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Improving the Tribological and Tribo-Electrification Properties of Epoxy Flooring Materials

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Abstract: Metals such as iron, aluminum, copper etc. are mostly used in industrial to manufacture nearly all types of industrial and consumer products. Every year, a large amount of metal chip solid waste is produced from the manufacturing industry. As mostly renowned recycling this metal chip wastes could reinforce the economic earning and minimize the environmental effect of manufacturing. The purpose of this research is to enhance the electrostatic and frictional behavior of epoxy polymer as flooring materials for many applications such as homes, gyms, fitness centers, community centers, health clubs, schools, and universities, play areas as well as police and fire stations. We proposed the aluminum machining chip wastes to use as filling material for epoxy flooring in order to increase friction coefficient and decrease the electrostatic charge generated from friction of shoes against flooring materials. Test results showed that, in presence of shoes with hardness 65 shore A, the maximum values of friction coefficient values observed at 2% and 4% Al. powder content. The minimum electrostatic charge observed at 4 and 5% Al. content. For shoes with hardness 63 shore A, the maximum values of friction coefficient values observed at 3% and 5% Al. powder content. The charge can be reduced by adding Aluminum powder to epoxy floor by 3 and 5%. In presence of shoes with hardness 67 shore A, the maximum values of friction coefficient values observed at 3% and 5% aluminum powder content. The minimum charge observed at 3 and 4% Al. content. We can recommend using the powder of aluminum chip in epoxy polymer as fillers for enhancing the frictional and tribo-electrification properties.

Keywords: Epoxy, friction coefficient, Shore hardness, electrostatic charge, aluminum powder.

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1. Introduction

Metals are mostly used in the manufacturing industry for manufacture a wide diversity of products. In 2009, the international manufacturing industry wasted a total of 1,125.3 million metrical tons of steel [1], 42.9 million metrical tons of aluminum [2], and 18.4 million metrical tons of copper [3]. Through industrialization processes, metal chips are generated concurrently with the created geometry, parts, and components. The metal chip squandering from the manufacturing industry is respectable from both economic and environmental perspectives. Recycling this metal chips can promote the economical profit and minimize the environmental effect of the manufacturing industry. Mostly, the first point for metal chip recycling is to dismiss diverse metals from any other, so as to ameliorate the quality of recycled metals. In manufacturing, iron is the most generally used metal in the industry. Recycling of iron and other metals order dismisses the ferrous and non-ferrous metal chips first. However, there is a reduction of influential and economic technicality in dismiss these ferrous and non-ferrous metal chips to achieve the needs of the manufacturing industry.

Current manufacturing corporations each put these wastes in landfills or thrust a third party to withdrawal them away. Our stringent literature investigation establishes no publications on recycling metal chips out of a concerted hydrodynamic and electromagnetic force. The following study is a review of some relevant task from our literature investigation. Some research substantive magnetic decisiveness as a physical separation of separated particles instituted on the three-way tournament amidst attractive magnetic forces, gravitational, frictional, or inertial forces, and appealing or repulsive inter-particle forces [4, 5]. Researchers study the separation of ferromagnetic materials from blended household wastes. The ferromagnetic material primarily was ruptured with non-ferromagnetic materials, and then was undergo to a magnetic separation wherein generality of the ferrous metals is extracted [6, 7].

Researchers developed a procedure and device for crushing and dismiss scrap material. They utilized this procedure to dismiss magnetic and nonmagnetic fragments from the blended scraps by utilize multiple sets of magnetic dismiss [8]. Investigators developed a magnetic separator, whose has a tank with a pair of dual conveyor chains, spaced apart, at opposite sides of the tank. The liquid in the container flows out of the frames and ferrous particles are attracted to the magnetic bars [9]. Investigators developed a Vortex Current Separator for dismissing ferrous fine features from non-ferrous materials. They improved the vortex-current separator with different new features, such as inclusive a magnet assembly whose is metal sleeved for saving the magnets from effect by particles [10]. researchers developed a technique and device for dismiss ferrous metal particles from non-ferrous metal particles unsettled in a fluid, such as a coolant from a machining process, in which the ferrous metal particles are hold by a magnetic force extend by an array of parallel magnets organized underneath the dismiss surface [11]. Comer's style and system are for dismiss ferrous and non-ferrous particles unsettled in a fluid such as coolant, however our style is to utilize hydrodynamic force of water flows in who's the metal chips cannot hanged in the water since the metal's density is higher than that of water.

