

ANATOMY OF A BRUSH STROKE

THE TECHNICAL COACH SERIES

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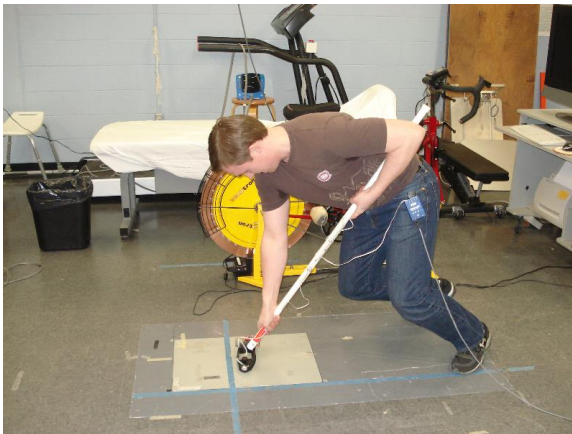
GLENN PAULLEY, ONTARIO CURLING COUNCIL

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NO. 1

OVERVIEW

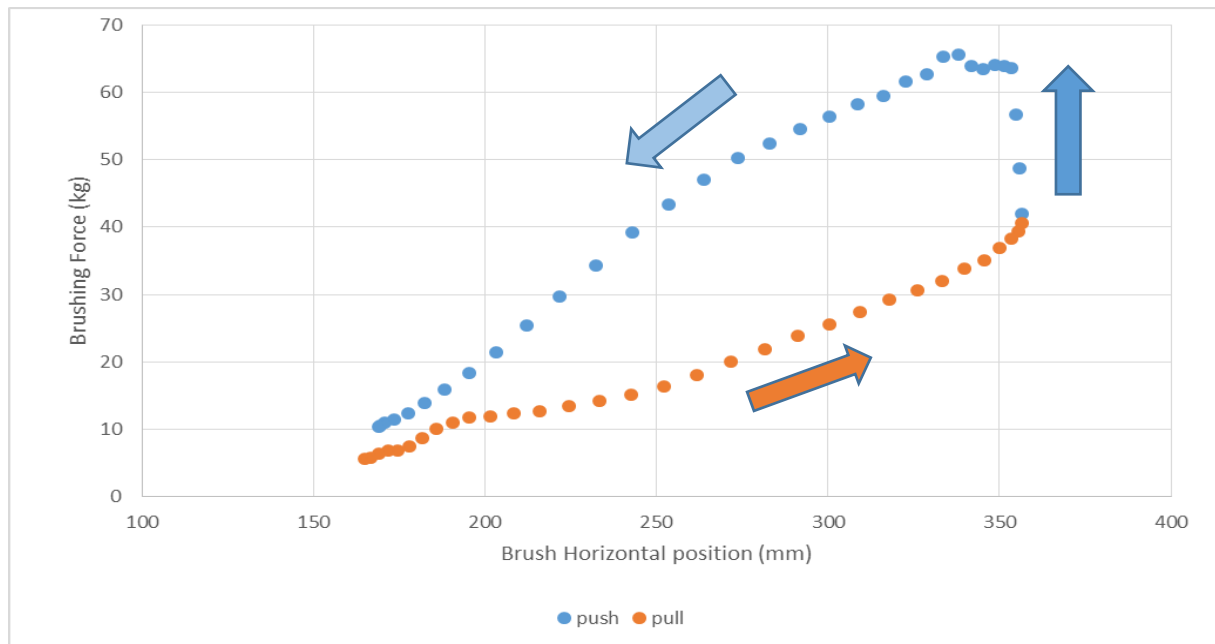
We present an overview of the forces involved during the brushing of a curling stone, and introduce standardized terminology for describing the motion and the forces during a brushing stroke. We concentrate on two principal measurements of brushing performance: the amount of vertical force (or pressure) applied by brush head to the surface of



the ice, as well as the number of brush strokes per second. We captured the detailed force and motion components involved in brushing using an AMTI BP400600-100 force plate, located in the Kinesiology Laboratory at the School of Human Health and Performance at Dalhousie

