Friction Measurements in a Hand Tool Factory

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Abstract. Floor slipperiness has been identified as one of the major risk factors affecting the occurrence of slipping and falling on workplaces. Floor slipperiness assessment was conducted in a factory manufacturing hand tools in Taiwan. Three areas in the machine shop factory were measured. The friction measurements were conducted using the Brungraber Mark II slipmeter. A total of 96 measurements of the coefficient of friction on the floor were conducted. In addition, six employees were interviewed concerning their experiences of slipping and falling in the sector and their perception of floor slipperiness. The results showed that the floor in the sink area had significantly (p<0.0001) lower COF values than the other two areas. The COF values in the sink area were all less than 0.5, a safety standard commonly adopted in the USA. Six of the employees in the factory were interviewed concerning their perception of floor slipperiness and their experiences of slipping & falling in the working areas. The results were discussed.

Keywords: slip & fall, floor slipperiness, coefficient of friction, field measurement.

1 Introduction

Slipping and falling create serious occupational safety burdens worldwide [1-2]. The Labor Inspection Annual Report [3], publish by the Council for Labor Affairs annually, indicates that there were 1,835 fall incidences in 2011 in Taiwan. This accounted for 15.97% of all occupational incidences. This means that there was one occupational incidence in every 6.26 incidences. Falling, only next to being caught in or compressed by, was the number two leading cause of occupational incidence. It is a common belief that the risk of slip and fall is floor slipperiness dependent [4-9]. The coefficient of friction (COF) on the floor has been adopted to indicate floor slipperiness [8-13]. The COF on the floor may be measured using a friction measurement device [13-18]. A measured static COF of 0.5 has been adopted as a safety guideline in the USA [19].

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There are many factors affecting the COF on the floor. Floor contamination is probably one of the most commonly discussed issues in practice. Water contamination is not uncommon. It is a common belief that wet and oily floors are more slippery than the dry ones. This belief has been supported by both scientific theory and empirical studies. The squeeze film theory [20] is probably the most frequent adopted scientific basis describing the effects of liquid on the friction on a floor.

Field studies on floor slipperiness measurements are common. However, most friction measurements in the field were focused on restaurant, dining services, and college campus [21-25]. Friction measurements on hand tool manufacturing are rare in the literature. In this study, a field measurement of floor slipperiness in a food manufacturing factory was conducted. The objectives of such measurement was to assess the risk of slipping & falling in a real working environment and to compare the measurement results with those reported by the workers in the same locations.

2 Method

A hand tool manufacturing factory in central Taiwan was selected for study. This factory produces wrench of different specification. The manufacturing process includes heating, cutting, punch, polishing, electroplating, and so on. Upon arrival at the factory, the research personnel took a walk through tour in the factory to visually check the floor conditions in each sector. Three areas were selected for measurement upon mutual agreement between the research personnel and the factory manager. One area was in a machine shop area (see Fig. 1 (a)). The second area was a storage room for tools waiting for maintenance and repairs (see Fig. 1 (b)). The third area was in the sink area adjacent to a laboratory (see Fig. 1 (c)). The floor in the machine shop is concrete floor with epoxy payment. The floor in the storage room is concrete floor. Both the floors in the machine shop and storage room were dry but covered with sticky oil. The floor in the sink area is flat ceramic tile. The workers in the areas need to wash their hands before they can answer a cell phone call or to take a break as their hands were dirty with machine oil most of the time during the day. There are no hand drier and paper towels in this area. The floor in this area was wet and greasy as workers came to wash their hands frequently and dripping on the floor after hand washing. There is no floor cleaning during the day.

The Brungraber Mark II (BMII) slipmeter was used in the friction measurements. This slipmeter is commonly used in the USA for field study involved slipping & falling incidences. The standard test method of using the BM II is published by the American Society for Testing and Materials (ASTM) [26]. The measurement protocol by Chang [27] was adopted. A flat Neolite footwear pad was used. The temperature and humidity in the popcorn sector at the time of measurement were 33 ℃ and 62%, respectively. For each of the three areas, eight points on the floor were measurement.

