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ENHANCING THE SAFETY OF EPOXY FLOOR MATERIALS BY USING COPPER CHIP

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ABSTRACT

The present study is part of wide research project conducted by authors, whose overarching purpose is to develop design recommendations for epoxy floor materials regarding friction requirements and slip resistance based on friction measurements and avoid danger of electro-static charge generating during walking.

The epoxy test specimens in a form of a tile of 150 × 150 mm^2 prepared by mixing copper chip with epoxy resin then poured on wooden block. The tested materials were epoxy filled by different contents of copper chip with 5 micron particle size. The copper chip was added to epoxy with different content 1, 2, 3, 4 and 5 wt. %. The Friction test was carried out at different values of normal load, for covering the light and heavy loads for persons. The sliding behavior measure by use the rubber shoes with 63, 65 and 67 shore A hardness. Static friction coefficient was measured at the start of sliding.

Test results showed that, the epoxy filled by copper chip show remarkable increases in friction coefficient and reduces electrostatic charge accumulated on contact surface. At water sliding conditions, the water helps for release of the electrostatic charge out of contact surfaces. Thus, the value of electrostatic charge reduces in water wet condition. The friction coefficient increase with adding copper chip to epoxy resin in all types of rubber shoes. Adding copper chip to epoxy resin as floor materials show significant reduction in electrostatic charge generated from sliding of rubber shoes against epoxy floor materials.

KEYWORDS

Epoxy, Static friction coefficient, Electrostatic charge, Water, Copper chip.

INTRODUCTION

In recent years, numerous industries are increasingly using polymers as substitutes for metals because of the several benefits for various applications they offering. Polymers are cheap, light, and non-toxic, and they easy to manufacture, are resist corrosion, and extend outstanding design flexibility, [1, 2]. A polymer material with motivating engineering applications is the epoxy based thermosetting resin (epoxy thermoset), which can be applied as a matrix in an enormous range of high-special composites because its high stiffness; resistance to heat, chemicals, and creep; huge adhesion; easiness of processing; and insulation attributes, [3].

Nearly one third of all earnest work accidents are falls, both indoors and outdoors caused by workers tripping, slipping or for some other cause losing their balance. Researches have shown that slip and fall accidents are more widespread through winter months and cool

conditions, [4-6]. In a study through outdoor workers in northern Sweden fall proceedings were reported to occur most repeatedly on icy surfaces also enveloped with snow, [7].

Also in the United Kingdom slip and trip accidents are the major cause of occupational injury (HSE, 2013a). Within the makeup industry, slip, trip and fall accidents are widespread, and inadequate or worn-down footwear has been specified as one of the opener risk factors, [8]. Other profession uncovered to elevation risks for falls is post transmission workers. Slippery aground conditions and indigent slip resistance from footwear were considered as the plumber risk-factors for slips through posts delivery workers in United Kingdom, [9].
Within healthcare falls are also major causes of occupational injury however the risk factors of falls in this section have only newly been advised. A high risk for falls has been reported for society health workers and these falls predominantly occurred outside, in patients' rooms and cookery. Slippery surfaces due to liquid contaminants or icy conditions were a prime contributing agent and the falls were more repeated through the colder months (January to March), [10]. Injuries correlating with occupational falls reason both personage hardship as well as increased costs for employers and organization. Popular injuries recorded by AFA (2011) are forearm and lower leg fractures and half of the injuries command to medical incompetence. These injuries are connected with a major risk of long period sick holiday, mostly when they come in higher ages. Effective preventative measures are thus guaranteed.

The danger of a slip or a fall circulating is not just a result of the coefficient of friction amidst the shoe and the underfoot surface however also subsidiary on the individual's capability to set for the imbalance. A range of human factors affecting balance control in relation to a slip, such as anticipation of slipperiness and gait adaptation, have been summarized by, [11]. There are studies investigated that gait kinematics play an important role in the severity of an ensuing slip, [12, 13]. Especially strategies including movement in the ankle joint looks to be significance, [14, 15]. Characteristics of the shoes that affect ankle mobility may therefore be supposed to affect balance control. In addition, shoe requirements may change depending on individual physical prerequisites, job task and environmental circumstances. All of these aspects need to be considered for optimal balance control. At the same time other factors such as safety, usability, comfort and individual priorities should be borne in mind.

The propensity for amnesty floor encasement to electrically charge can have consequences for the employer. A charge can construct, when an insulating material, such as insulating floor, comes into touch to another material, such as footwear, [16]. For human beings the starting of feeling is nearly 2 kV of body voltage when touching grounded objects. According to that, practical solutions for antistatic laminate floor encasement have been found by manufacturers of amnesty floor coverings strive to be able to advertise products as "antistatic", defined in EN 14041. This standard is based on measurements of a bodies' voltage, according to the new EN 1815.The material integration of footwear and floor surface is the definitive factor for the polarity and the grade of charge build-up when walking on floor concealment (Fig. 1). The melamine resin used to pollinate the covering, and the corundum integrated to progress abrasion resistance are lock to the positive ending of the tribo-electric series. This is because forgive overlay have a high charge build-up tendency against soles made of rubber and PVC negative end. In addition to the chemical composing of the surface coating, its electrical surface resistance is important parameter of the floor. The transported material may have an effect over its volume resistance. A person's walk, the rapidity, and the humidity of the ambient air influence the grade of charge build-up. A faster walk and shuffling movements concentrate charge build-up. Moreover, the entourage material has an effect as well, acting as an insulator and vapor partition. Static dissipative substrates expedite the redirection of the charges. An insulating

entourage may even reason additional charge build-up on the underside of the floor coverage, due to trembling.