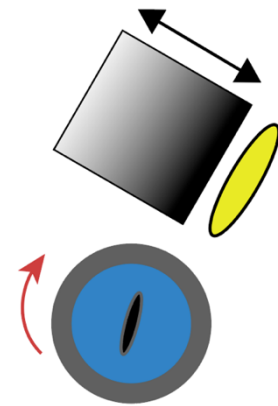
University in Halifax, under the direction of Assistant Professor Michel Ladouceur. The force plate in the laboratory has a 4450 Newton capacity. Signals from the force plate were scanned at 100 Hz or higher using custom-built MatLab software, developed to the manufacturer's specifications. Force is measured in units called newtons. Newtons are not a common or familiar unit outside of science and engineering. To make the vertical force values more tangible to both coaches and athletes, the vertical 'force' in the plots are expressed in kilograms.

ANATOMY OF A SINGLE BRUSH STROKE

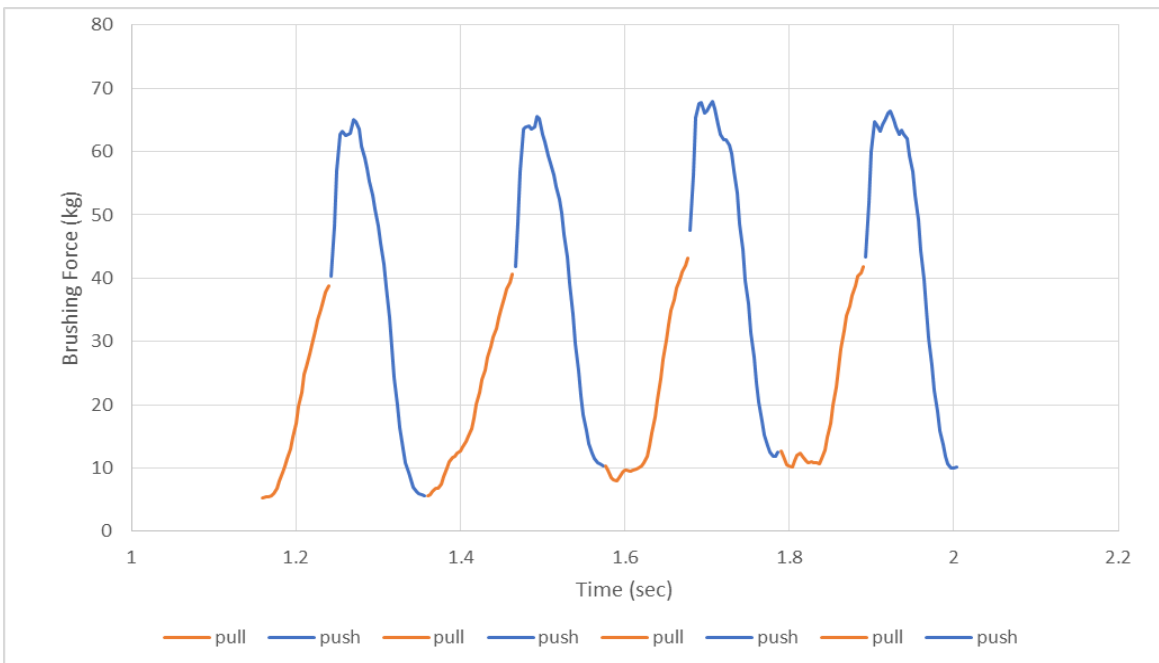


This graph plots the vertical force attained during a trial to the distance of the brush head from its initial position, some distance from the feet of the athlete. The distances shown are relative to the far left-hand side of the force plate. This plot is oriented such that the brusher is standing on the right-hand side of the force plate, as shown in the second photograph above, on Page 1. The brush head is closest to his feet at approximately 360 mm, and the athlete pushes it away from his body to approximately 160 mm before pulling it back again. This gives a brush stroke length of approximately 200 mm. During the initiation of the push portion of the stroke (shown in blue above), where the athlete begins with the brush closest to their feet, the vertical force applied increases rapidly. The dark blue arrow illustrates the near-vertical slope of the force curve during the start of the push motion, in this example increasing