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ROLLING RESISTANCE OF CASTOR WHEELS BASED ON BS EN 1728:2012

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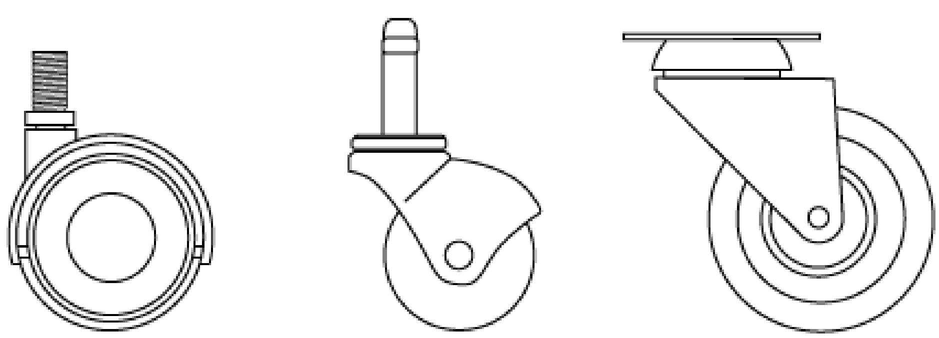
INTRODUCTION

A castor is an important part of the moveable furniture. There are three common types of castor wheel (Figure 1). Type 1 and Type 2 are commonly used for office chairs, while Type 3 is used for heavy-duty applications such as trolleys, wheeled chairs, and hospital beds. The design, diameter, material, mounting, and axial movement will vary according to the load capacity and types of flooring. Dual-wheel castors are commonly used in office chairs because it has a wider contact surface for effective weight distribution, thus minimising damage to the floor surface. Single-wheeled castors are stronger than dual-wheeled castors because of its solid construction, therefore they are commonly used for heavy duty uses. Locking castors and reverse-locking castors provide additional safety and functionality. Locking castors allow movement of chair when sitting, but resists unwanted movement when load is removed. In contrast, reverse-locking castors will lock in place when load is applied but allow movement of chair when the weight is removed. In contrast, reverse-locking castors will lock in place when load is applied but allow movement of chair when the weight is removed. Stems are often used to attach the wheel to the base of office chairs using insert nut, while most heavy-duty castors are installed using a mounting plate. Most office chairs are installed with 50 mm, 60 mm, or 65 mm diameter wheels. Larger wheels are more durable, have less rolling resistance, and are more easily overcome the obstacles such as high-pile carpet. Smaller wheels have higher rolling resistance but suffer increased stress. The tread of castor wheel for office chairs is typically made from plastic (nylon, PP, PU, and TPU) or rubber material for high rolling resistance, while metal tread is commonly used for high load applications.



(a) (b) (c)

Figure 1 Types of castor wheel: (a) dual-wheeled (Type 1); (b) round-ball (Type 2); and (c) fork-wheeled (Type 3)

The base of office chairs are comonly installed with castor wheels, enabling them to be easily moved at close distances in any direction while in use. However, inadvertent operation of castor wheeled chair often causes injuries to the users (Anton 2016). According to BS EN 1335-2:2018, an unloaded chairs with castor wheel shall be tested for rolling resistance after conducting stability, strength and durability tests. The rolling resistance shall be less than or equal to 12 N.

According to BS EN 1728:2012, 6.30, rolling resistance test of unloaded chair shall be carried out after the stability, strength and durability tests. Rolling resistance is measured as the force required to move the castor wheeled chair on a flat surface at a constant speed. When castor-wheeled chair is intendedly or unintendedly moved, it will gradually slow down due to the rolling resistance. Factors that contribute to rolling resistance are the load, diameter and deformation of the wheels, roughness and deformation of the surface, load on wheel, surface adhesion, sliding, and relative micro-sliding between the surfaces of contact (Chan et al. 2017, Zepeda et al. 2016, Wargula et al. 2019). Rolling resistance increases with decrease in radius of wheel, elasticity of wheel surface material, and roughness of floor surface (Rabinowicz 1995, Frank & Abel 1989, Zepeda et al. 2016). FRIM Furniture Testing Laboratory (FTL) reported that most swivel chairs failed to comply with minimum resistant force as stated in the standard test requirements (personal communication).

A preliminary study was conducted to examine the effect of wheel diameter and prong material on the rolling resistance of castor wheeled office chair. The results obtained in this study could be used to improve the performance of castor wheel.

MATERIALS AND METHOD

Plastic wheels of two diameters that are commercially available for office chairs were tested in this study: 50 mm and 60 mm (Figure 2). The wheels were mounted on the plastic and metallic prongs to form the legs of chair (Figure 3). Four sets of legs were prepared for each wheel diameter and prong material, and were assembled to the same non-domestic single seating unit, i.e., an office chair. The specifications of castor wheels and prongs used in the present study that might affect the rolling resistance are listed in Table 1 and Table 2, respectively. Table 3 shows the weight and height of assembly.

