

Mussel Shell Powder as a Filler Material in Brake Linings

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Abstract In this study, brake linings made of mussel shell powders as a filler material were investigated in terms of wear behaviour, braking performance, friction coefficient and thermal stability to have an idea about the possibility of implementing mussel shell as a candidate of filler material. Brake linings are composed of relatively soft but wear resistant and high thermal conductive materials with a high dynamic friction coefficient in order to keep stability of the friction force and move the heat away under different braking pressures and travel speeds. The manufacture of semi-organic brake linings requires to identical combination of various type of materials such as metals, ceramics, organic materials, resins and friction modifiers followed by characterization of powders, cold pressing and curing processes to acquire final product. For those purposes, the samples manufactured under optimized 15MPa cold pressing and curing at a temperature of 150°C for 2 hours, undergo braking tests in a specially designed experimental setup enabling to measure variation of temperature and friction coefficient during operation. Weight percentage of the samples was preferred to be 5, 10, 15 and 20% by mass. Mussel shell reveals acceptable braking behaviour as a result of microstructure examinations via Scanning Electron Microscopy (SEM) and evaluations which are; hardness 27.5HB, corrosion resistance 1.63% by mass loss and average friction coefficient of 0.39.

Keywords: Wear, Organic Material, Brake Lining, Friction Coefficient

I. INTRODUCTION

The production steps of brake lining materials in a form of fine particles include homogeneous mixing of metal and non-metal materials, cold pressing by a desired form and curing process under controlled environment at a specified time. This method enables to manufacture in only one stage [1]. The main purpose of selecting this method is to perform manufacture without worsening mechanical properties of different ingredient particles of brake lining mixture. Polymer and organic based components in a brake lining with lower resistance to elevated temperatures can be a critical issue during production in terms of getting burst. In the manufacture of a brake lining through powder metallurgy, all components keep their mechanical properties, a structure with desired dimensions and porosity can be obtained for different material particles in different sizes and shapes as well as high

performance and precise parts [2]. Steps of production of a simple brake lining generally consist of grinding of particles, mixing process, cold pressing and then curing or sintering in a controlled furnace consecutively (see Figure 2.1).

As the mussel shells are magnified 300000 times in a scanning electron microscopy, a brick wall like image is seen. This mentioned brick-like wall comprises of a protein as a binder and calcium carbonate as the reinforcement structure. Although, calcium carbonate has a brittle material behaviour, the shell is quite solid and less brittle than conventional ceramics due to layered shell structure. In addition, mussel shells are continuously exposed to corrosion by brine water so that they have high corrosion resistance with relatively low mass loss. Accordingly, the resistance against burning is adequately high due to ceramic based calcium carbonate in the structure [3]. Mussel shell powders are considered to be implemented as a filler material in the manufacture of brake linings as a result of all above mentioned parameters then samples of these materials were subjected to tribological tests for further evaluation.

II. MATERIAL AND METHOD

2.1. Fabrication of samples

The amount of organic powder in brake lining samples were chosen as only one variable during manufacture in order to observe its effects on the wear behaviour and variation of friction coefficient. Weight percentage of mussel shell powder as a filler material in the production of brake lining samples are given in Table 2.1, respectively.

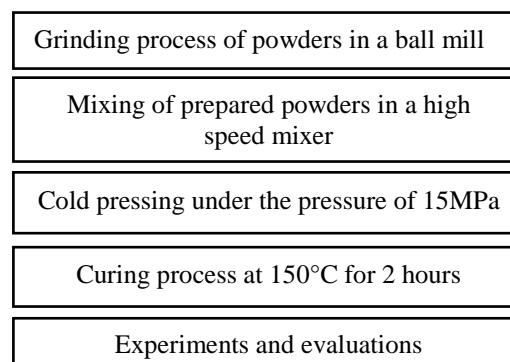


Figure 2.1: The main steps of manufacture of specimens.

Mill ball process of particles, taking place at the beginning of the production process of brake linings, provides the desired particle size. Aforementioned organic-based materials were brought to the same grain size through the 200 mesh sieve after the grinding process. The type of mixing depends largely on the types of materials forming the mixture. In particular; density, particle size and surface characteristics and shape that may be difficult sometimes stirring at significantly different powder components. Mixing should be done very carefully in terms of preventing segregation. Lubricant (graphite) was usually added to mixture to avoid segregation. Considering current studies, stirring ten minutes of mixing time was deemed appropriate for the components.

The moulding process is the process of compacting in a die after mixing with the powder particles uniformly dispersed in a hydraulic or mechanical press. The intensity of the applied pressure increases, the powder density is increased, and thus porosity is reduced. Besides, porosity is directly related to the Young's Modulus and damping property. In order to optimize the pressing pressure on the sample, produced samples were tested with different pressures between 10 and 30MPa. The resulting wear and the average coefficient of friction values are shown in Figure 2.2.