the vertical force on the brush by 58%. During the complete push portion of the stroke (light blue arrow), the vertical force tails off to a low of 10 kg. Note the significant difference in vertical force applied, even though the brush has moved only 200 mm further away from the athlete. During the pull stroke, shown in orange, vertical force increases slowly as the brush gets closer to the athlete, until the athlete is ready to initiate another push, and the process repeats.

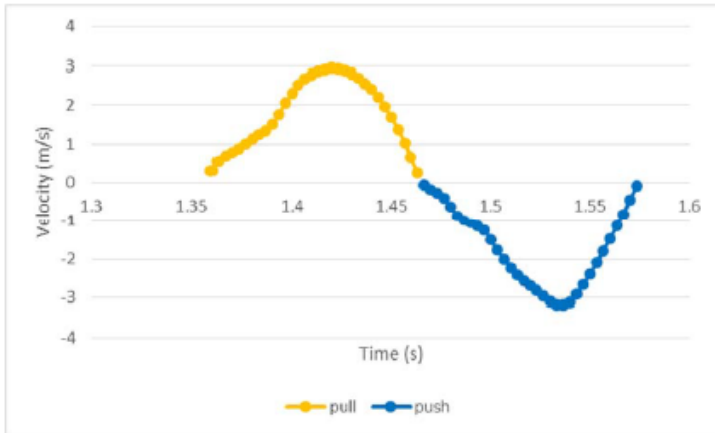
The figure on the previous page illustrates that significantly more force is generated when the brush is nearer to the athlete than when the brush is further away at the end of the stroke. This yields a brushing force pattern that we call a *pressure signature*, seen here at right. The darker areas signify greater vertical force applied to the ice surface through the brush head.



If this process is graphed over time for repeated strokes, then the force curve appears as follows; in this example, we have four complete strokes, where the pull portion of the stroke is again highlighted in orange, and the push portion in blue:

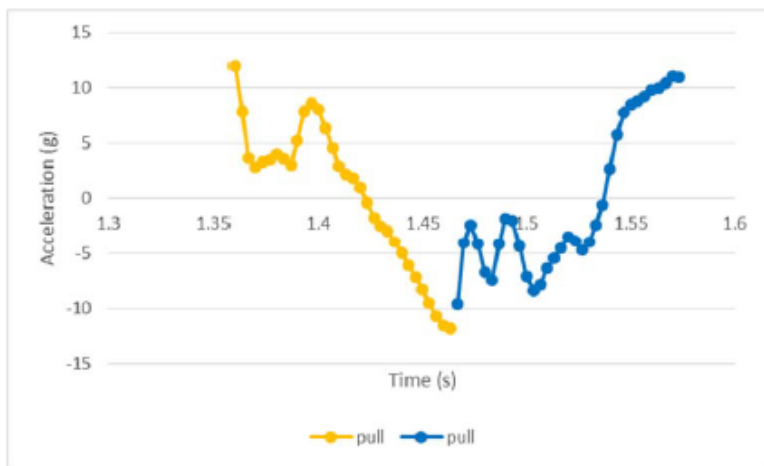


During a bout, while the stroke rate through a bout may change, athletes tend to brush with each half of the stroke taking the same amount of time. However, both the velocity of the brush head, and its acceleration, differ slightly between the push and pull portions of the stroke. This is because of the significant increase in vertical force that tends to be applied when initiating the push portion of the stroke.

