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Shapes and their slip resistance in shoe sole designing

Shoe soles are mostly made of thermoplastic rubber (TPR) because of its light-weight, durability, flexibility, and slip resistance[1]; however little is known about the correlation between the pattern or shape and its friction force. Thus I measured the amount of force needed to start rubber soles of various shapes sliding from a stationary state, as well as to well as that of kinetic friction. Here I will show how the pattern and shape of a surface is closely related to its friction force; the coefficient of static friction varies more by the shape of the surface in contact than the kinetic friction. Conventional shapes in shoe sole patterns are therefore deliberately configured by shapes that are easy to orient in space, and achieve the optimum amount of friction to provide maximum comfort. Regulating friction force by arranging shapes in an expedient configuration may have applications in manufacturing more effective precision instruments and engines.

The coefficient of friction (COF) measured in this experiment is defined in Wikipedia (3 December, 2008) as the ratio of the friction to the normal force, the perpendicular force compressing two parallel surfaces together. For the COF of static friction, the maximum friction force applied before the surfaces slide is used. It is used to approximate the value of friction between any two given surfaces; generally the COF of static friction is greater than that of the kinetic. The COF varies depending on the temperature and the velocity of sliding on the surface, whereas it is independent of surface area.

Out of ten random shoe soles I surveyed[2], lines were the most common pattern found on shoe soles, with an average of 11.2 lines per shoe, followed by trapezoids and circles with 6.1 and 6.0 shapes per shoe, respectively. Semicircular shapes, typically used in high heel soles, had a low average of 0.8 semicircular shapes per shoe in the rest, mostly used to fill in empty spaces. [Fig.2]

shoe number	1	2	3	4	5	6	7	8	9	10	total
rectangular	13		24			2			16		55
cross		8						6			14
hexagon	2										2
trapezoid	3	24						32	2		61
semicircular	2		2	2	1		1				8
line			1	68					12	31	112
triangle		11			14	17					42
circle					20			14	26		60
square						17				36	53

Fig.1 Number of shapes observed in each shoe sole pattern among ten randomly chosen shoes

Furthermore, [Fig.1] shows that each shoe sole pattern consists of a few distinct shapes. For example, shoe sole number 3 consists mainly of rectangular shapes, and a few semicircles and a line. Rectangles and squares were often seen in clusters with a relatively high average of 5.5 and 5.3 shapes per shoe, respectively. Despite the fact that some sport shoe soles consist only of hexagons, hexagons were least recorded with an average of 0.2 hexagons per shoe.

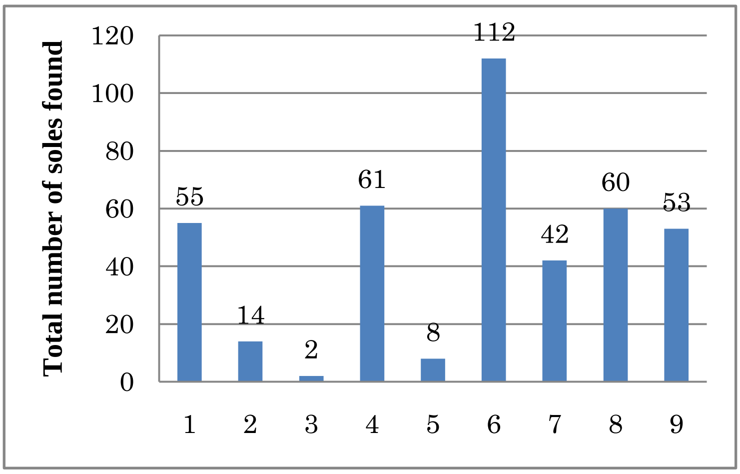


Fig.2 Total number of shapes observed in ten random shoe soles I surveyed ten random shoe soles, and counted the number of shapes observed in each shoe sole pattern. Numbers 1-9 correspond to the shape found: rectangle, cross hexagon, trapezoid, semicircle, lines, triangle, circle, and square, respectively.

