# Improvement of the Sharpening Style of Ice Hockey Skate Blades

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STREAM A

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## Abstract

Several aspects of the sharpness of ice hockey skate blades have been investigated. These aspects include the radius of hollow, radius of curvature, and point of tangency of the blade. Several blades were sharpened to separate specific radii of hollow, radii of curvature, and points of tangency. The features were then tested using the players' responses to surveys administered following each trial. The analyzed data showed that a smaller radius of hollow improved grip, stopping ability, and both acceleration and deceleration. A larger radius of hollow decreased grip, stopping ability, and slightly decreased acceleration and deceleration; however, it increased gliding time and distance. A larger radius of curvature increased gliding speed, time, and distance, but made turning more difficult. A smaller radius of curvature decreased gliding speed, time, and distance, but made turning easier. A skewed point of tangency led to adverse effects in the performance of the test subjects. Finally, a centered point of tangency provides equal skating ability in either direction.

## Literature Review

### Ice Hockey Skates

Ice hockey skates have been much improved since their creation; however, only two aspects of the skate can be effectively altered: the boot and the blade. Being what brings the boot and the ice together, the blade is equally crucial to the use of an ice skate as the boot. While the boot has been continually modified to near perfection, the blade has seen relatively little change. Specifically, the sharpening of the ice skate has had minor changes with no set standard or recommendation (Federolf & Redmond, 2010).

### Chemistry and Physics of Ice

To understand how ice skating works, a person must establish a basic understanding of ice. Ice skating depends on the unique physical and chemical properties of ice.

### Freezing and Melting

Water freezes at 0°C, and ice melts at just above 0°C. As water approaches the freezing point, its density increases. This change is extremely small, on the order of a few thousandths of a gram per cubic centimeter and is at its highest at 4°C (“Ice”, n.d.). This increase in density is caused by the breakdown of the ice crystals into the more dense liquid state. Beyond 4°C, the density begins to increase. As water freezes, its density decreases and its volume increases. In addition, as ice temperature decreases below 4°C, its density continues to decrease (Ma, 2007).

## Strength of Ice

The strength of ice depends on several factors; however, the most important factor when ice skating in a rink is temperature. As the temperature of ice decreases below 4°C, the density decreases; conversely, the strength of the ice increases (Niehus, 2002). The bonds between the $H_2O$ molecules in the ice become stronger with lower temperatures; therefore, the ice becomes harder and can withstand more stress. As the temperature of ice increases and comes nearer to the melting point, the bonds become weaker, and the ice becomes softer and more likely to fracture under stress.

Although the strength of ice also depends greatly on its thickness, this is of no concern in an ice skating rink. Ice in a rink is generally only approximately 2.54cm thick, not nearly wide enough to support a person, a large group of people, or an ice-resurfacing machine; however, the ice handles these stresses without cracking or shattering. The cause of this is the way the ice skating rink is constructed; layers of concrete and sand support the thin ice. Because the concrete-sand support does not shift or give under pressure, the ice is much more stable and can withstand far greater stress.