Rolling resistance tests of the unloaded chair were performed at the FRIM Furniture testing Laboratory (FTL) according to BS EN 1728:2012, clause 6.30. The chair was placed on the horizontal, flat smooth and rigid steel test surface and was pushed or pulled over a distance of at least 550 mm at a constant speed of 50 ± 5 mm/s (Figure 4). The force was applied at a height of 200 ± 50 mm above the test surface, measured using a force gauge held at the pedestal leg. The force used to push or to pull the chair over the distance from 250 mm to 500 mm was recorded as the rolling resistance. Three readings were recorded for each test.

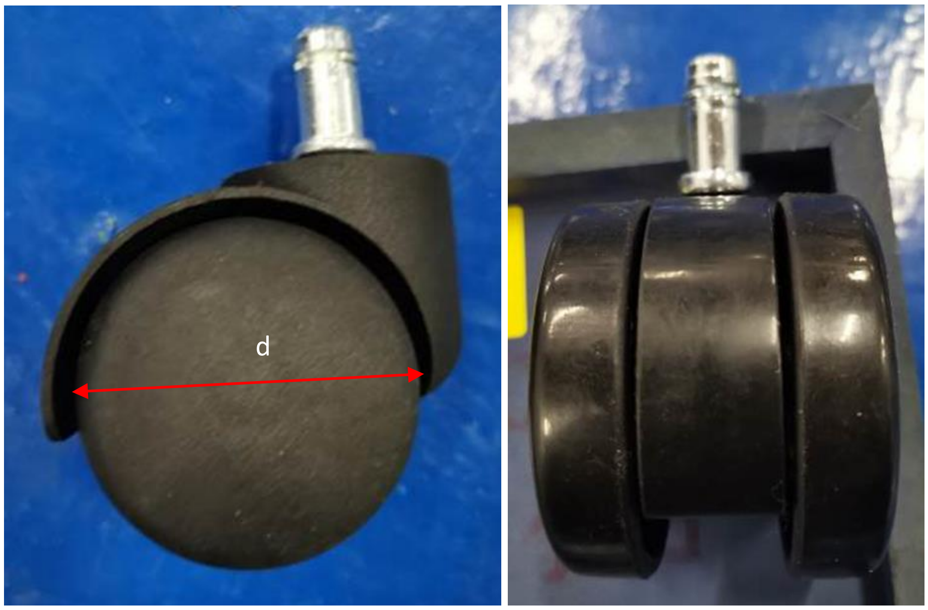


Figure 2 50-mm (left) and 60-mm (right) diameter (d) wheels made of nylon plastics

Figure 3 Plastic prong (left) and metallic prong (right)

Figure 4 Rolling resistance test of castor wheel mounted on an office chair

Table 1 Specifications of castor wheels and prongs

Parameter	50 mm diameter	60 mm diameter
Weight (g)	97.5	112.4
Height of plastic part (mm)	58.0	60.0
Wheel diameter (mm)	50.0	60.0
Wheel thickness - side (mm)	18.0	16.0
Overall wheel thickness (mm)	55.0	51.0
Contact surface thickness - 1 side (mm)	8.0	10.0

Table 2 Specifications of prongs

Material	Weight (g)	Diameter (mm)	Height (mm)
Plastic	1,640	700.0	79.0
Metallic	2,080	700.0	94.5

Table 3 Castor wheel assembly

	50 mm wheel		60 mm wheel	
	Plastic prong	Metallic prong	Plastic prong	Metallic prong
Weight (g)	2127.5	2567	2202	154
Height (mm)	124.5	140	2642	169.5

A 2 × 2 repeated measures two-way analysis of variance (ANOVA) test was performed at 95% confidence level using Microsoft Excel Data Analysis Tool (Anova: Two-Factor with Replication) to determine the significant levels of the studied variables.

RESULTS AND DISCUSSION

The rolling resistance of castor-wheeled chair for different prong materials and wheel diameter are shown in Table 4. Metallic prong had greater rolling resistant than plastic prong for both diameter. From a two-way ANOVA test (Table 5), the rolling resistant of castor wheel was significantly influenced by wheel diameter (p-value < 0.05). The larger the wheel diameter, the lower the rolling resistant because surface area increased as diameter increases. In general, rolling resistance is inversely proportional (Figure 5) to the wheel diameter. As compared to the wheel diameter, prong material did not significantly influence the rolling resistant (p-value ≥ 0.05). The interaction between the effects of wheel diameter and prong material on rolling resistant was also not statistically significant (p-value ≥ 0.05). Based on similar tests conducted on wheelchair pulled over the indoor and outdoor surfaces, Chan et al. (2017) concluded that smaller castors significantly increased rolling resistance.