Triboelectric static charges establish up on human skin and or clothes in immediate contact with human body are highly hurtful and can make dangerous health problems, [12]. Established on the experiments carried out, it was noticed that, at dry sliding, iron nanoparticles filling into epoxy composite increased coefficient of friction with rising iron content. Voltage remarkable decreased with increasing iron content. Voltage displayed the maximum values for pure epoxy test specimens. Voltage produced from the sliding of rubber footwear specimens against epoxy floor lightly raised with increasing applied load, furthermore that generated from PVC floor showed higher values, [13, 14]. The highest value accomplishes 2400 volts. Bare foot sliding versus epoxy floor showed relatively lower voltage than that display by rubber footwear specimens, wherever the maximum value achieves 280 volts. It is clearly known that PVC floor generated lowest voltage than that displayed by 100% epoxy floor, wherever the maximum voltage did not exceed 520 volts. This noticing can assure the suitability of PVC floor to be used as indoor floor where bare foot walking is authoritative.

Experimental results display that, rubber particles remarkable increased coefficient of friction. This manner refers to the distortion of rubber through scrabbling. Pure epoxy specimens had the lowest friction coefficient value, it was 1.5 at 4 N applied load, however, epoxy filing by 10 wt. % rubber of 0.5 – 1.0 mm particle size had the maximum value, it was 2.5, [15]. The investigated material is polyester filled by different contents of recycled rubber 5, 10, 15, 20 and 25 % with different particle sizes. Experiment shows that, increases rubber content shows important increasing in friction coefficient for polyester composite. The maximum coefficient of friction was (1.75) for polyester specimens recorded at polyester specimens contain 25 % rubber. However: the minimum friction coefficient value was (0.18) noticed at pure polyester composite. Increasing particle size of rubber powder displays significant increase in wear value of polyester composite, [16].

Decreasing slip and fall accidents can be done by selecting materials of with higher coefficient of friction. It is well familiar that floors in different workplaces are predominating made from hard and smooth materials for increased strength, however rubber mat has become a common floor material due to the increased comfortable, [17 – 23]. Recycled rubber is used in floors in health clubs, gyms, community centers, fitness centers, universities, fire, and police stations and play areas as well as schools. The impact of sand particles, on the friction coefficient showed by rubber sliding versus ceramic tiles at various situation, was studied, [24]. Tests were carried out at water, dry, soap, detergent, oil, and water oil emulsion. It was noticed that, at dry sliding, dust particles caused excessive reduction in friction coefficient. In this state, it is recommended to utilize rounded protrusion in the rubber surface. In the presence of sand, dust particles instill in rubber surface this action related to increased friction coefficient. The results show, wet square protrusions are bespoken to have comparatively higher friction coefficient values. At surfaces lubricated by soap diluted by water, smooth rubber embedded by sand particles accord higher friction compared with protruded rubber surface; however, sand particles embedded in rubber surface lubricated by oil display higher coefficient of friction values. Many studies have been investigated for improving the tribological and tribo-electrification properties of epoxy flooring materials, [25-28]

The present research aims to reuse the machining aluminum chip for improve the frictional properties and reduce the electrostatic charge of epoxy as used a flooring material for different applications.

2. Experimental Work

The (Ultra Stable Surface Voltmeter) was used to measure the electric static charge (electric static filed) after contact and separation of the specimens against rubber to measure the generated charge under applied loads, **Fig. 1**. It measures down to scale 0.1 volt on a surface, and up to 20 kV. Measuring values (Volts) are normally done with the sensor 25 mm from the surface of specimens being tested.

Friction coefficient tests were carried out by using a device designed and implementation to measure the friction coefficient between the test specimens and the surface of tested flooring tiles through determine the friction force and normal load.

Fig. 1 Electric static charge (voltage) measuring device.

The tested flooring surface is placed in a base connected with two load cells, the first one measures the horizontal force (friction force) and the second measures the vertical force (normal load). Friction coefficient is computed by the ratio between the friction and the normal forces. The test rig is shown in **Fig. 2**

Test specimens in a shape of a layer of 150 × 150 mm^2 molded on wooden block. The proposed tested materials where epoxy contain different contents of aluminum powder with 3-micron particle size, was mixed with epoxy resin with various content 1, 2, 3, 4 and 5 %. The Friction experiments were carried out at different values of normal load. The sliding condition measure by use the rubber specimens with hardness 63, 65 and 67 shore" A" hardness. The friction force measure from load cell and the normal load measure by variable weight. The rubber shoes specimens used in experimental was shown in **Fig. 3**. Epoxy resin mixed with aluminum powder the mold on wooden block, **Fig. 4**.