Measurements of the static coefficient of friction between rubber specimens and ceramic surfaces were done at dry, water lubricated, oil diluted by water, oil and sand contaminating the lubricating fluids, [17-19]. It was obtained that, dry sliding of the rubber test samples showed the higher value of coefficient of friction. For wet lubricated ceramics, the value of the coefficient of friction reduced compared to dry sliding. For ceramic lubricated by oil, friction coefficient reduced with increasing length of the grooves comes in the rubber specimens. Besides, diluting oil by water showed values of friction coefficient much lower than that spotted for oil lubricated condition. As for ceramic covered by water and soap and contaminated by sand, coefficient of friction show remarkable increase compared to the sliding case, of water and soap only. In the existence of oil and sand on the sliding surface, the friction coefficient lightly increased. This attitude may be occasion by sand embedment in rubber surface and consequently the contact became amidst sand and ceramic. At lubricated sliding surface by water and oil dirty by sand, the friction coefficient showed higher value than that of sand and oil sliding conditions.

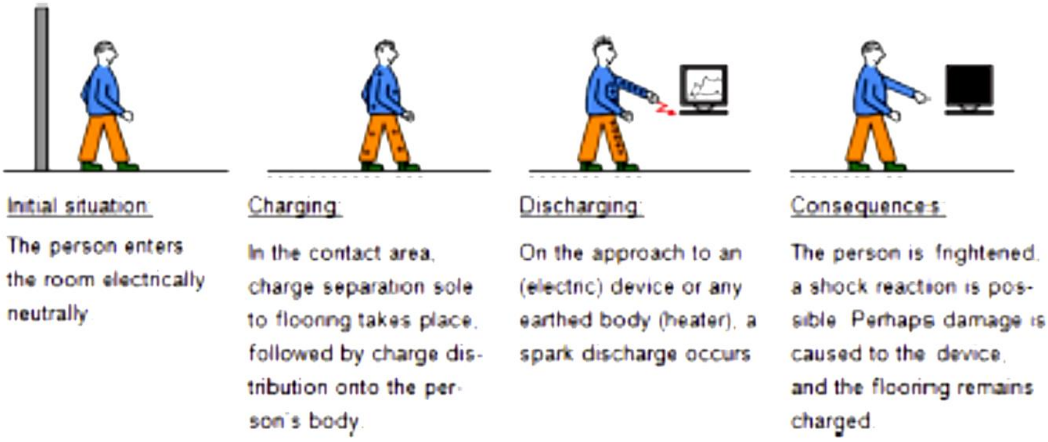


Fig. 1 Schematic illustration of human charging when walking on flooring and spark discharge to grounded device.

The present research aims to develop design recommendations for epoxy floor materials regarding friction requirements and slip resistance based on friction measurements, beside avoid dangerous of electro static charge generating during walking.

EXPERIMENTAL

The electrostatic Voltage measuring by device Ultra Stable Surface DC Voltmeter was used to measure the electrostatic charge generated from sliding rubber shoes test specimens against surface of epoxy filled by copper particles, Fig. 2.

Fig. 2 Electric static charge (voltage) measuring device.

Friction coefficient displayed by the sliding of the tested shoes on epoxy surface was determined by using test rig designed and manufactured for that purpose through measuring the friction force and applied normal force. The epoxy surface in form of a tile (150 × 150 mm^2) was placed in a base supported by two load cells to measure both the horizontal force (friction force) and vertical force (applied load). The ratio between the friction force and the normal load is used to determine the coefficient of friction. The details of the test rig are shown in Fig. 3.

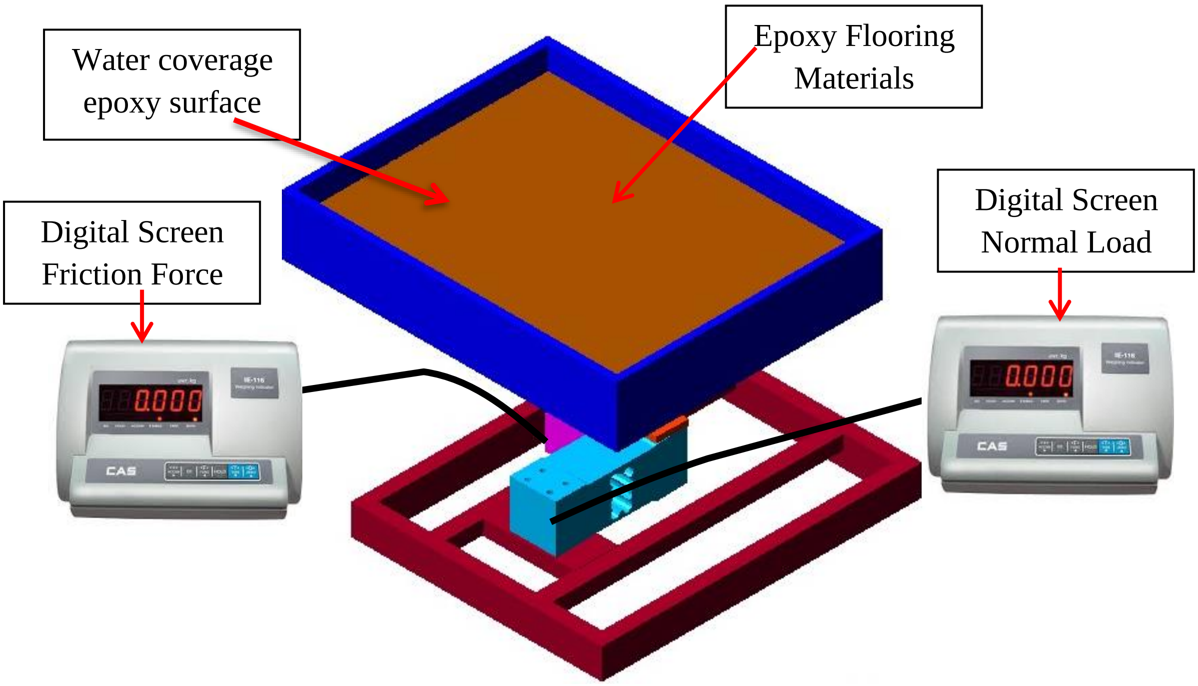


Fig. 3 Details of friction tester.

