castings of disk brake and compared with the results of the original disc brake. External and internal defects of the as cast disc brakes were investigated using NDT such as, visual inspection, Liquid penetrant and ultrasonic test.

3. Results and Discussion

3.1. Original disk brake composition and microstructure

The chemical composition of the original disc brake was obtained using spectrometer and the results shown in Table 2.

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C %	Si%	Mn%	P%	S %
3.6	1.74	0.698	0.05	0.05

Table 2 Chemical composition of original disc brake

This chemical composition of the original grey cast iron disc brake is close to G2500 and G3500 according to ASTM standard of grey cast iron as shown in Table 1.

The microstructure of the original disc brake shows rosette graphite shape of type B grey cast iron, according to ASTM standard. The microstructure is shown in Fig.1.

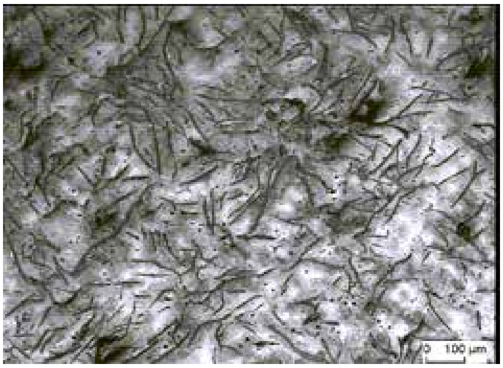


Fig. 1 Microstructure of original disc brake magnified by 100x

3.2 Manufactured disc brake
The chemical composition of gray cast irons D1 and D2 used in this study is shown in **Table 3**. The carbon content slightly increased from alloy D1 to D2 in the range from 3.44 to 3.54wt. %, while silicon decreased from alloy D1 to D2 in the range of 2.44 to 2.1wt. %.

Table 3 Chemical composition of gray cast iron disc brakes used in this study

Alloy	C	Si	Mn	S	P
D1	3.44	2.44	0.854	0.13	0.15
D2	3.54	2.08	0.856	0.14	0.18

3.2.2 Microstructure
The microstructures of the produced disc brakes were investigated using light microscope with magnification of 100x. The microstructure of D1 shows mainly type A flake graphite gray cast iron in a matrix of pearlite and some traces of ferrite as shown in Figure 2-a. The microstructure of D2 shows grey cast iron with type A and some of type C flake graphite in matrix of pearlite with some traces of ferrite, shown in Figure 2-b.

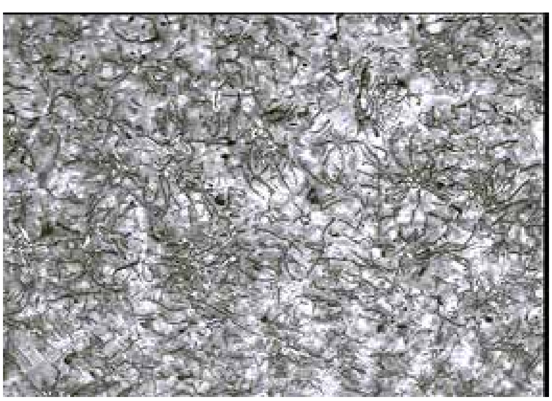
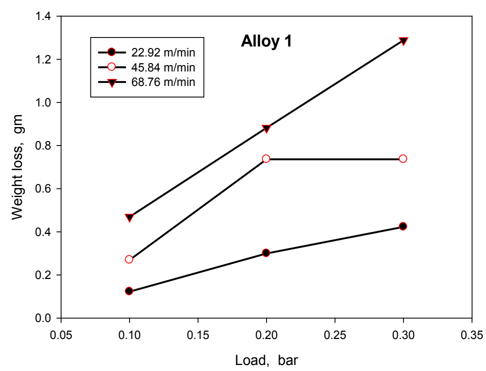


Fig. 2 Typical microstructure of gray cast iron disk brake: (a) D1 and (b) D2. 100x

3.3 Non Destructive Testing
Liquid penetration inspection was carried out for the four to two disk brakes. D1 and D2 showed clean free cracks surface. Ultrasonic inspection was carried out on the produced disk brakes D1 and D2. Gray cast iron disk brake D1 and D2 seems to be clean of any kind of defects. Some cracks and small porosities were found in D2. A crack near to the edge of D2 and some porosity were found in the fins.