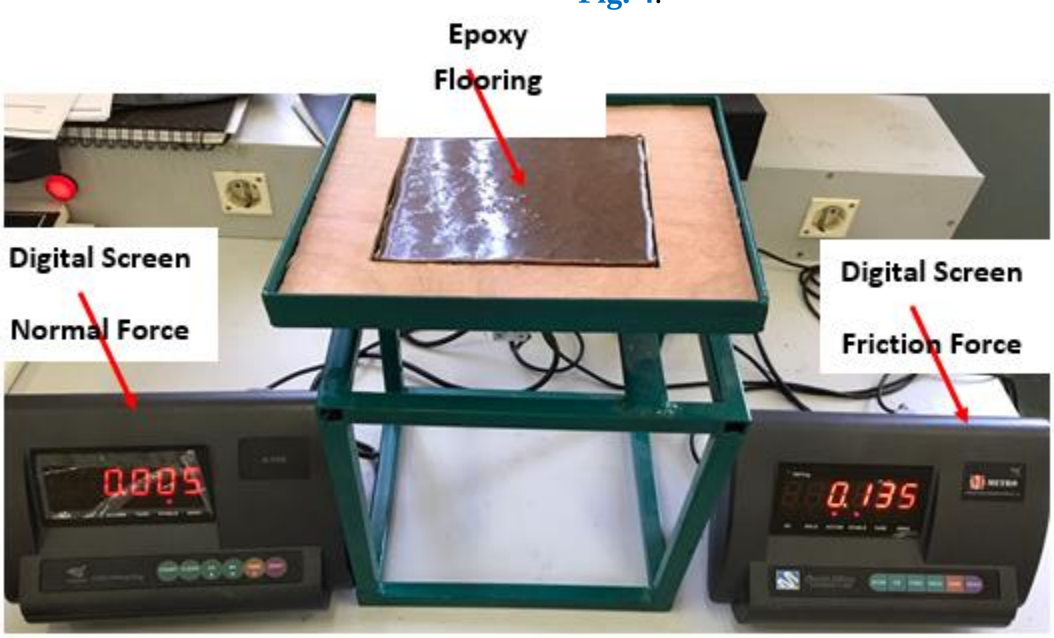

Fig. 2 Friction tester

Fig. 3. Tested rubber shoes.

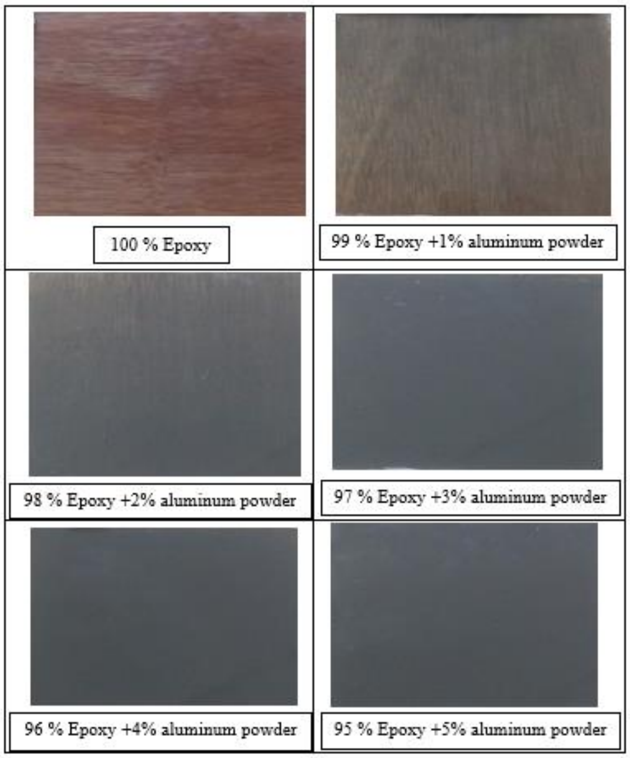

Fig. 4 Specimens of epoxy filled with aluminum powder.

3. Results and Discussion

Coefficient of friction of epoxy flooring material filled by powder of aluminum chip is display in Fig. 5. Friction coefficient slightly increases with increasing aluminum powder content. Increase the hardness value of rubber shoes show decreasing in friction value compared to the lower hardness specimens. The minimum friction coefficient was observed for 100% epoxy specimens. Increasing aluminum powder content up to 3% show remarkable effect in increasing friction coefficient.