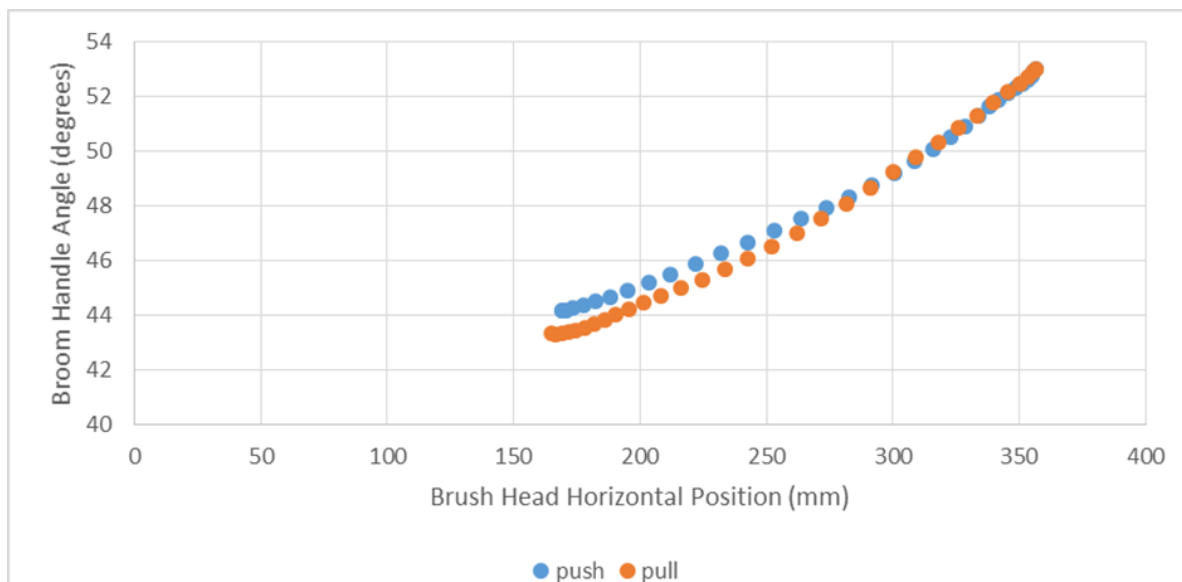


Note that the velocity profile is very similar, although in opposite directions, for the push and pull portions of a stroke. The brush head does reach a slightly higher speed during the push portion (approximately 3.15 m/sec in the plot) than during the pull portion of the stroke. However, note that the time it takes to perform both portions of the stroke is approximately the same.

In this chart, which plots brush head acceleration (in *g*) over time, the acceleration record is richer in variation as the brusher accelerates and decelerates the brush head during the various parts of the brush stroke, especially during the switch in brush stroke direction closest to the brusher's feet.



In our testing, optical tracking devices were placed on the broom handle, which allowed the angle of the handle relative to the horizontal to be measured during brushing. This angle is plotted against brush head position. The angle of the handle is steepest when closest to the athlete's feet (53°), and flattens out to a more shallow angle when farthest away from the athlete's feet (43°), for a variation of 10 degrees during a single stroke.