The results of NDT can be concluded that, small gas porosity and/or non-metallic inclusion was revealed in D2 after machining by liquid penetrant test. The observed cracks and porosity are too small and acceptable and don't affect the life time of the disc brakes, it could be due to casting defects.

3.4 Destructive tests
3.4.1 Wear resistance test



The wear rate of the two gray cast irons used in this study was carried out, the weight loss was measured after 30 minutes under different loads of 0.1, 0.2, and 0.3bar at different speed of 100,200 and 300rpm (22.92, 45.84 and 68.76m/min). It is clear that, the weight loss remarkably decreased with increasing the load and speed for all of the gray cast iron alloys D1 to D2 as shown in Figures 3.

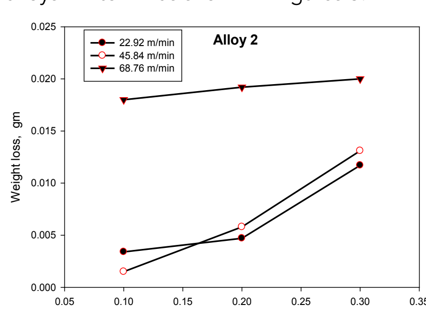


Fig. 3 Wear resistance of gray cast iron alloys: alloy 1 and 2 (D1 &D2).

Gray cast iron D1 reveals the highest weight loss especially at higher speed. Compared with alloys D2, D1 has lower carbon of 3.44% and higher Si of 2.44%. The increase in weight loss of gray cast iron D1 could be due to the presence of ferrite in the microstructure shown in Fig.2-a. This ferrite revealed to be around the graphite flaks. Alloys D2 shows lower wear rate, increasing the speed to about 69m/min significantly increase the wear rate even at lower load, see Fig.3. The microstructure of D2 shows mainly type A and some of type C flaks in matrix of pearlite with some traces of ferrite as shown in Figure 3-a. This microscopic photography is in a good agreement with the wear behavior of these two alloys.

3.4.2 Hardness test

Vickers hardness of the original disc brake was measured and shows 224.5Hv. Vickers hardness test was carried out for gray cast iron disk brakes D1 and D2. Gray cast iron disk brake, D1 reveals lower hardness compared with D2. Gray cast iron D2 shows hardness value very close to the original one of 224.5Hv as shown in Fig. 4-b. The result of hardness is in a good agreement with the wear resistance and microstructure. Considering the chemical composition of the two disc brakes, D2 have lower values of Si% and lower value of C%, this could be the reason for this hardness and wear resistance increase. The result of hardness is in a good agreement with the wear resistance and yield strength.

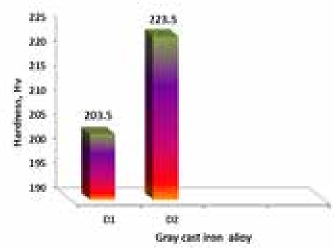
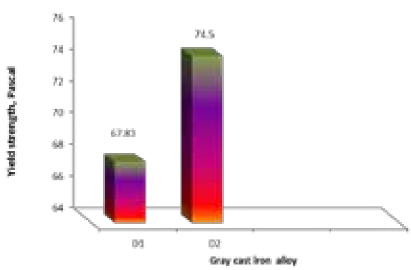


Fig. Hardness value for different gray cast irons



Yield strength for gray cast iron

Fig. 4 Mechanical properties, (a) hardness and (b) yield strength.

Conclusion

The final conclusions of this work can be summarized as:

- NDT revealed small gas porosity or/and non-metallic inclusion after machining for gray cast irons D2, the observed cracks and porosity is small and can be accepted.
- The weight loss of gray cast iron D1 shows higher value compared with D2, D1 has higher Si% of 2.44.
- Gray cast iron alloy D2 is the best to be used as disc brake for automotive industries with slightly better properties than the original disk brake.

Acknowledgments

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