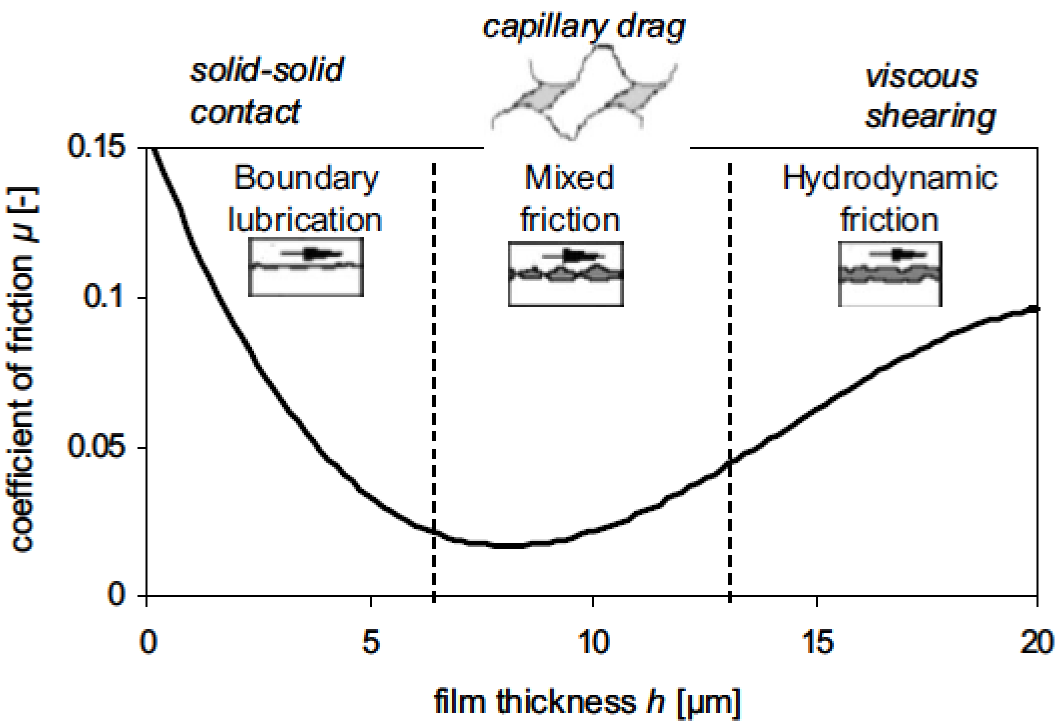


Figure 1. Coefficient of friction of ice as it varies with film thickness. The liquid film on ice ceases to exist at approximately -200°C. As the ice temperature approaches this point, the thickness of this film decreases and the coefficient of friction is affected in a non-linear manner (Kietzig, 2010).

## Friction of Ice

Although ice is a solid, it expresses unusual and unique properties. The coefficients of static and kinetic friction between ice and steel are 0.10 and 0.05 respectively; however, the coefficient of kinetic friction of ice is 0.15 between ice and steel under certain conditions, as shown in Figure 1. The increased coefficient of friction could only be caused by an absence of a lubricating layer. This lubrication has been found to be a liquid-like, water film.

An average person standing on ice with a pair of ice skates would not produce nearly enough pressure to melt ice and produce a liquid film. Even while wearing ice skates, the pressure the person would produce lowers the freezing temperature only approximately 0.028°C (Chang, 2006); therefore, the temperature would have to be exactly 0°C for any melting to occur. Ice skating is, however, possible at temperatures well below 0°C (Chang, 2006).

There is not enough friction between ice and steel to produce the heat needed to melt the ice (Kietzig, 2010). Once again, the temperature would have to be exactly 0°C for melting to occur; otherwise, the ice would simply increase slightly in temperature for a short while, then return to its original temperature without a change of phase. In addition to this, when standing still on ice with a pair of shoes, a person produces no friction on the ice, yet the ice is still slippery.

It has been determined that the liquid-like film noted above nearly always covers the ice (Rosenberg, 2005; Haché, 2008). The film is produced by molecular interactions. The outermost layer of atoms of the ice is unstable because the atoms do not have other atoms and molecules surrounding them on all sides. In turn, they vibrate and break free, causing surface melting. This outermost layer melts until the liquid-like film covers the entire surface, and every atom in the ice structure is surrounded on all sides. The liquid-like film, however, ceases to exist at temperatures near -200°C; this is the point at which the coefficient of friction of 0.15 is present (Kietzig, 2010). In any other case, the coefficients of static and kinetic friction between steel and ice are approximately 0.10 and 0.05 respectively.

## Structure of Ice Hockey Skate Blades

The shape and overall features of an ice skate blade vary among hockey skates, figure skates, and speed skates. The blade of an ice hockey skate is designed specifically for the needs of an ice hockey player.

### General Features

Most ice hockey skate blades are made of stainless steel for several reasons. First, stainless steel will not rust, so the blade will remain in usable condition for as long as possible. Second, stainless steel is hard enough to endure the wear of prolonged use. Third, while being hard enough to resist most damage, stainless steel is soft enough to be easily sharpened to suit the user.

The width of the blade is constant at all points on an ice hockey skate and is approximately 3mm (U.S. Patent No. 4,907,813, 1990). This width is necessary for ice hockey skate blades because of the material of the blade and because of the effect the blade has on the ice. A stainless steel blade width of less than 3mm can easily be malformed by impacts with the ice, with the hockey puck, or with ice skates. A thinner width would also cause the blade to dig into the ice during ice hockey maneuvers. Most actions performed in ice hockey use the toe section of the blade, ranging from the toe of the foot to the ball of the foot, and would cause it to cut into the ice deeply, interfering with the movement of the user (U.S. Patent No. 4,907,813, 1990). A stainless steel blade width of greater than 3mm would slow the user because of the greater surface area of blade being in contact with the ice at any given point.

There are three major sections to the ice hockey skate blade: the toe, the median, and the heel. The median is the section of the blade that is exposed to the ice while the user is motionless. The toe and heel are the sections before and after the median that are curved upward toward the user. They end where the blade meets the structure that secures it to the boot. While the median is shaped and sharpened in a specific manner, the toe and heel are shaped in a general manner and sharpened in a way similar to that of the median.