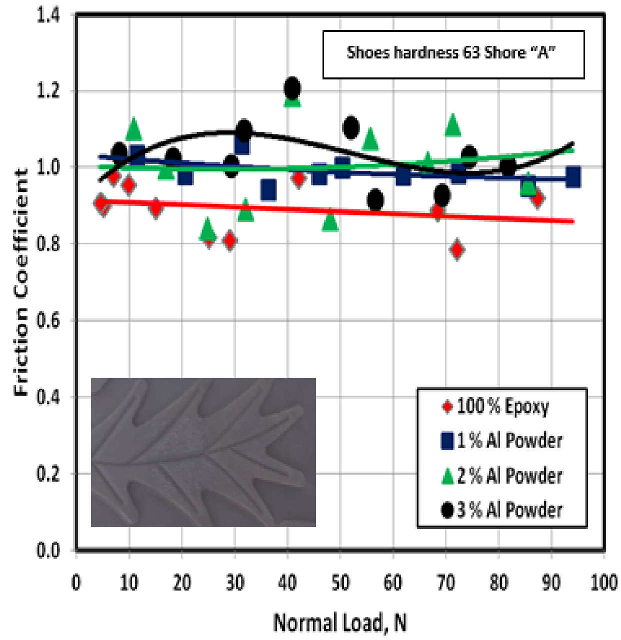

Fig. 5 The relation between friction coefficient and normal load of rubber shoes with Hardness 63 shore A sliding against dry epoxy specimens filled with aluminum powder.

Figure 6 show the relation between friction coefficient and normal load, for epoxy flooring test specimens contain powder of aluminum chip. It can be noticed that the friction coefficient decreases with increasing normal load. The same behavior was shown at 4% and 5% powder of aluminum content. The friction coefficient increases with increasing powder of aluminum content. The minimum values of friction coefficient displayed at 100% epoxy specimens. Figure 7 show the relation between friction coefficient and normal load, for epoxy contain powder of aluminum chip. It can be noticed that the friction coefficient increases with increasing aluminum powder content up to 2%. This behavior may be closed on increase the adhesion between rubber test specimens and aluminum powder.

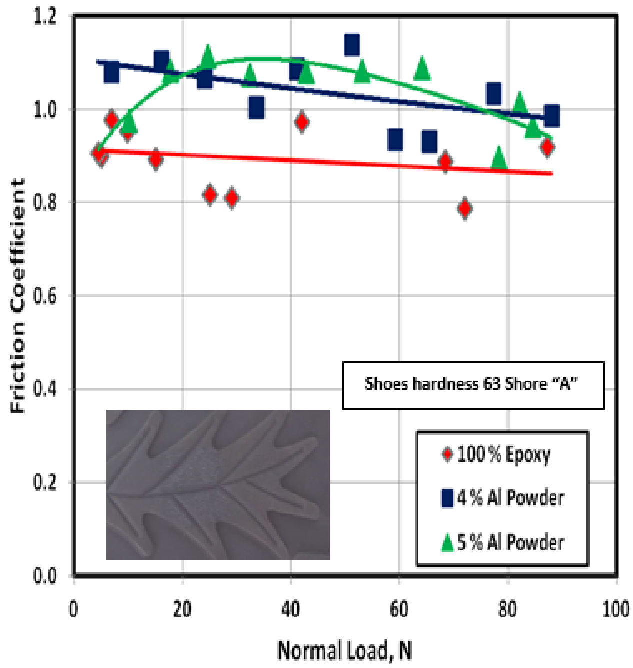

Fig. 6 The relation between friction coefficient and normal load of rubber shoes with Hardness 63 shore A sliding against dry epoxy specimens filled with aluminum powder