The test specimens prepared by mixing the chip of copper with epoxy resin then molded on wooden block in a form of a tile of 150 × 150 mm^2. The electro-scanning microscope for epoxy test specimens was shown in Fig 4. The copper chip with 5 micron particle size was added to epoxy with different content 1, 2, 3, 4 and 5 wt. %. The test specimen's preparation was shown in Fig. 5. The Friction test was done under different values of applied load, for covering the light and heavy loads. The sliding modes measured by use the rubber shoes with 63, 65 and 67 shore" A" hardness. The tested rubber shoes used in experimental were shown in Fig. 6. The water was applied on epoxy surface by 5 ml. Water found over the surface of epoxy filled by copper chip, show Fig. 7.

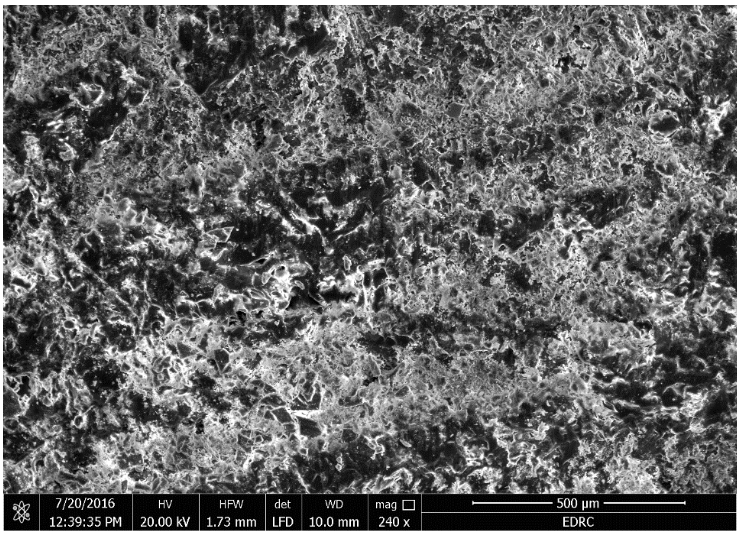
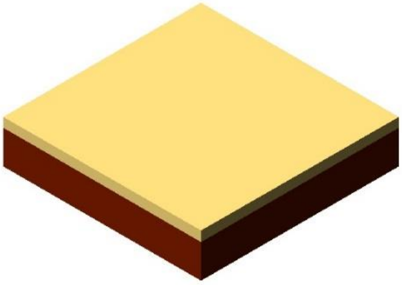
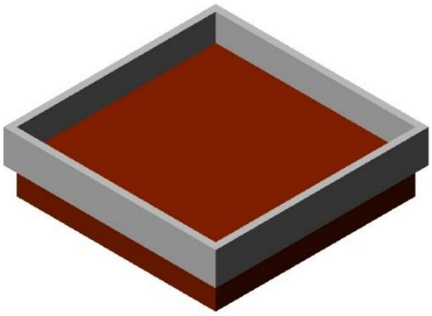


Fig. 4 The electro-scanning microscope for epoxy test specimens.

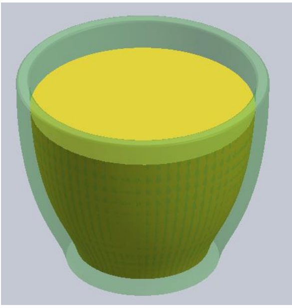


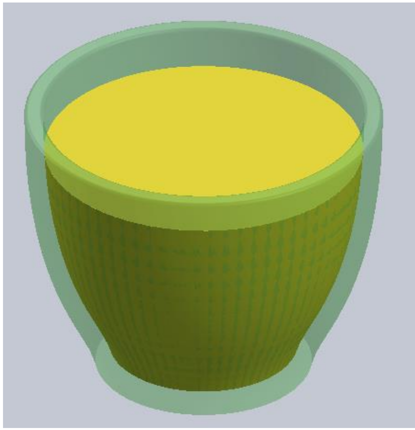


Epoxy Specimens

Die

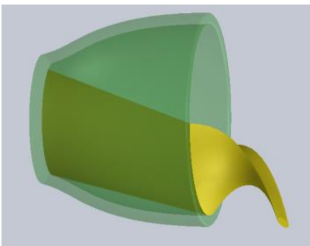
Copper Chip

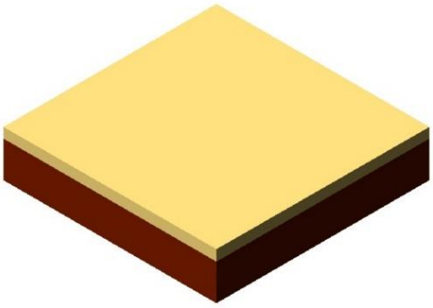


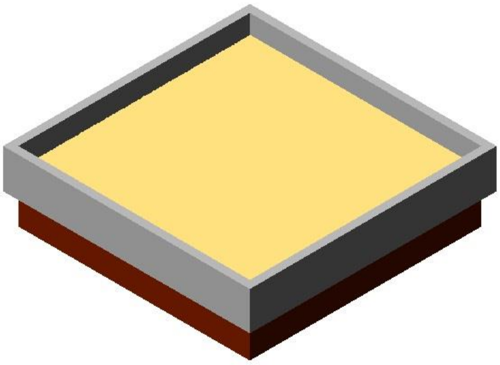


Epoxy

Mixing the mixture







Final shape of test specimens

Pouring the mixture in the die

Fig. 5 Preparation of test specimens.

Fig. 6. Tested Rubber shoes.

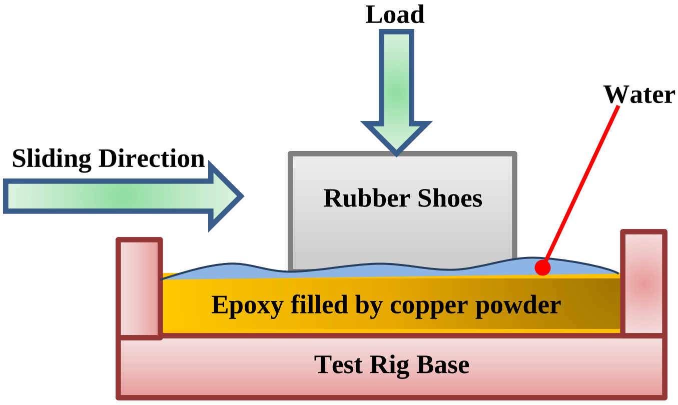


Fig. 7 Illustration of the tested rubber shoes sliding against epoxy surface filled by copper powder in water sliding conditions.