To investigate the correlation between the shape of the surface in contact and the coefficient of friction (COF), I measured the amount of force needed to start rubber soles of various shapes to slide from a stationary state, as well as to keep them sliding, and calculated the COF. Rubber shoe soles were cut into seven distinctive shapes observed in my survey of shapes found in shoe sole patters: triangles, circles, squares, hexagons, crosses, semicircles, and trapezoids. For each experimental replicate, rubber soles were attached to a kitchen scale with string, and pulled horizontally on the ground. [Fig.3] Weights were placed on top of each

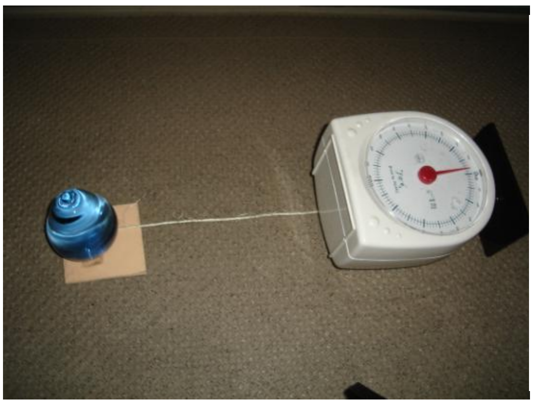
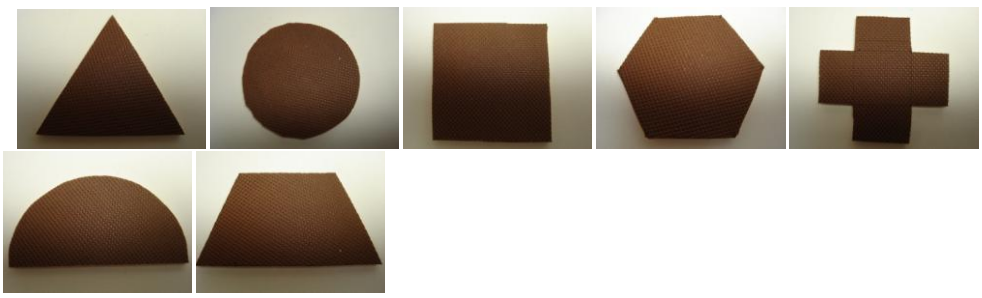


Fig. 3 Right: Square shaped rubber sole pulled by kitchen scale **Left:** Distinctively shaped rubber shoe soles used to measure coefficients of friction. (Left to right) triangle, circle, square, hexagon, cross, semicircle, trapezoid.



rubber sole to amplify the friction force, which makes the differences more perceptible. Next, I conducted an otherwise identical experiment with the floor wet; this experiment is intended to simulate the lack of traction due to rain. Five trials were performed with all possible combinations of distinctive shapes and wet or dry floor.

I found that the coefficient of static friction varied more with different shapes, than did the coefficient of kinetic friction. [Fig.4] For both COFs, the trapezoid rubber sole