In Figure 2.2, an increase in corrosion resistance and reduction in average friction coefficient are observed with the increase of cold pressing pressure. Friction coefficient reaches the maximum value at 10MPa, although porosity rate is higher than desired level and high amount of wear occurs. On the other hand, the pressure increase yields high hardness and improve abrasion resistance. But the surface thereof undesirable level of noise caused by vibration is observed as the friction coefficient falls. Regarding to that observation, the optimum pressing pressure of 15Mpa would be proposed as the appropriate value.

For the friction test, specimens with dimensions of 25mm×25mm×10mm were cut from the manufactured samples. The friction and wear tests were performed on a specially designed friction tester. This machine includes a cast iron drum with a nominal diameter of 300 mm. The machine is fully computer controllable and comprises of data

acquisition software. During the friction tests, the COF and the drum temperature were recorded.

III. RESULTS AND DISCUSSION

Friction coefficient trends of mussel powder added samples with respect to braking time and temperature are given in Figure 3.1. The coefficient of friction for excluding mussel powder (sample N-1) was found to show an increase up to 200 seconds. At this point the temperature is between 200 and 225 °C for exactly the friction film slightly formed, the other samples including mussel powder are also evident from the graph being formed between these temperatures. 5% mussel powder added sample was exhibited a stable coefficient of friction trend, although a significant reduction was observed with the temperature.

Thus, the rate of the mussel powder content above a certain value, abrasive particles break off from the surface and are thought to be involved in the friction layer and friction coefficient increases accordingly. This was expressed in the same way in the literature [4]. Optimum mussel powder content was observed in N-3 coded sample with 10% mussel shell powder according to temperature and friction coefficient change rate. Average coefficient of friction and specific wear rate values of the samples during the tests are shown in Figure 3.2.

Although, the best corrosion resistance was obtained in N-3 coded sample with 10 percent mussel shell content, generally all specific wear values are close to each other. The reason of exhibiting less amount of wear in mussel shell-free sample is due to little splitting of active particles from the surface. Changes in the coefficient of friction emerges as an indicator of this situation. When it is characterized by less breakage and abrasion, particle from the surface covered onto other matrix materials to create the friction layer by creating the thin film, exhibits a more stable friction coefficient [5].

Density of the mussel powder added samples, Brinell hardness and corrosion loss values are presented in Table 3.1. As an overall evaluation, sample density decreases and corrosion resistance increases at high mussel shell powder contents.

Table 2.1: Content of the brake lining specimens with the mussel shell by mass percentage.

Sample Designation	Phenolic Resin	Steel Wool	Copper (Cu)	Barite (CaCO ₃)	Mussel Shell	Alumina (Al ₂ O ₃)	Synthetic Graphite	Friction Powder
N-1	20	10	15	30	0	5	5	15
N-2	20	10	15	25	5	5	5	15
N-3	20	10	15	20	10	5	5	15
N-4	20	10	15	10	20	5	5	15
N-5	20	10	15	0	30	5	5	15

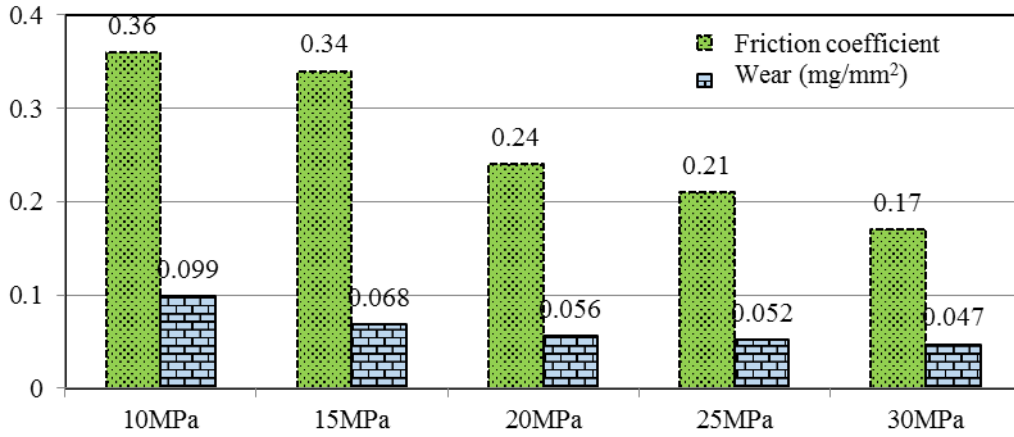


Figure 2.2: Average friction coefficients and wear losses for different cold pressing pressures.