RESULTS AN D DISCUSSION

Coefficient of friction for rubber shoes sliding against wet epoxy test specimens filled by copper chip was shown in Fig. 8. Coefficient of friction increases with increasing copper chip content up to 1 wt. %. This observation may be related to increase the adhesion between rubber shoes and sliding surface. Increase deformation of rubber shoes play important role in increasing friction coefficient. The higher value of coefficient of friction was observed at epoxy specimens filled by 1 wt. % copper chip. The lowest value of friction was observed at 100 wt. % epoxy specimens. Figure 9 shows the relation between coefficient of friction and applied load, for epoxy floor materials at 4 wt. % and 5 wt. % copper chip content. It can be observed that the coefficient of friction increase at 4 wt. % copper chip content. Friction coefficient show significant increase for epoxy floor contain 4 wt. % copper chip. This observation related to easy escape of water from contact area. The lowest value of coefficient of friction was noticed at pure epoxy specimens.

Figure 10 shows the relation between coefficient of friction and applied load, for wet epoxy surface filled with copper chip. It can be observed that the friction coefficient increases with increasing copper chip content. This result may be due to increase the ability of water to escape from contact area. Coefficient of friction decrease with increasing normal load, this observation related to detention of water in contact area. The lowest value of coefficient of friction was observed at pure epoxy floor. The higher values of friction coefficient were investigated at 3 wt. % copper chip. Increase chip of copper chip content in wet epoxy surface is shown in Fig. 11. Friction coefficient shows increase with increasing copper chip content. Coefficient of friction decreases with increasing normal load. This observation related to trapped of water in contact area during sliding, this behavior decreases the contact between the contact surfaces. Minimum values of coefficient of friction were noticed at pure epoxy floor. Increasing copper chip content to 4 and 5 wt. % show remarkable effect on friction values compared to pure specimens (100 wt. % epoxy).

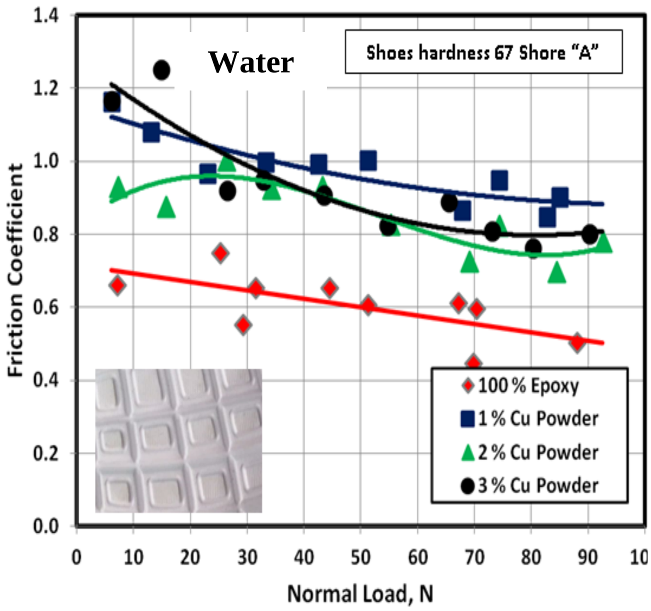


Fig. 8 Friction coefficient of rubber shoes with Hardness 67 shore A, sliding against wet epoxy floor filled by copper chip.

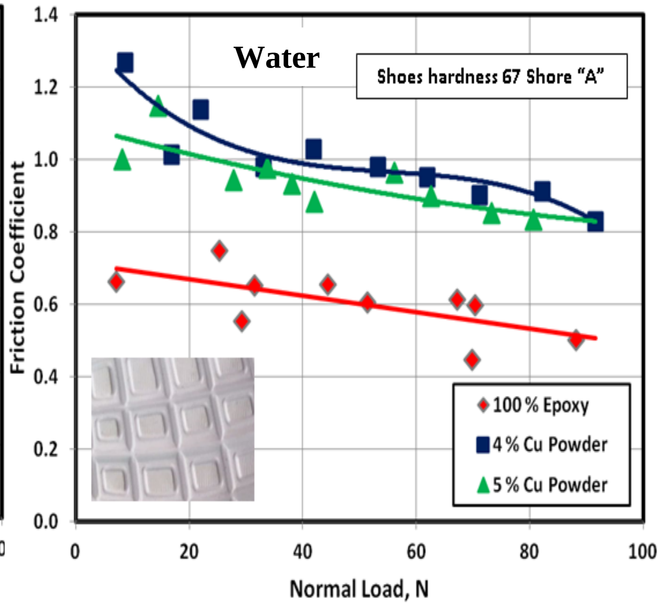


Fig. 9 Friction coefficient of rubber shoes with Hardness 67 shore A, sliding against wet epoxy floor filled by copper chip.

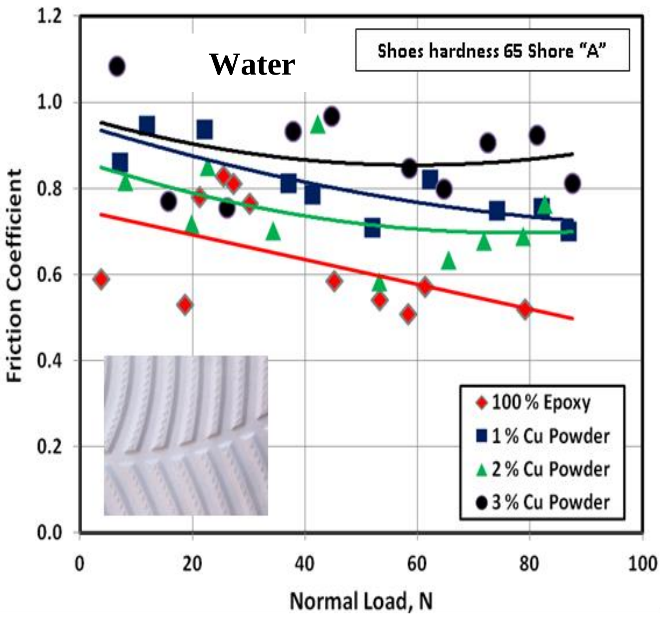


Fig. 10 Friction coefficient of rubber shoes with Hardness 65 shore A, sliding against wet epoxy floor filled by copper chip.