Sharpening Features

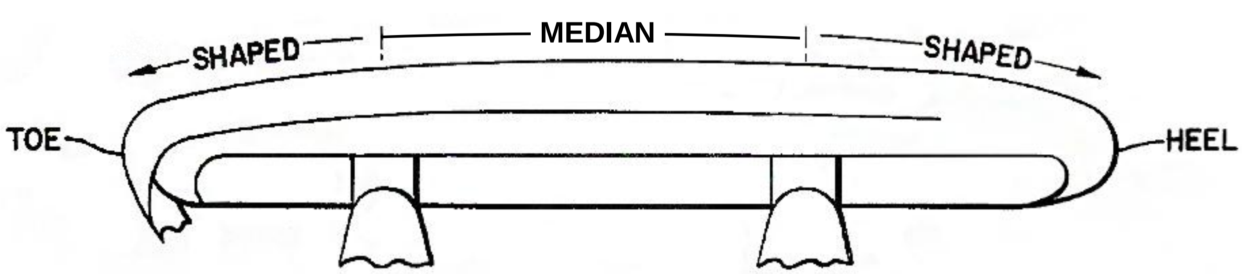


Figure 2. Profile of ice hockey skate blade. From left to right, the blade comprises a shaped toe, median section, and shaped heel. The median section is the portion that is sharpened to match the radius of curvature. The point of tangency is not restricted to this boundary; it can be located anywhere from the shaped toe to the shaped heel (adapted from U.S. Patent No. 4,907,813, 1990).

All ice hockey skate blades have three main sharpening features: the radius of curvature, the point of tangency, and the radius of hollow. Each of these features plays a separate role in the overall function of the blade and can be altered independently of one another.

The radius of curvature of the blade determines the length of blade that encounters the ice at any given point. It is simply a small portion of the circumference of a circle with a radius between 1.83m and 4.57m; the larger the radius, the larger the circumference and the longer the length of the blade that is touching the ice at any one point and vice versa with a smaller radius. The smaller the radius, the more speed and stability decrease; turning ability, however, increases. With a larger radius, the opposite occurs: speed and stability increase while turning ability decreases.

The point of tangency is best described as being the highest point of the skate blade. It is the first point of the blade that comes into contact with the ice during ice skating and can be located at an infinite number of different positions on an ice skate blade. A point of tangency that is located toward the heel of the blade aids in skating backward; therefore, a point of tangency located toward the toe of the blade aids in skating forward (Christopher Davidson-Adams, personal communication). Additionally, a tangent point located in the center of the blade gives equal maneuverability in the forward and backward direction. A U.S. Patent for a skate blade analyzer indicates three major points at which the tangent point can be located with a limited number of graduations between them (U.S. Pat. No. 4,161,822, 1979). These points are center, slightly nearer the toe, and slightly nearer the heel and are relatively close together when compared to the overall length of the ice skate blade. Conversely, a U.S. Patent for a skate sharpening machine shows that the point of tangency can be at an infinite number of positions from the toe to the heel of the blade, giving numerous options to satisfy any preference (U.S. Pat. No. 3,988,124, 1976).

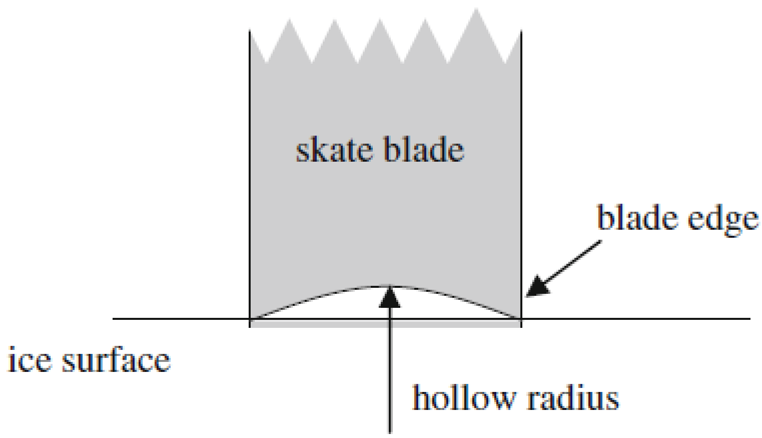


Figure 3. Diagram of ice skate blade showing hollow radius. The radius of hollow of the skate blade determines how deep the blade will cut into the ice. A smaller radius will cause the blade to dig deeper into the ice; a larger radius will not cut as deep (Federolf and Redmond, 2010).