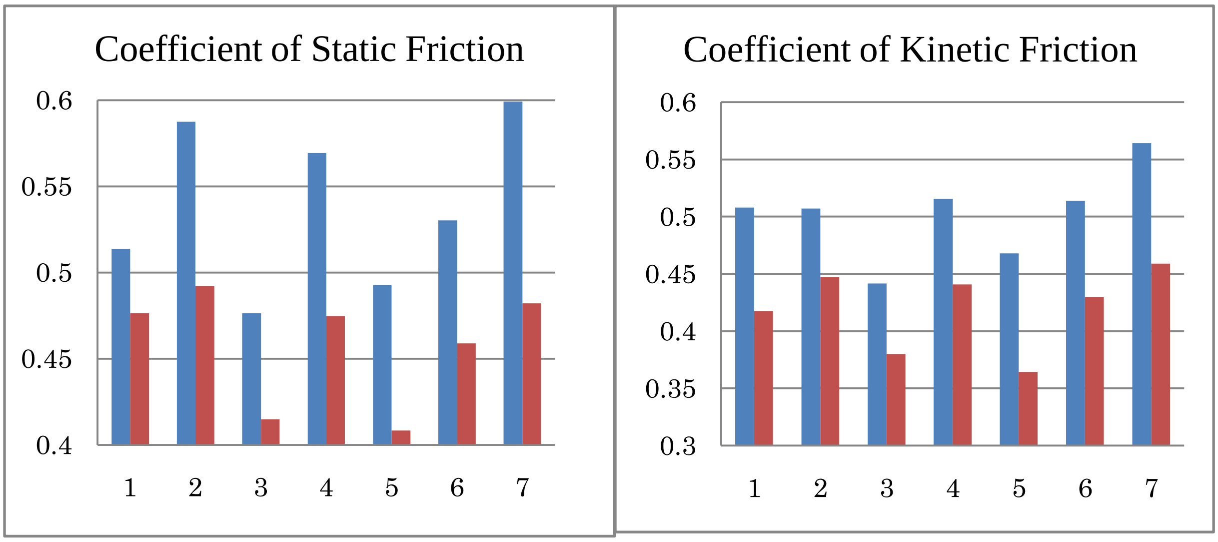


Fig. 4 Coefficient of friction measured for dry floor (blue) and wet floor (red). Vertical axis: average coefficient measured for five trials. Horizontal axis: shape tested. Numbers 1-7 correspond to the shape triangle, circle, square, hexagon, cross, semicircle, trapezoid, respectively.

exhibited the largest COFs (0.5992 for static friction, 0.5643 for kinetic friction both with a dry surface), followed by the circle and the hexagon. On the other hand, the square rubber sole exhibited the least COFs (0.4763 for static friction, 0.4415 for kinetic friction both with a dry surface), followed by the cross. Compared with the number of shapes observed in shoe sole patterns in my survey, the results show that shapes that have greater static friction tend to be used more frequently in shoe sole patterns, though there are exceptions such as the hexagon and the square. Furthermore, there was a 16 percent (0.08) decrease on average in both COFs, when the floor was wet; this confirms the lack of traction between shoe soles and the floor due to rain, as measured by the COFs.

In the production of shoes, however, the shapes on shoe soles patterns are likely to be determined not only by the size of friction force resulting from particular shapes in contact with the ground, but also by the easiness of spatial orientation of the shape itself. [Fig.5] Although circles and hexagons have similar COFs, circles are considerably more common in

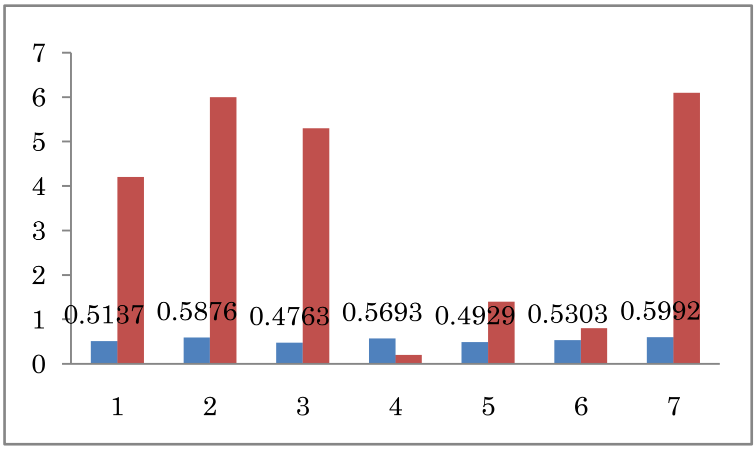


Fig.5 The average number of shoe soles observed in shoe sole survey (red) and their coefficient of static friction (blue). Horizontal axis: shape tested. Numbers 1-7 correspond to the shape triangle, circle, square, hexagon, cross, semicircle, trapezoid, respectively.

conventional shoe sole patterns, presumably because of its easiness of spatial orientation. While both circles and hexagons are symmetric and therefore are relatively easy to distribute spatially, circles are more likely to fit easily with other shapes. Squares and rectangles are seen in clusters not only because it increases the total amount of friction force but presumably because it is relatively easier to place rectangular shapes in high density. This probably explains the results of my shoe sole survey that each shoe sole pattern consisted of a few distinct shapes. These shapes had fit in well together, and were easy to orient in space.

These results suggest that regulating the configuration of shapes may open a new door to controlling the friction force between two surfaces, aside from the popular way of modifying the material itself. Frictional force plays an important role in determining and therefore regulating the strength and stability of precision instruments and engines. My results, for example, suggest that trapezoids should be used for curves in order to achieve maximum friction force, whereas semicircular shapes may be the best way to decrease friction force without adding lubrications. Regulation of friction force by arranging shapes in their most expedient configuration may have applications in manufacturing more effective precision instruments and engines.

References

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