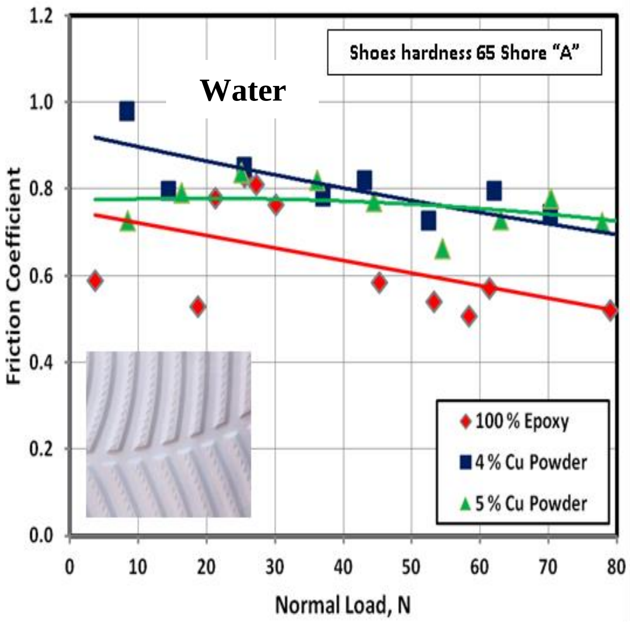


Fig. 11 Friction coefficient of rubber shoes with Hardness 65 shore A, sliding against wet epoxy floor filled by copper chip.

Coefficient of friction for epoxy specimens filled with chip of copper chip is shown in Fig. 12. Coefficient of friction decrease with increasing applied load. Increase copper chip show remarkable effect in increasing Coefficient of friction. Increase hardness of rubber specimens show reducing in friction value compared to the previous shoes. This behavior related to the fact of friction coefficient for polymers depends on the deformation of rubber shoes on floor surface. The lowest values of coefficient of friction were observed for pure epoxy specimens. Increasing copper chip content show more effect in increasing friction coefficient. Figure 13 shows the relation between friction coefficient and applied load, for epoxy surface filled by copper chip. It can be observed that the same behavior observed at Fig.10. Increase copper content up to 4wt. % show remarkable effect on increasing friction coefficient. This observation related to increase adhesion between rubber and copper particles in epoxy floor. Increasing copper chip content to 5wt. % show slightly decreases in

friction values compared to 4wt. %. The lowest values of coefficient of friction shows at 100wt. % epoxy test specimens.

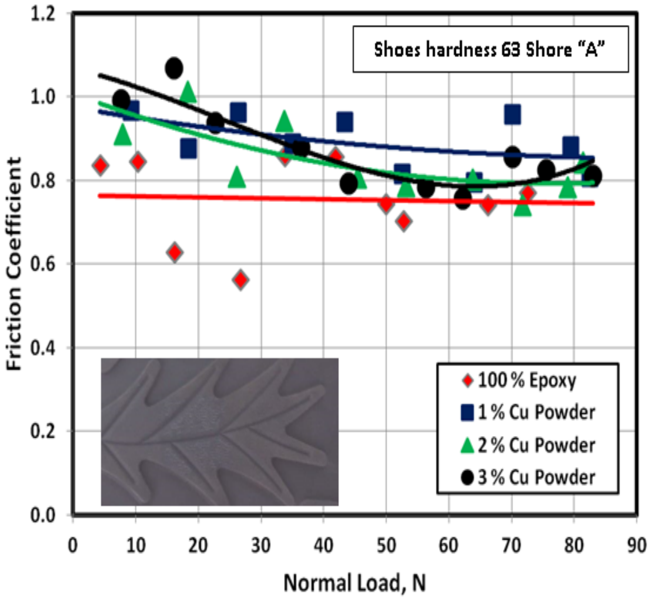


Fig. 12 Friction coefficient of rubber shoes with Hardness 63 shore A, sliding against wet epoxy floor filled by copper chip.

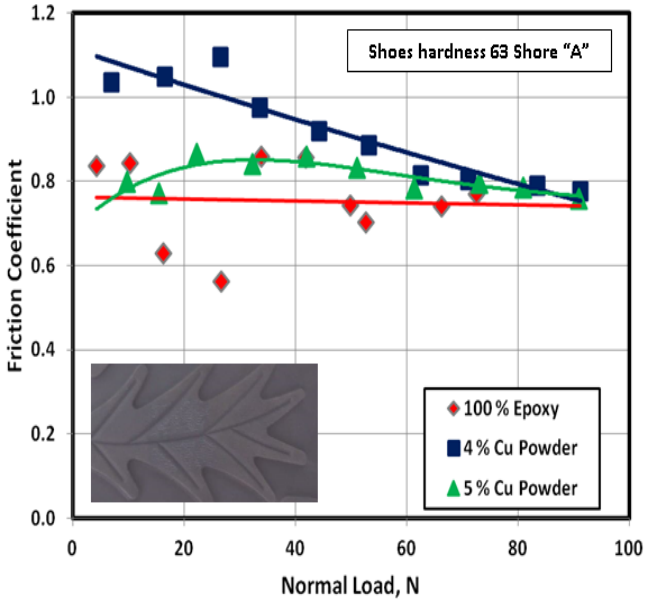


Fig. 13 Friction coefficient of rubber shoes with Hardness 63 shore A, sliding against wet epoxy floor filled by copper chip.