Based on BS EN 1335-2:2018 requirement, the minimum rolling resistance of castor wheel assembled with unloaded chair is 12 N. The results showed that all assemblies did not meet the test requirement. The results from the present studies were varied from 6.03 N to 7.14 N. The percentage of deviation from the minimum rolling resistant was 41.25 % (50 mm/plastic), 49 % (60 mm/plastic), 40.5 (50 mm/metallic) and 49 % (60 mm/metallic).

An alternative way to increase the rolling resistance of chair is to use elastic (deformable) materials such as rubber. During wheeling, the deformation of rubber wheel over the surface will cause hysteresis loss, and thus increase dissipation of energy. At the same force, wider wheels have higher rolling resistance due to its higher contact area than narrow wheels.

Table 4 Rolling resistance (in N) of castor wheel

	Plastic prong								Metallic prong							
	Wheel 50 mm				Wheel 60 mm				Wheel 50 mm				Wheel 60 mm			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
Set 1	6.6	7.2	6.9	6.90	6.6	6.3	6.1	6.33	7.2	6.8	7.4	7.13	6.3	5.8	6.1	6.07
Set 2	7.3	7.1	6.8	7.07	5.8	6.1	6.4	6.10	6.9	7.4	7.1	7.13	5.9	6.1	6.2	6.07
Set 3	7.4	7.1	7.5	7.33	6.2	5.7	6.1	6.00	7.1	6.8	7.3	7.07	6.1	6.3	5.9	6.10
Set 4	6.9	7.1	6.7	6.90	5.8	5.4	5.9	5.70	7.4	7.1	7.2	7.23	6.4	6.2	6.1	6.23
Mean ± SD	7.05 ± 0.20				6.03 ± 0.21				7.14 ± 0.07				6.12 ± 0.09			

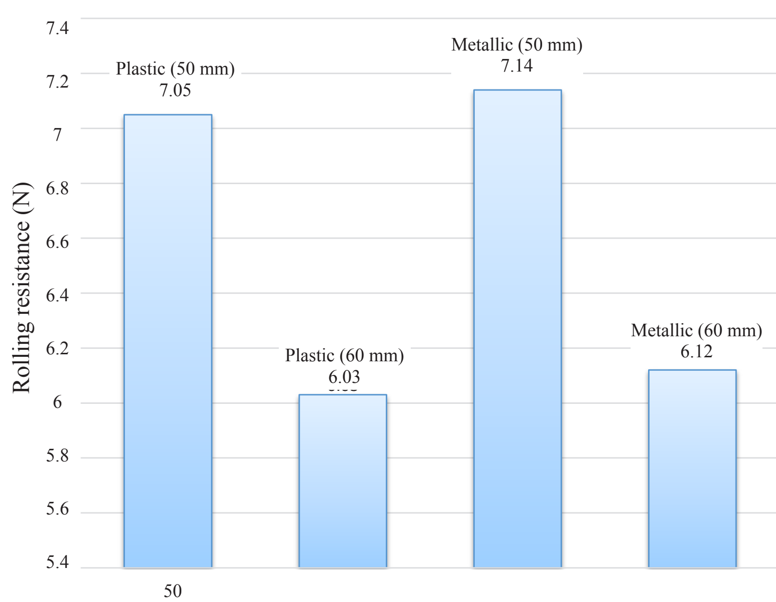


Figure 5 Rolling resistance of castor wheels

Table 5 Statistical analysis

Anova: Two-Factor with replication

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
prong material	0.0919	1.0000	0.0919	1.3738	0.2475	4.0617
Wheel diameter	12.5052	1.0000	12.5052	186.9938	0.0000	4.0617
Interaction	0.0002	1.0000	0.0002	0.0031	0.9557	4.0617
Within	2.9425	44.0000	0.0669			
Total	15.5398	47.0000				

CONCLUSION

The results the present study showed that the rolling resistance force decreased with increase in wheel diameter, but did not significantly influenced by the prong material. However, all assemblies did not meet the test requirement. For future study, it is recommended to determine the rolling resistance of loaded chair attached with castor wheels made from different material (e.g. rubber or silicone) tested on different surface material.

ACKNOWLEDGEMENT

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A preliminary study was conducted to determine the effect of castor wheel diameter and types of prong on rolling resistance of plastic castor wheels mounted on an office chair. The determination of rolling resistance of the unloaded chair was carried out according to BS EN 1728:2012, clause 6.30. The rolling resistance was measured as the force used to push or to pull the chair on the flat surface at a constant speed of 50 ± 5 mm/s over the distance from 250 mm to 500 mm. The rolling resistant of 50-mm castor wheels were 7.05 ± 0.20 N and 7.14 ± 0.07 N when mounted on plastic and metallic prongs, respectively. For 60-mm castor wheels, rolling resistant were 6.03 ± 0.21 N (plastic prong) and 6.12 ± 0.09 N (metallic prong). The results showed that all assemblies did not meet the test requirement, i.e. all test results were less than 12 N. It was found that the rolling resistant of castor wheels increased with increase in wheel diameter. Prong material did not significantly influence the rolling resistant.

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