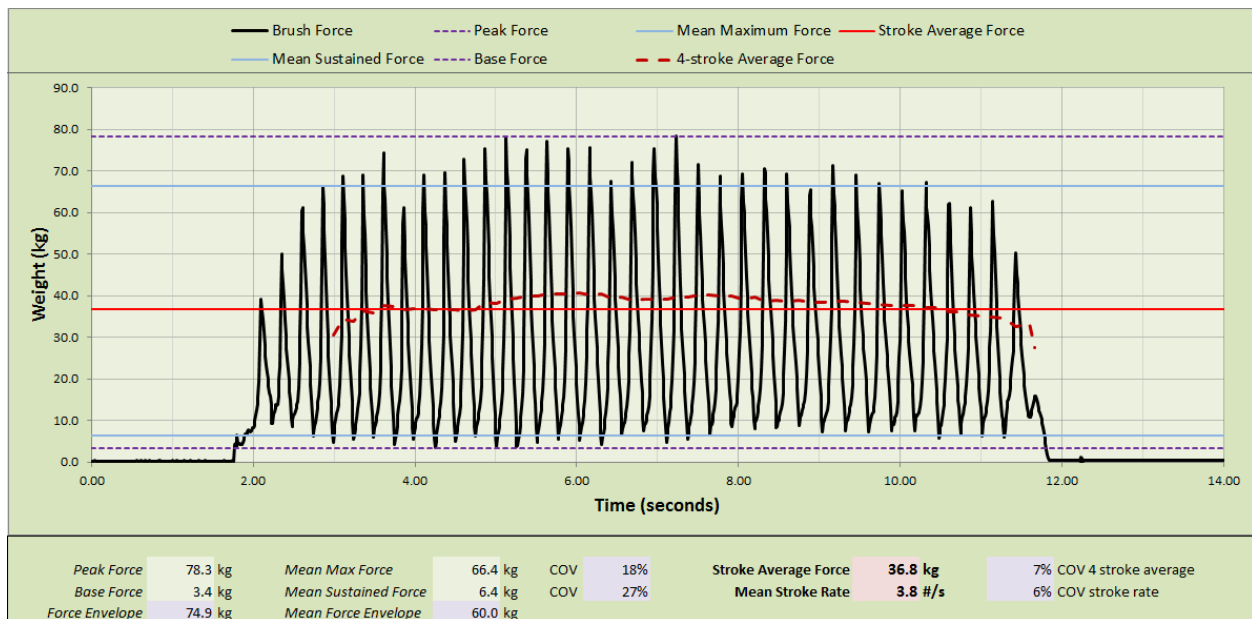


With these graphs in mind, we define the following terms:

- **Bout:** a one-time experiment that sees an athlete brushing a curling stone down a sheet of ice, using a smart broom, measured over a certain distance (often, but not always, hog-line to hog-line).
- **Mean Force** (also called **Stroke Average Force**): the mean of the vertical force values taken over the entire bout.
- **Mean Normalized Force:** the mean force for the bout, divided by the athlete's body weight and expressed as a percentage.
- **Mean Maximum Force:** the mean of the highest force values obtained during each stroke. In essence, the average of the "peaks" of the force curve over the entire bout.
- **Peak Force:** the highest vertical force attained during the bout.
- **Base Force:** the lowest vertical force attained during the bout.
- **Mean Sustained Force:** the mean of the lowest force values obtained during each stroke. In essence, it is the average of the "valleys" of the force curve over the entire bout. Valleys occur typically with the initiation of each "pull" portion of each brush stroke.
- **Force Envelope:** the difference between the Peak Force and the Base Force for the bout.
- **Mean Force Envelope:** the difference between the Mean Maximum force and the Mean Sustained force for a bout. For example, if the Mean Maximum Force was 75kg, and the Mean Sustained Force was 10kg, then the Mean Force Envelope is $75 - 10 = 65$ kg.

- **Displacement:** the length of 1/2 of a brush stroke; that is, the distance the brush head travels between starting and reversing direction at the end of the portion of the stroke.
- **Mean displacement:** the average displacement of all of the strokes during a bout.
- **Mean Stroke Rate:** the mean number of strokes per second performed by the athlete during a bout.
- **Brush handle angle:** the angle of the brush handle relative to the horizontal (or ice surface).

SAMPLE FORCE CHART FROM FORCE PLATE



In the above chart, we see a force curve saved from the AMTI BP400600-100 force plate, based on an experiment with a stationary brusher in the lab. From this graph, we see that the athlete attained:

- A mean force (red line) of 36.8kg over the bout (of approximately 11.75 seconds) with a mean stroke rate of 3.8 strokes per second;
- A mean sustained force of 6.4kg (lower blue line);
- A mean maximum force of 66.4kg (upper blue line);
- A peak force of 78.3kg;
- A four-stroke moving average of approximately 40kg (dashed red line);
- A force envelope of 74.9kg, denoted by the dashed purple lines;
- A mean force envelope of 60.0kg.

QUESTIONS

We are pleased to provide whatever assistance we can to coaches and athletes. Our contact information is below.

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