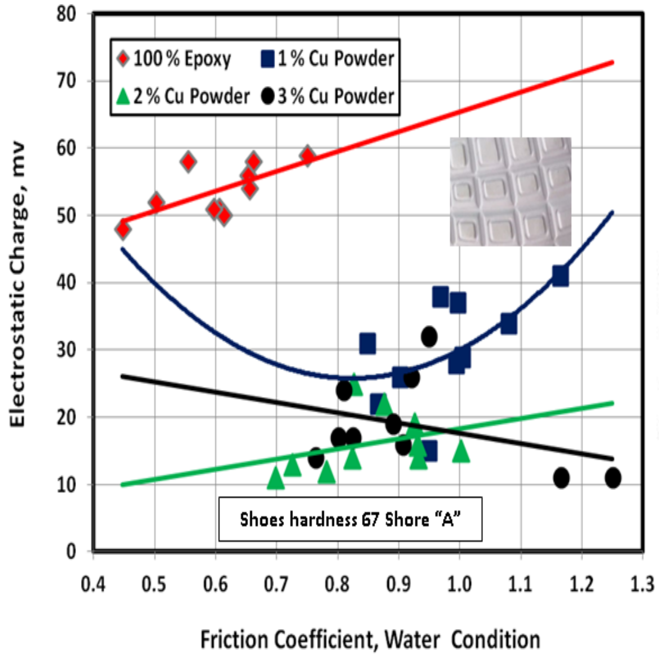


Fig. 14 Electrostatic charge of rubber shoes with Hardness 67 shore A, sliding against wet epoxy floor filled by copper powder.

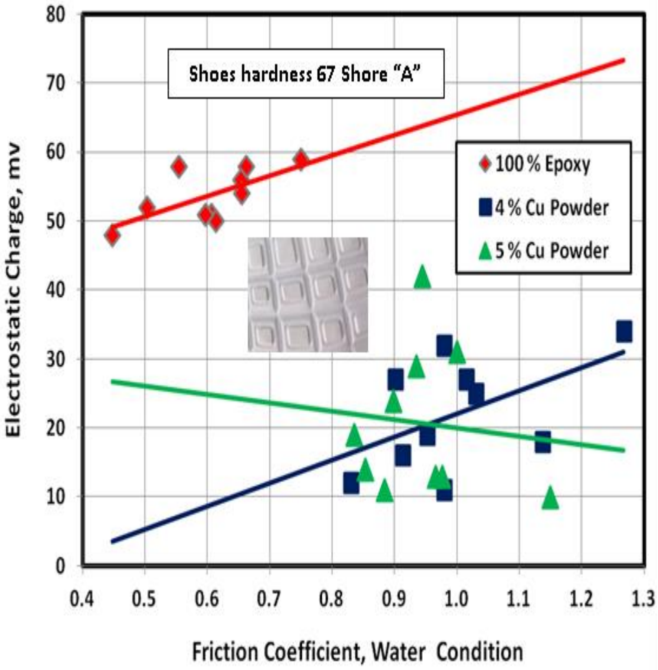


Fig. 15 Electrostatic charge of rubber shoes with Hardness 67 shore A, sliding against wet epoxy floor filled by copper powder.

Figure 14 shows the electrostatic charge of rubber specimens with hardness 67 Shore A, sliding against epoxy test specimens filled by copper chip. 14. Electrostatic charge reduces with increasing content of copper chip. This observation may be related to found of copper chip in epoxy resin increase the ability of floor to disposal from this charge. The highest value of electrostatic charge was noticed at epoxy floor without any additives. The lowest results of electrostatic charge were noticed at epoxy specimens contain 2 wt. % copper chip. Figure 15 show the results between electrostatic charge and coefficient of friction, for epoxy specimens contain 4 wt. % and 5 wt. % copper chip. It can be investigated that the electrostatic charge decrease with increasing copper chip content. Increase copper content to 4 wt. % shows significant reduction in electrostatic values. This behavior related to the water distributed the charge on surface of floor and copper particles disposal from this charge to ground. The highest value of electrostatic charge was noticed at pure epoxy specimens. The lowest values of charge observed at epoxy floor contain 4wt. % copper chip at low friction coefficient.

Figure 16 shows the results between electrostatic charge and coefficient of friction, for epoxy specimens filled by copper chip. It can be observed that the electrostatic charge decrease with increasing Cu. chip. This results may be related to increase the ability of floor for disposal from electrostatic charge through copper particles to ground. The maximum electrostatic charge value was observed at pure epoxy floor. The minimum static charge was noticed at 1 wt. % copper chip. Increase chip of copper chip for epoxy specimens is shown in Fig. 17. Electrostatic charge shows other decreases with increasing copper chip content. Electrostatic charge increases with increasing coefficient of friction. This observation related to the fact of electrostatic charge more depends on friction between two bodies. Higher values of electrostatic charge were noticed at pure epoxy specimens. The recommendation content for reducing electrostatic charge in presence of water on sliding surface is epoxy floor contain 5wt. % copper chip, for rubber shoes with hardness 65 Shore A.

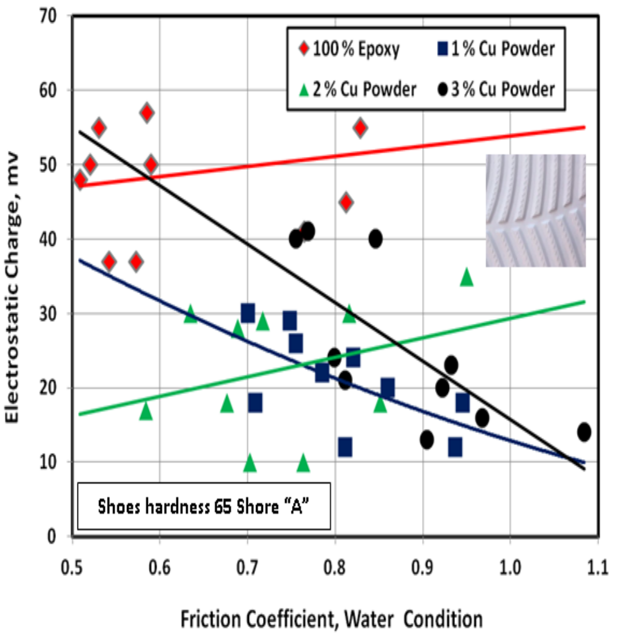


Fig. 16 Electrostatic charge of rubber shoes with Hardness 65 shore A, sliding against wet epoxy floor filled by copper powder.

