Walking Difficulties in Snow: Stress Distribution

Birpratap S Virk

Walking in snow wearing normal footwear is very hard and every footstep results in your shoes sinking down into the snow. Walking for long periods can be very tiring as the continual sinking and dragging up of feet is more strenuous then walking on solid ground.

Figure 1

The concept behind this issue is stress distribution. The principle of stress distribution is for a given external or internal force, the smaller the area of the member resisting the force, the higher the stress[1]. The equation for stress is given as:

$$Stress, \sigma\ (Pa = Nm^{-2}) = \frac{Force, P\ (N)}{Area, A\ (m^2)}$$

From this equation it can be seen that stress is inversely proportional to area meaning for a constant force the stress would be significantly lower if spread over a larger area.

Model: Replicating the action of snowshoes on snow. This concept can be demonstrated using cushions to imitate snow and two tennis rackets to act as snowshoes. The force shall be kept constant and has been measured at 598.41 N (61kg, body weight + clothing + shoes). The experiment involves comparing the effect of normal shoes on these cushions and the effect of snowshoes (tennis rackets) on the cushions.

Figure 2

Figure 3

Figure 5

Figure 4

From the pictures above it is clear that the larger area of the tennis rackets compresses the cushions less than the smaller area of the pair of shoes. The tennis rackets have a larger area than the soles of the shoes; this does mean that the force is distributed over a larger area which in turn lowers the stress on the cushions causing them to compress less.

Using the equation for stress it can be demonstrated that the stress is much lower when the tennis rackets were tested. Both the area of the sole of the shoes and the area of the tennis rackets were measured by drawing the outline onto graph paper and counting the number of squares.

Shoes:

$$\sigma\,(Pa) = \frac{P\,(N)}{A\,(m^2)} = \frac{598.41}{0.0196} = 30.53\ kPa$$

Tennis Rackets:

$$\sigma\,(Pa) = \frac{P\,(N)}{A\,(m^2)} = \frac{598.41}{0.114} = 5.25\ kPa$$

The stress applied by the shoes was 30.53 kPa, considerably larger than the stress exerted by the tennis rackets which was 5.25 kPa.

Different forms of equipment are used to aid travelling in snow. The stress exerted by this equipment is listed below using the same constant force previously used. The area has been estimated using data from online stores.

Snowshoes: Men's Xpedition Snowshoe, Area = 0.129 m2

$$\sigma\ (Pa) = \frac{P\ (N)}{A\ (m^2)} = \frac{598.41}{0.129} = 4.64\ kPa$$

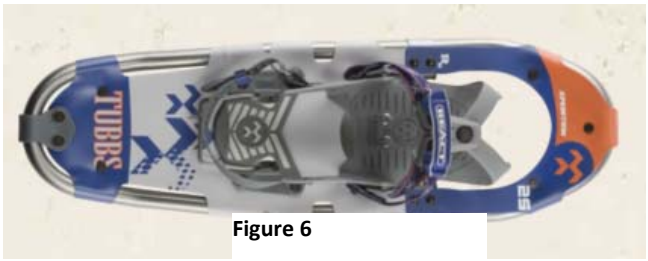

Figure 6

Snowboard: Salomon Snowboards Sick Stick, Area = 0.48 m2

$$\sigma\ (Pa) = \frac{F\ (N)}{A\ (m^2)} = \frac{598.41}{4.8} = 0.598\ kPa$$

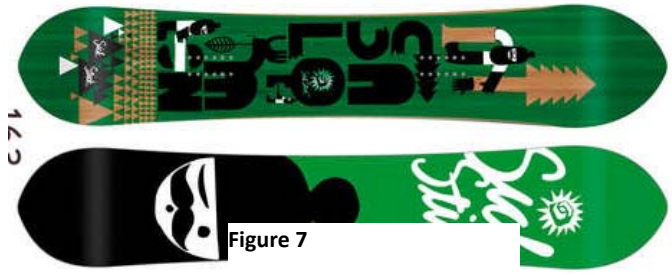

Figure 7

Skis: Atomic Race D2, Area= 0.32m2

$$\sigma\ (Pa) = \frac{P\ (N)}{A\ (m^2)} = \frac{598.41}{0.32} = 1.87\ kPa$$

Figure 8

These calculations show that the as the snowboard has the largest area it has a much lower stress compared with the value of stress for the shoes. It is clear that the larger the area the lower the stress exerted. Using the equipment listed above would significantly reduce the stress on the snow and would mean that when travelling you would not sink into the ground.

References

Figures
Figure 1: http://4.bp.blogspot.com/_h40Ph0ZqsTI/TVMnSaoR6XI/AAAAAAAABP0/uU_uzWJNe5s/s1600/snow+feet.jpg
Figure 2: Taken by myself
Figure 3: Taken by myself

Figure 4: Taken by myself
Figure 5: Taken by myself
Figure 6: http://tubbssnowshoes.com/snowshoes/mens/xpedition-m
Figure 7: http://www.snowandrock.com/salomon-snowboards-sick-stick-10/11/boards/ski-snowboard-outdoor-sports/fcp-product/15426
Figure 8: http://www.snowandrock.com/atomic-race-d2-sl-w-+-atomic-x16-binding-10/11/skis/ski-snowboard-outdoor-sports/fcp-product/13268

Text
1: http://www.mace.manchester.ac.uk/project/teaching/civil/structuralconcepts/

General Reading:
http://www.scienceclarified.com/everyday/Real-Life-Physics-Vol-2/Pressure-How-it-works.html
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