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REDUCTION OF BRAKE SQUEAL BY OPTIMIZING BRAKE DISC MATERIAL CONSIDERING BRAKING PRESSURE AS PARAMETER

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Abstract— ***"Brake squeal" groups a large set of high frequency sound emissions from brake systems. The onset of the squeal is due to the unstable behavior occurring in linear conditions during the braking phase. It is a noise problem caused by vibrations induced by friction forces. There are different parameters which causes the brake squeal. Such as friction induced vibrations, braking pressure, temperature and roughness of disc surface. The lot of suggestions has been given in different papers for reducing brake squeal of passenger cars. In this paper the braking pressure is considered as a parameter for reducing brake squeal. For this purpose different materials are tested on pin on disc wear testing machine. Here my objective was to reduce the braking pressure for achieving same braking performance as existing since braking pressure is directly proportional to the vibrations which are generated during braking. (Main cause of squeal generation) Here gray iron grade 250, high carbon gray iron, and compact graphite iron used in brake disc rotor are tested. Out of these compact graphite iron disc requires low braking pressure for braking action. So this material is suggested for brake disc rotor.***

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I.INTRODUCTION

The disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor) usually made of cast iron or ceramic composites (including carbon, and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically,hydraulically,pneumatically,electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Most modern cars have disc brakes on the front wheels, and some have disc brakes on all four wheels. This is the part of the brake system that does the actual work of stopping the car.

The optimization of automotive vehicles braking systems, subjected to mechanical and thermal stresses, depends on a combination of properties. In general, a complex state of stress is found and it is practically impossible to select a material and design a component based only on one of these properties. The material used in brake rotors should be able to bear thermal fatigue and should absorb and dissipate, as soon as possible, the heat generated during braking [1]. The hydraulic pressure exerted during typical braking procedures, lies between 2 and 4MPa [2]. Friction makes rotors reach, during very small periods of time, temperatures as high as 800 ◦C, resulting in a thermal gradient between the surface and the core of the rotors, which may reach up to 500 ◦C [3].

Gray iron has good thermal conductivity due to the graphite phase, which is a excellent thermal conductor. Graphite flakes are interconnected and disposed in the form of plates, constituting an easy path for fast heat dissipation. In ductile iron, spherical graphite particles are isolated from one another, the contribution of that phase for the thermal conductivity being very small. Vermicular graphite, present in compact graphite iron (CGI), is also interconnected, resulting in intermediate mechanical and thermal properties between those of gray and ductile irons. Mechanical and thermal properties of cast irons may be improved through the addition of alloying elements. In the case of CGI, the use of Mo and high levels of Si has been reported, for application in exhaust manifolds, with the purpose of improving thermal fatigue [6].

Recently, manufacturers have introduced high-carbon, high-conductivity gray iron brake rotors, sometimes alloyed with Mo or Nb, for passenger cars and heavy trucks. These alloys show lower mechanical strength (classes 200 or 150MPa), and the rotors are, for this reason, bigger and heavier. The high thermal conductivity is due to a greater amount of graphite in the microstructure, allowing lower temperatures in the region under friction, which contributes to an increase in life of the component [6].

CGI is being used in Europe in railroad brake rotors where both thermal and mechanical stresses are intense. CGI is an alternative material that has not yet been thoroughly explored by the automotive industry, possibly due to the limited knowledge of its use in that type of application [4].

According to Zhang et al. [5], the wear resistance of compact graphite irons is greater than the wear resistance of gray and ductile irons, independent of contact

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pressure or sliding speed. This is due to an excellent combination between high mechanical resistance and good heat-transfer capacity, which gives the material good thermal fatigue peeling resistance [5].

Although the mechanical and thermal properties of the CGI are very well known, there is little information in literature relative to its use in brake rotors applications. In this work, the wear performance of a CGI used in the manufacture of engine blocks is studied, aiming at its usage in brake rotors of passenger vehicles. This test is carried out to find out amount of minimum braking pressure required for effective braking. The results are compared to the ones obtained in similar tests carried out with gray irons normally used.

II. Experimental Procedure

Three types of gray irons were studied: one grade 250 (GI250), one high-carbon (GIHC), and a compact graphite iron(CGI-0 to CGI-3), whose chemical compositions and basic mechanical properties are shown in Table 1.

Material	GI250	GIHC	CGI-0	CGI-1	CGI-2	CGI-3
Carbon	3.71	3.73	3.54	3.63	3.69	3.44
Manganese	0.41	0.78	0.51	0.51	0.40	0.42
Silicon	1.70	2.07	2.16	2.06	1.90	1.64
Phosphorus	0.091	0.058	0.054	0.04	0.087	0.13
Sulphur	0.002	0.085	0.01	0.015	0.059	0.069
Titanium	0.005	0.014	0.012	0.014	0.002	0.001
Copper	0.002	0.56	0.69	0.47	0.005	0.003
Tin	0.001	0.039	0.061	0.045	0.002	0.002
Hardness (HB)	167/168	180/181	195/196	220/221	169/170	196/197

Table 1. Chemical composition (wt.%) and mechanical properties of irons

The wear tests were performed in a pin-on-disc wear-testing machine, where the load is manually applied. The pin specimens were manufactured from brake pads used in the Tata Truck. They had a round base (area of 78.54mm2) and were ground with sand paper grade 400. The disc specimens were manufactured in iron with 160 mm in diameter and 8mm in thick and surface finished by polishing with 1 µm diamond paste.