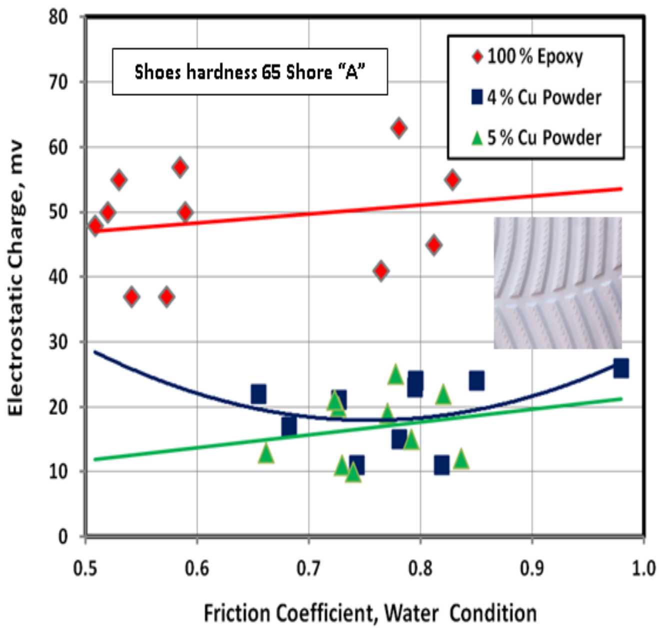


Fig. 17 Electrostatic charge of rubber shoes with Hardness 65 shore A, sliding against wet epoxy floor filled by copper powder.

The effect of copper chip on reduce electrostatic charge generated from sliding between rubber specimens and epoxy surface, shown in Fig 18. The copper is good conducting material and helps for disposal the electrostatic charge from contact surface to ground. The water on contact surface helps for distribution the electrostatic charge on the contact surface

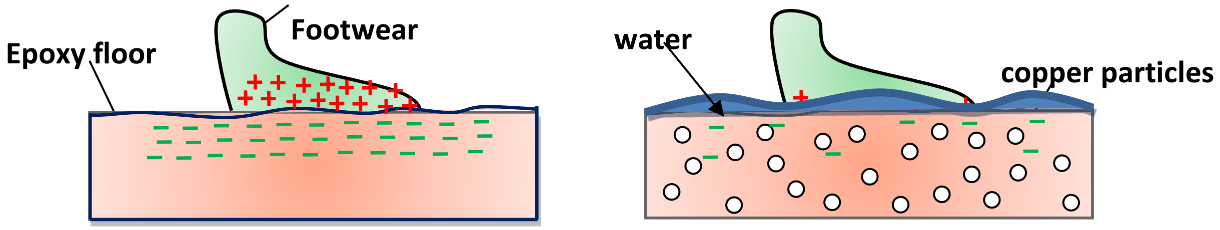


Fig. 18 The effect of copper powder and water on reduction the electrostatic charge.

Electrostatic charge of wet epoxy surface filled by copper chip was shown in Fig. 19. Electrostatic charge decrease with increasing copper content. Increase copper chip content show remarkable effect in decrease the electrostatic charge on floor surface. Increase the hardness of rubber shoes to 63 Shore A, show easy escape of water from contact area and escape charge through copper particles to the ground. Pure epoxy specimens investigated the highest values of electrostatic charge. Increasing copper chip up to 2 wt. % show other reduction in electrostatic charge. Figure 20 show the results between electrostatic charge and coefficient of friction, at wet epoxy test specimens filled by copper chip. It can be investigated that the electrostatic charge decrease with increasing Cu chip content. The copper has a good conductive properties and enhancing the epoxy floor to disposal from electrostatic charge. The lowest values of coefficient of friction displayed by epoxy floor contain 5 wt. % copper chip.

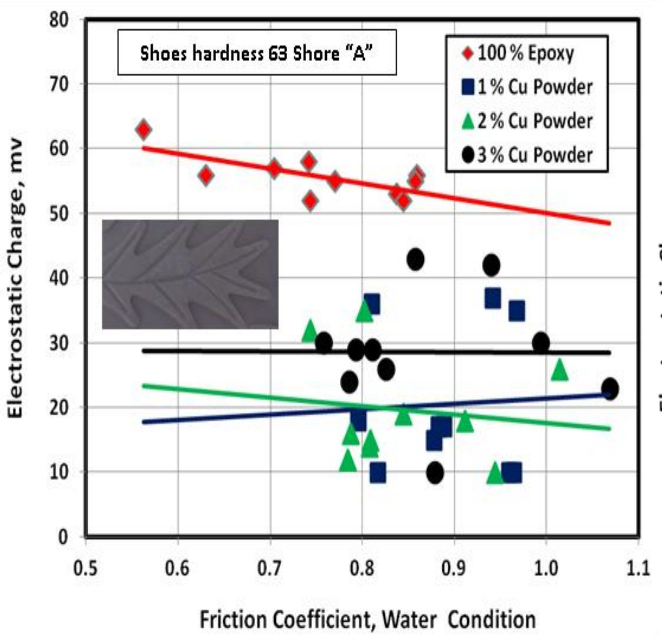


Fig. 19 Electrostatic charges of rubber shoes with Hardness 63 shore A, sliding against wet epoxy floor filled by copper powder.

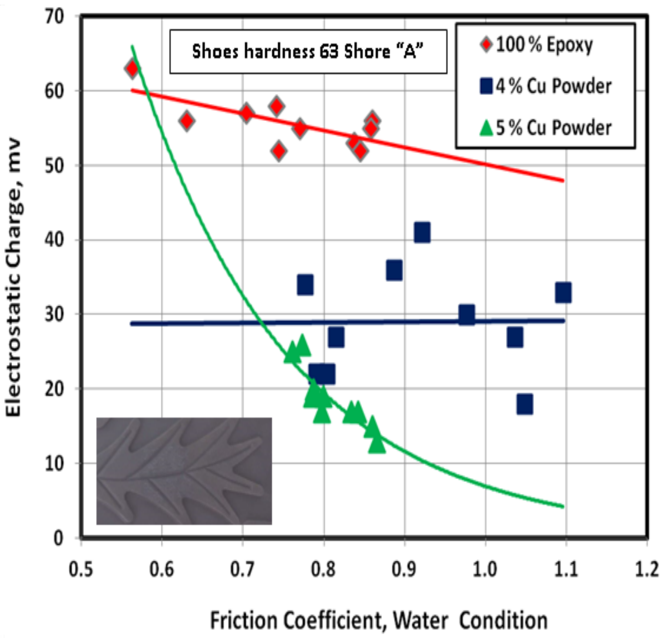


Fig. 20 Electrostatic charges of rubber shoes with Hardness 63 shore A, sliding against wet epoxy floor filled by copper powder.