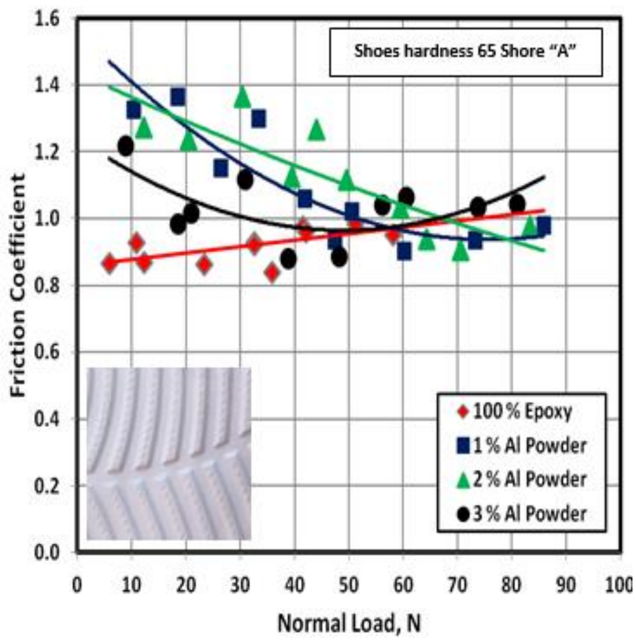

Fig. 7 The relation between friction coefficient and normal load of rubber shoes with Hardness 65 shore A sliding against dry epoxy specimens filled with aluminum powder

Friction coefficient decreases with increasing normal load, this result related to the shear strength of rubber shoes which decrease with increasing normal load. The minimum friction coefficient was observed at 100% epoxy flooring. The maximum friction coefficient was showed at 2 % aluminum powder.

Increase powder of aluminum chip content in epoxy flooring is shown in Fig. 8. Coefficient of friction shows slightly increase with increasing Al. powder content. Friction coefficient decreased with increasing applied normal load. This observation related to decrease the deformation of tested rubber shoes and decrease the shear strength. Minimum values of coefficient of friction t were observed for 100% epoxy flooring.

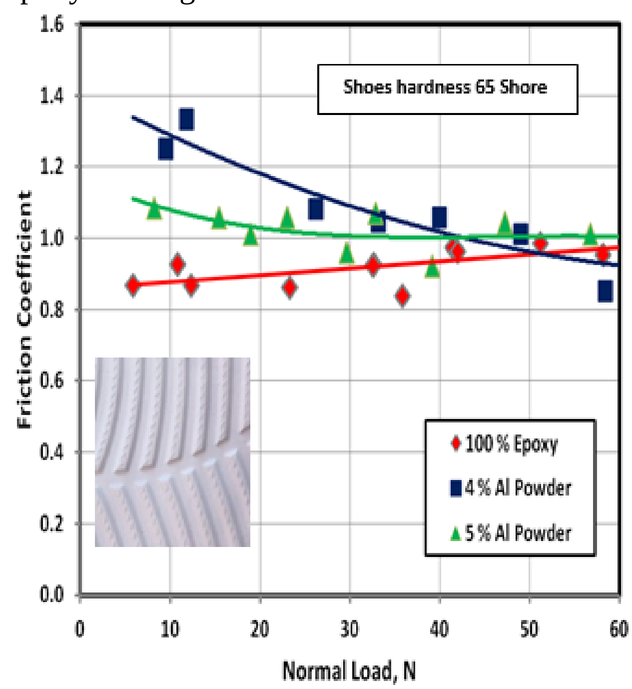

Fig. 8 The relation between friction coefficient and normal load of rubber shoes with Hardness 65 shore A sliding against dry epoxy specimens filled with aluminum powder

Coefficient of Friction of rubber tested shoes sliding against epoxy flooring test specimens filled by powder of aluminum chip is display in Fig. 9. Coefficient of friction normally increased with increasing powder of aluminum chip content. This behavior may be closed on aluminum powder is very smooth and not stick with shoes. The maximum value of coefficient of friction was observed at specimens of epoxy filled by 1% aluminum. The minimum value of friction coefficient was observed at 100% epoxy flooring material.

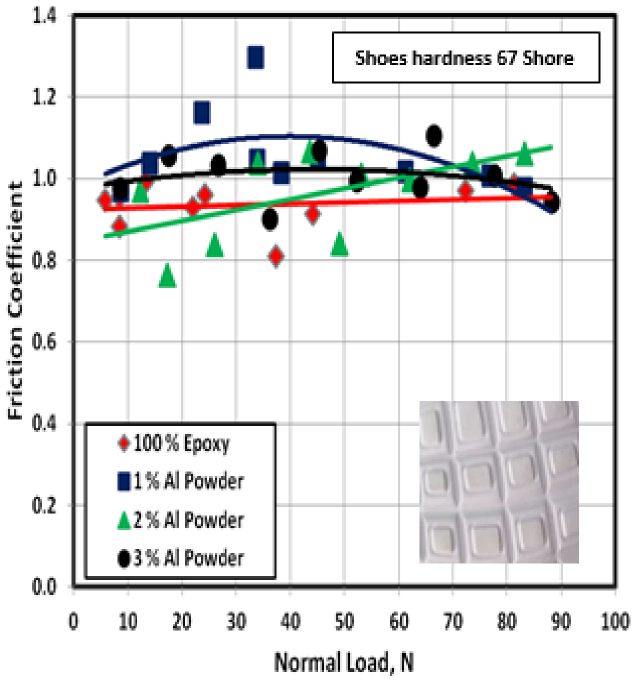

Fig. 9 The relation between friction coefficient and normal load of rubber shoes with Hardness 67 shore A sliding against water epoxy specimens filled with aluminum