The wear tests have been carried out as follows: a load of 4.06, 7.01, 12.60, 16.50, 21.23, 32.21 and 40.85 N was applied through the pin to the spinning rotor (1000 & 500 rpm). load was applied for 5 min leaving the rotor spinning unloaded for the next 5min, the total cycle being 10 min long. During the cycles the normal and tangential forces were also recorded. The wear in rotors was measured by the accumulated mass loss after the cycles. In short following (Table 2) parameters are selected for testing of each disc. All readings are taken at room temperature.

Table 2.Running parameters selected for experimental analysis.

Sr. No.	Load (N)	Disc velocity (rpm)
1	40.85	1000 and 500
2	32.21	1000 and 500
3	21.23	1000 and 500
4	16.50	1000 and 500
5	12.60	1000 and 500
6	7.01	1000 and 500
7	4.06	1000 and 500

III. Experimental Work and Observations

Experimental tests are carried out for each material sample test disc for each normal load and each sliding velocity.

Experimental data of slide wear and coefficient of friction of each sample type of cast iron test discs against brake pad pin with time is tabulated in the table 3 to 7 for each disc velocity of 4.3 m/s (500 rpm i.e.15 Km/hr), 8.4 m/s(1000 rpm i.e.30km/hr) and each normal load of 4.06 N, 7.01 N, 12.60 N, 16.50N, 21.23N, 32.21N and 40.85 N under dry condition using a pin-on-disc Tribometer (TR-20LE). Using these tables, for each sample disc, graphs of variation of wear in micrometer with time and variation of coefficient of friction with time are plotted as shown in figure. 7.1 to figure. 7.5. The load was applied for total cycle of 5min long. During the cycles frictional forces are recorded and respective coefficient of frictions are tabulated as below

Table 3.Mean value of Coefficient of Friction vs applied load and type of cast iron

Applied load →	Mean Value of Coefficient of Friction (μ) for disc velocity 1000						
	40.85 N	32.21 N	21.23 N	16.50 N	12.60 N	7.01 N	4.06 N
GI250	0.24	0.25	0.26	0.29	0.40	0.60	1.80
GIHC	0.14	0.15	0.17	0.24	0.26	0.50	1.31
CGI-0	0.15	0.16	0.19	0.24	0.26	0.50	1.38
CGI-1	0.18	0.19	0.20	0.21	0.24	0.60	2.08
CGI-2	0.19	0.20	0.21	0.22	0.26	0.50	2.08
CGI-3	0.18	0.21	0.22	0.24	0.27	0.50	2.08

Table 4 .Mean value of Coefficient of Friction vs applied load and type of cast iron

Applied load →	Mean Value of Coefficient of Friction (μ) for disc velocity =500 rpm						
	40.85 N	32.21 N	21.23 N	16.50 N	12.60 N	7.01 N	4.06 N
GI250	0.21	0.23	0.24	0.26	0.27	0.39	2.08
GIHC	0.15	0.16	0.17	0.21	0.23	0.37	2.08
CGI-0	0.13	0.14	0.17	0.21	0.22	0.33	1.45
CGI-1	0.16	0.17	0.19	0.20	0.21	0.31	3.73
CGI-2	0.17	0.18	0.19	0.18	0.22	0.36	2.35
CGI-3	0.24	0.25	0.29	0.30	0.32	0.37	2.08

IV. RESULTS

In Table 3 and 4, we can see that mean coefficient of friction values are quite the same for the two gray irons(GI250 and GIHC). When testing CGI discs, the highest friction forces (means lower coefficient of friction) reached. That the high friction forces (lower coefficient of friction) developed during the tests suggests that a CGI rotor would show higher braking efficiency, and hence, it would require lower braking pressures, compared to those necessary to stop a vehicle with the same momentum in the same braking distance having gray iron rotors.

Therefore, CGI tests using lower applied loads (32.21N, 16.50N, 4.06N,) were carried out to reach the same order of friction forces (coefficient of friction) obtained for the gray irons. Table 3 and 4 also shows the results including an extra test carried out with 12.60 N applied load to evaluate more precisely the tendency of the CGI results. One can see that the friction forces reached by CGI tested at loads of 32.21N, 16.50N, 4.06N are similar to those reached by gray irons tested at 40.85 N, 21.23 N and 7.01 N, respectively. These results confirm the hypothesis of a greater braking efficiency of brake rotors made of CGI, for a given load.

V .CONCLUSION

From this test it found that for low applied pressure, the CGI brake disc shows greater braking efficiency as that of other conventional brake disc rotor material and my objective was to reduce braking pressure (applied pressure) for minimizing brake squeal which is satisfied by using CGI brake disc.

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