CONCLUSIONS

1. Epoxy filled by copper chip shows remarkable increase in friction coefficient and reduces electrostatic charge accumulated on the contact surface.
2. At water sliding conditions, the water helps for disposal electrostatic charge away contact surfaces. Thus, the electrostatic charge reduces in water condition.
3. The friction coefficient increase with adding copper chip to epoxy resin in all types of rubber shoes.
4. Adding copper chip to epoxy resin as floor materials show significant reduction in electrostatic charge generated from sliding of rubber specimens against epoxy floor materials.

REFERENCES

1. Jaramillo A. F, Medina C., Flores P., Canales C., Maldonado C., Rivera P. C., Mel´endrez M. F., "Improvement of thermomechanical properties of composite based on hydroxyapatite functionalized with alkylsilanes in epoxy matrix", Ceram Int.; 46: pp. 8368–78, (2020).

2. Fouly A., FathEl-Bab A. M., Nasr M. N., Abouelsoud A. A., "Modeling and experimental testing of three-tip configuration tactile sensor for compensating the error due to soft tissue surface irregularities during stiffness detection", Measurement; 98: pp. 112–22, (2017).
3. Kim K., Kim M., Hwang Y., Kim J., "Chemically modified boron nitride-epoxy terminated dimethylsiloxane composite for improving the thermal conductivity", Ceram Int.; 40 : pp. 2047–56, (2014).
4. Bentley, T. A., Haslam, R. A., "Identification of risk factors and countermeasures for slip, trip andfall accidents during the delivery of mail", Appl. Ergon. 32 (2), pp. 127–134, (2001).
5. Bentley, T. A., Haslam, R. A., "Slip, trip and fall accidents occurring during the delivery of mail", Ergonomics 41 (12), pp. 1859–1872, (1998).
6. Bell, J. L., Gardner, L. I., Landsittel, D. P., "Slip and fall-related injuries in relation to environmental cold and work location in above ground coal mining operations" Am. J. Ind. Med. 38, pp. 40–48, (2000).
7. Leamon, T. B., Murphy, P. L., "Occupational slips and falls: more than a trivial problem", Ergonomics 38 (3), pp. 487–498, (1995).
8. Gao, C., Holmér, I., Abeysekera, J., "Slips and falls in a cold climate: underfoot surface, footwear design and worker preferences for preventive measures", Appl Ergon. 39 (3), pp. 385–391, Epub. 2007, September 18, (2008).
9. Bentley, T., Hide, S., Tappin, D., Moore, D., Legg, S., Parker, R., et al., "Investigating risk factors for slips, trips and falls in New Zealand residential construction using incident-centred and incident-independent methods", Ergonomics [serial on the Internet] 49 (1), 62–77, January 15 (12.02.12), (2006).
10. Drebit, S., Shajari, S., Alamgir, H., Yu, S., Keen, D., "Occupational and environmental risk factors for falls among workers in the healthcare sector", Ergonomics 53 (4), pp. 525–536, (2010).
11. Grönqvist, R., Abeysekera, J., Gard, G., Hsiang, S.M., Leamon, T.B., Newman, D.J., et al. Human-centred approaches in slipperiness measurement. Ergonomics 44 (13), pp. 1167–1199, October 20, (2001).
12. Moyer, B., Chambers, A., Redfern, M., Cham, R., "Gait parameters as predictors of slip severity in younger and older adults", [serial on the Internet]. Ergonomics 49 (4), pp. 329–343, March 15 (12.02.12), (2006).
13. Redfern, M.S., Cham, R., Gielo-Perczak, K., Grönqvist, R., Hirvonen, M., Lanshammar, H., Marpet, M., Pai, C.-Y., Powers, C. Biomechanics of slips. Ergonomics 44 (13), 1138–1166, (2001).
14. Chiou, S., Bhattacharya, A., Lai, C., Succop, P., "Effects of environmental and jobtask factors on workers' gait characteristics on slippery surfaces", Occupat. Ergon. (serial on the Internet) 3 (4), pp. 209–223 (12.02.12), (2002).
15. Fong, D., Hong, Y., Li, J. Lower-extremity gait kinematics on slippery surfaces in construction work sites. Med. Sci. Sports Exer. [serial on the Internet] 37 (3), pp. 447–454 (12.02.12), (2005).
16. Detlef K., "Electrostatic behaviour of wood and laminate floor coverings and current situation in standardization", Journal of Electrostatics 88, pp. 218-224, (2017).
17. Samy, A. M., Mahmoud, M. M., Khashaba, M. I. and Ali, W. Y., "Friction of Rubber Sliding Against Ceramics, I. "Dry And Water Lubricated Conditions", KGK Kautschuk Gummi Kunststoffe, 60, Jahrgang, Nr 607, June: pp. 322 – 327, (2007).
18. Samy, A. M., Mahmoud, M. M., Khashaba, M. I. and Ali, W. Y., "Friction of Rubber Sliding Against Ceramics, II. Oil And Oil Diluted By Water Lubricated Conditions", KGK, 60, Jahrgang, Nr 607, December, pp. 693 – 696, (2007).
19. Samy, A. M., Mahmoud, M. M., Khashaba, M. I. and Ali, W. Y., "Friction of Rubber Sliding Against Ceramics, III. Sand Contaminating The Lubricating Fluids", KGK Kautschuk Gummi Kunststoffe, 61, Jahrgang, Nr 608, January, pp. 43 – 48, (2008).