Figure 10 show the relation between friction coefficient and normal load, for flooring epoxy test specimens at 4% and 5% Al. powder content. It can be noticed that the coefficient of friction increases with increasing Al. powder content. Increase Al. powder content to 5% show slightly increasing in friction value. The lower value of friction coefficient was noticed at 100% epoxy specimens.

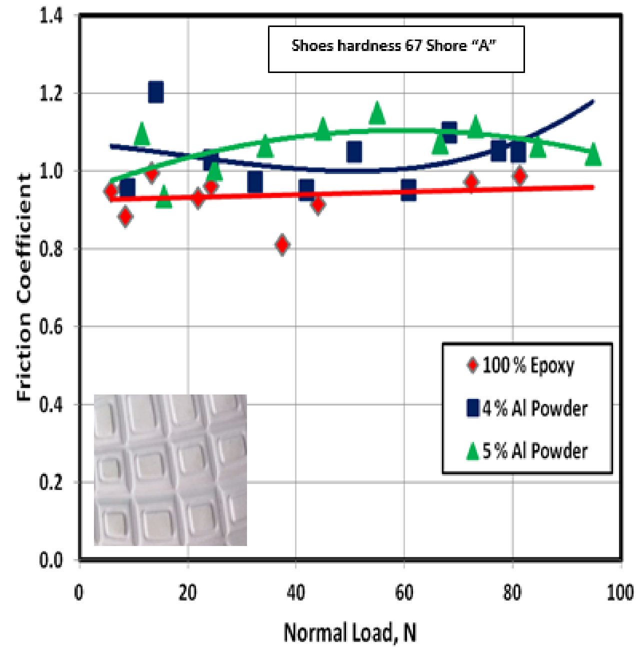

Fig. 10 The relation between friction coefficient and normal load of rubber shoes with Hardness 67 shore A sliding against water epoxy specimens filled with aluminum

Electrostatic charge of epoxy flooring material filled by aluminum chip powder is shown in **Fig. 11**. Electrostatic charge reduces with increasing Al. powder content. Increase Al. powder content show significant effect in decreasing this charge. Increase the value of hardness for rubber shoes show slightly increasing in electrostatic charge values. The maximum values of electrostatic charge were observed for 100% epoxy specimens.

Figure 12 show the relation between electrostatic charge and friction coefficient, for tested epoxy specimens filled by powder of aluminum chip. It can be noticed that the static charge decreases to minimum values at 5% Al. powder. Aluminum powder help to disposal charge to ground. This observation related to good conductive properties of aluminum powder.

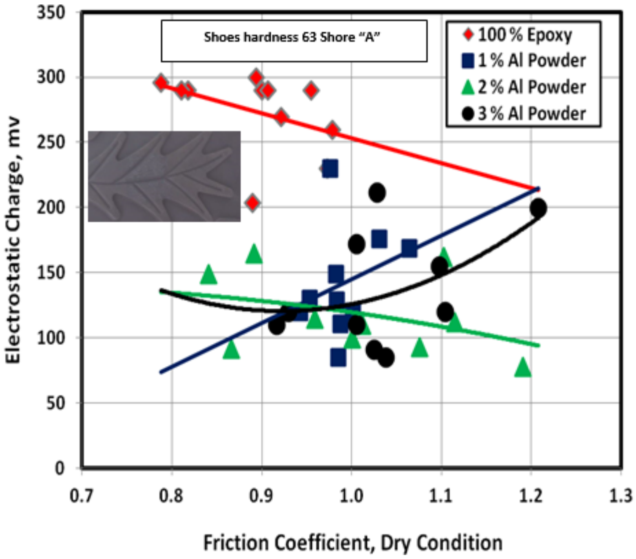

Fig. 11 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 63 shore A sliding against water epoxy test specimens filled with aluminum powder