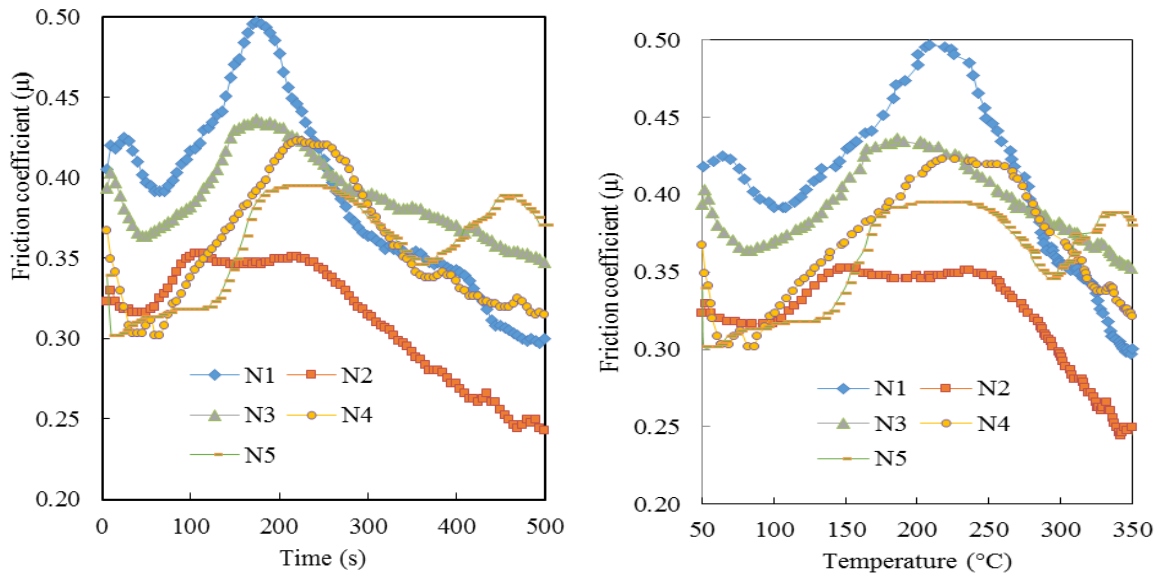


Figure 3.1: Friction coefficient versus time and temperature trends of mussel powder added samples under 1050kPa braking pressure

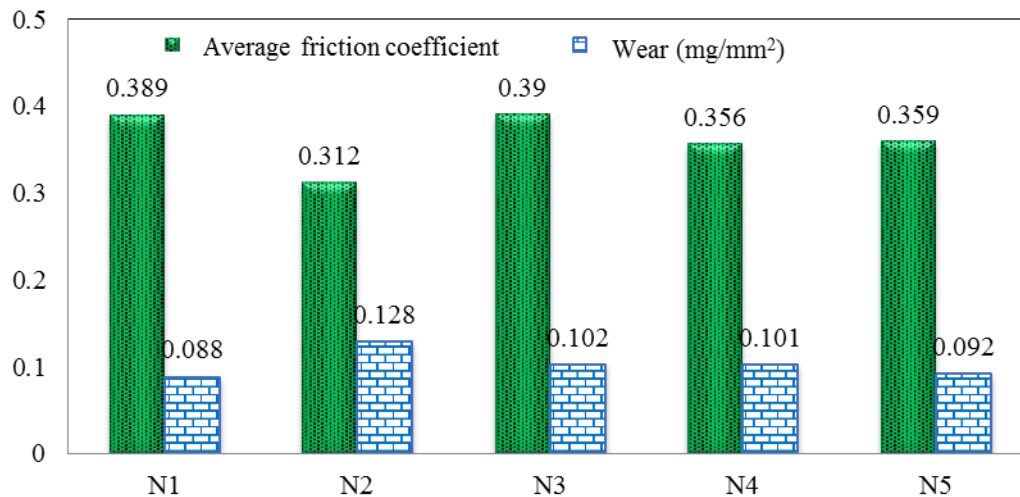


Figure 3.2: The variation of average friction coefficient and specific wear rate of mussel powder added samples.

Table 3.1: Density, hardness and wear loss values of mussel shell powder added samples.

Sample Designation	Density (kg/m ³)	Brinell Hardness (HB)	Corrosion Loss (Wt. %)
N1	1987	27.5	2.84
N2	1960	25.6	2.52
N3	1946	23.4	2.18
N4	1841	24.7	1.87
N5	1702	26.8	1.63

IV. CONCLUDING REMARKS

In this study, the usability and braking performance of brake lining samples including organic based mussel shell powder were examined. The resulting friction, wear and corrosion test results obtained are presented as follows;

- In the part of an organic composite brake pad, mussel shell powder may be used as filler material instead of barite and the highest friction coefficient was obtained as 0.39 in N-3 coded sample containing 10% w.t. mussel powder. All average coefficient of friction values were found to be in accordance with TS 555 standard.
- The high corrosion resistance with 1.23% change in mass was obtained from the sample containing 30% mussel powder. In this case, the mussel shell powder increases corrosion resistance and its corrosion limit satisfies TS 9075 standard for brake lining.
- Besides, mussel shell powder content affects hardness inversely, but this decrease was observed to be remained up to 2%. Thus, causing not considerable change, mussel shell powder can easily be implemented as a candidate of filler material in brake lining manufacture.

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