(a) (b) (c)

Fig. 1. Floors in three areas in the factory

The measured points were on the walking path in each area and were separated for approximately 30 cm for the adjacent points. Four measurements were collected on each point. There were a total of 96 measurements (8*3*4).

In addition to the friction measurements, six employees were interviewed concerning their experience of slipping & falling in these areas and their perception of floor slipperiness in these areas. The age of these interviewees was 31.33 (±8.73) yrs. Three of the interviewees were males and the others were females. The age of the male interviewees was 38 (±8.88) yrs. The age of the female interviewees was 24.6 (±4.04) yrs. A rating scale, from 1 (extremely slippery) to 5 (not slippery), was adopted for subjective slipperiness measurements. The interviewees were interviewed on one-on-one basis. The interviewees were also requested to report their experiences of slipping & falling in the working areas in the past twelve months. In addition, they reported their witnesses on the slipping and falling of their peers.

Descriptive statistics and analysis of variance (ANOVA), and Duncan's multiple range tests were performed. Kruskal-Wallis test was performed for the subjective rating of floor slipperiness.

3 Results and Discussion

The hand tool factory visited was belonged to a traditional manufacturing company. Such a company is normally regarded as having poor working environments as far as safety & health are concerned. Table 1 shows the mean COF values for each sampling point on the floor in each area. It was found that all the readings of the COF in the sink area were lower than 0.5, a safety standard proposed by the US industries [19], while all the readings in the other two areas had relative high COF values.

Table 1. Mean COF values on each

Machine shop	COF	Sink	COF	Storage area	COF
1	0.83	1	0.22	1	0.59
2	0.77	2	0.19	2	0.65
3	0.69	3	0.16	3	0.65
4	0.66	4	0.16	4	0.61
5	0.81	5	0.17	5	0.61
6	0.80	6	0.16	6	0.67
7	0.79	7	0.14	7	0.70
8	0.78	8	0.14	8	0.67

The ANOVA results on the COF data for the three areas were statistically significant. Duncan's multiple range test results showed that The COF in the machine shop (0.76 ±0.06) was significantly ($p<0.05$) higher than those of the storage room (0.64± 0.05) and sink area (0.17±0.03). The COF in the storage room was significantly ($p<0.05$) higher than that of the sink area. Engineer oils and other machining liquids are routinely used in the machine shop. The floors in both the machine shop and storage areas look greasy. However, the grease on the floor was sticky. The COF readings in these two areas were higher than we expected. This might be attributed to the facts that the sticky grease was solid instead of liquid. There was no squeeze film effects on floors contaminated with this type of contaminants.

The employees interviewed showed that three out of six employees had the experiences of slipping without falling in a year. Two of them slipped in the storage rooms and the third one slipped in the sink area. The reasons of the slipping without falling were grease on the floors. For the witness of slipping & falling of others, only one slipping and falling was reported. This case occurred in the metal cutting operating area where the floor was contaminated with grease. The Kruskal-Wallis test results indicated that the subjective ratings of floor slipperiness in the three areas were not statistically significantly. The rating for the machine shop, storage room, and sink area were 4.67 (±0.52), 4.5 (±0.55), and 2.38 (±0.98), respectively. The sink area had the lowest floor slipperiness score even though it was not significantly lower than the other two locations.

There are over 30 workers in the machine shop. However, most of them could not stop their work for an interview upon our visit. The small sample size of the worker interview created one of our limitations of the study. In addition, we could conduct friction measurements only on those floors that would not interfered with the traffic and operations of the workers. Some of the floors may possess low floor slipperiness but were not measurable due to safety concerns of the research personnel.

4 Conclusion

A friction measurement study was conducted in a hand tool factory. Six of the workers were interviewed concerning their perception of floor slipperiness in the working areas and their experiences slipping & falling for their self and their peer. The results found that the floors in the sink areas, where workers wash their hands frequently, had significantly the lowest COF values than the other two areas. The work interview results also indicated that the sink was the most slippery area even though the subjective score of this area was not significantly lower than the other two areas.

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