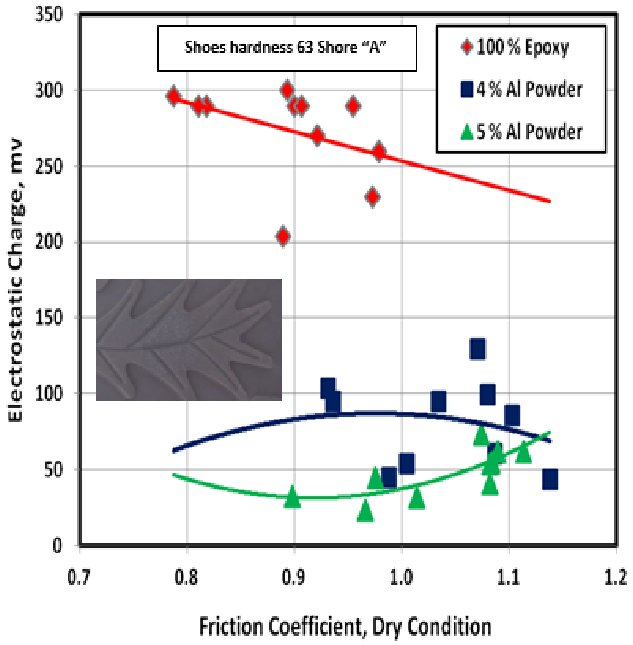

Fig. 12 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 63 shore A sliding against water epoxy test specimens filled with aluminum powder

Figure 13 show the relation between electrostatic charge and friction coefficient, for epoxy filled by aluminum chip powder. It can be noticed that the electrostatic charge reduces with increasing Al. powder content. This behavior may be related to good electrical properties of aluminum and disposal the charge to ground. Electrostatic charge decreased with increasing friction coefficient. The maximum value of electrostatic charge was observed at 100 % epoxy flooring. The lower value of electrostatic charge was observed at 3 % aluminum powder. Increase powder of aluminum chip content in epoxy flooring is display in **Fig. 14**. Electrostatic charge recorded other decrease with increasing Al. powder content. This observation related to increase the ability of flooring material to disposal the electrostatic charge. Aluminum powder plays important role for disposal this charge. Minimum values of electrostatic charge were observed for epoxy flooring filled 5% aluminum powder.

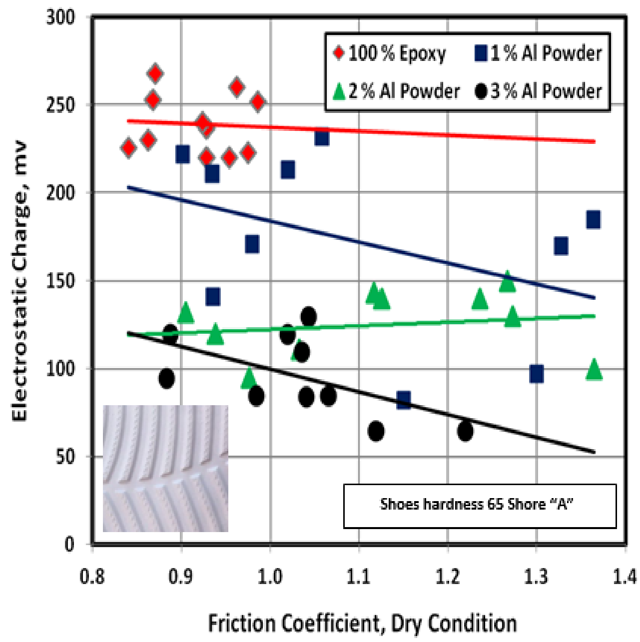

Fig. 13 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 65 shore A sliding against water epoxy test specimens filled with aluminum powder

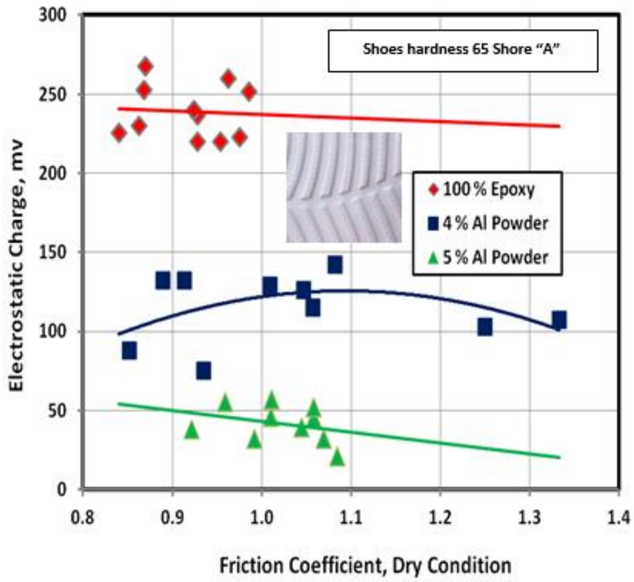

Fig. 14 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 65 shore A sliding against water epoxy test specimens filled with aluminum powder

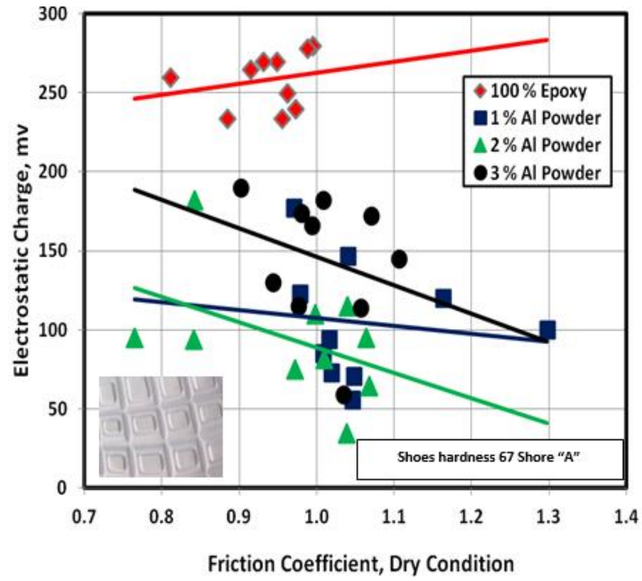

Fig. 15 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 67 shore A sliding against water epoxy test specimens filled with aluminum powder

Electrostatic charge of tested rubber shoes sliding against epoxy flooring test specimens filled by aluminum chip powder is shown in **Fig. 15**. Electrostatic charge decreased with increasing powder of aluminum chip content. This behavior may be related to increase aluminum content disposal from this charge to ground. The higher value of electrostatic charge was observed at specimens of pure epoxy. The minimum value of electrostatic charge was observed at epoxy floor contain 2% aluminum powder. **Figure 16** show the relation between electrostatic charge and friction coefficient, for epoxy flooring test specimens at 4% and 5% Al. powder. It can be noticed that the electrostatic charge increases with increasing Al. powder content. Increase Al. powder content to 5% show reduction in charge value. This observation related to the significant effect of aluminum powder for disposal this charge. The best result was recorded at epoxy floor filled by 5% Al. powder.

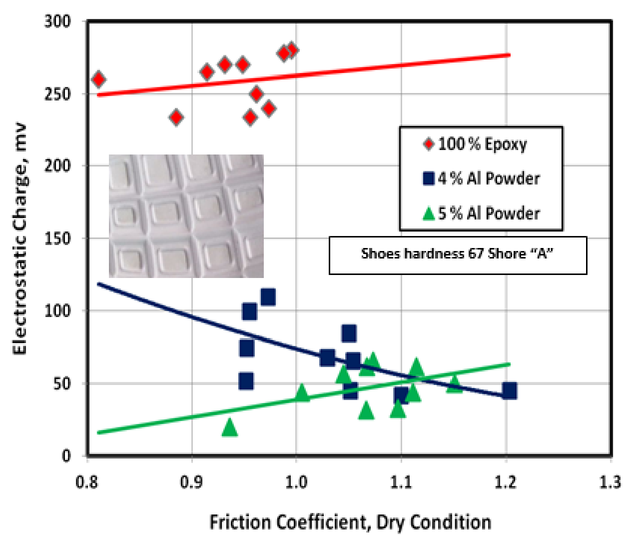

Fig. 16 The relation between electrostatic charge and friction coefficient of rubber shoes with Hardness 65 shore A sliding against water epoxy test specimens filled with aluminum powder

4 Conclusions

1. In presence of rubber shoes with hardness 65 shore A, the maximum values of friction

coefficient values recorded at 2% and 4% Al. powder content. The minimum electrostatic charge observed at 4 and 5% Al. content

2. For rubber shoes 63 hardness shore A, the maximum values of friction coefficient values recorded at 3% and 5% Al. powder content. The charge can be reduced by adding Aluminum powder to epoxy floor by 3 and 5%.

3. In presence of rubber shoes with hardness 67 shore A, the maximum coefficient of friction values observed at 3% and 5% aluminum powder content. The minimum charge observed at 3 and 4% Al. content.

4. We can recommend using the powder of aluminum chip as filling material for epoxy floor to enhancing the frictional and tribo-electrification properties.

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