The radius of hollow of the ice skate blade determines how large the gap is between the parallel surfaces of the blade. As the radius of hollow of an ice skate blade decreases, the drag of the blade on the ice, the sharpness, and the traction of the blade increase. As the radius increases, the drag, sharpness, and traction decrease. The hollow radius is generally altered by increments of 3.18mm between 3.18mm and 38.1mm. The two edges that result from this hollow use the thin liquid film on the ice to glide. The hollow also affects how this film is formed and distributed. Few studies relating to the radius of hollow have been completed; for example, a study has been done on the radius of hollow as it relates to oxygen consumption while skating. In addition, a separate study has reported varying lactic acid accumulation with no effect on performance. Federolf and Redmond (2010) infer, however, that users may not be skating with their optimal skate configuration. The hollow radius could be altered more than it was in either study and the change could affect performance.

## Research Proposal

The current objective is to improve the physical function of an ice hockey skate as it relates to the blade’s radius of hollow, radius of curvature, and point of tangency by standardizing the sharpening style of the blade. This objective will be completed by testing various levels of sharpness of the ice hockey skate blade for speed, acceleration, deceleration, and drag. Specifically, the project will test positions of the point of tangency of the slate blade as well as various radii of hollow of the blade and several radii of curvature of the blade. Technology and techniques for skate sharpening will be employed by Chris Davidson-Adams, the Head Equipment Manager of the Worcester Sharks. Following this, the velocity, acceleration, and drag of the modified skate blades will be compared. These modifications include levels of sharpness, points of tangency, radii of hollow, and radii of curvature. The modified skates will be tested by several members of the Worcester Sharks ice hockey team at the DCU Center in Worcester, MA.

# Methodology

## Sharpening the Ice Hockey Skate Blades

The rivets securing the blade support (TUUK brand) to the skate boot were visually checked for damage and other flaws. The blade (TUUK brand) was then visually checked to ensure its straightness and stoned using a 100-grit sandstone abrasive to flatten the sides. The abrasive was firmly pressed against one of the exposed parallel sides of the blade and rubbed from heel to toe and back until the side was flat (approximately 7 passes in each direction). The process was then repeated on the other parallel side. The blade was visually assessed for nicks along its sharpened surface and placed aside on a table. The grinding wheel (80-grit) was dressed to the appropriate radius using a standard spinner disc (Blackstone Spinner System, for which a patent is pending) with the appropriate radius. The center of the skate blade was then aligned to the center of the standard ice hockey skate holder, and the skate was secured in place. The exhaust fans and grinding wheels of the sharpener were then activated. The fans and wheels were allowed to reach their maximum velocity. The handles of the skate holder were then grasped firmly, and the skate and holder were aligned with the grinding wheel such that the median of the blade was at approximately a 30° angle to the grinding wheel shield and the toe of the blade was on the right side of the grinding wheel. The blade was then translated across the surface of the grinding wheel from right to left at a slow, constant speed, following the contour of the blade from the toe to the heel. The process was repeated until all nicks were removed and the desired radius was achieved. Prior to the last repetition, cutting oil (Fine Shine brand) was applied to the sharpened surface of the skate blade. In addition, the last repetition was slower than the previous passes. The skate was then unsecured and removed from the holder. The blade was stoned once more with a sandstone abrasive (220-grit) in a method identical to the prior stoning to give it a smoother finish. Blade glaze (Maximum Edge brand) was applied to remove burrs and excess metal shavings. A small drop of the blade glaze was placed on a piece of leather (2cm by 3cm) and spread evenly across the surface. The coated side of the leather piece was then rubbed firmly along the entire surface of the blade. The entire process was repeated for the other skate.

## Testing the Modified Ice Hockey Skate Blades

Several members of the Worcester Sharks professional ice hockey team were recruited from the DCU Center in Worcester, MA. The subjects, Caucasian males between the ages of 20 and 30, were informed that they would be testing various styles of sharpening of skate blades. The TUUK brand skate blades were sharpened immediately before each trial, and it was ensured that the sharpened edge of the blades was not exposed to any unprotected or damaging surfaces prior to the trial. The blades were sharpened using a skate blade sharpening machine (Blackstone brand Stealth model) and were kept protected until the trial using standard hard ice hockey skate blade guards. Once the trial had begun, the blade guards were removed, and testing commenced. Each trial comprised a five minute period of free skating that included skating forwards, skating backwards, at least one turn of a large radius (approximately

12.8m), one turn of a small radius (between 3m and 7m), one instance of freely gliding forwards, and at least one stop. When the testing was completed, the skates were removed, dried thoroughly using a standard paper towel, and the blade guards were replaced. Immediately after the subjects left the ice, they were given a survey to complete. The survey was a short questionnaire in which the subjects rated their testing experience based on several possible effects of the altered blade sharpening style. The surveys were then collected by the researcher and filed according to the respective subject.

## Results

| | Player #1 | | | Player #2 | | | Player #3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Current | Adjusted | | Current | Adjusted | | Current | Adjusted | |
| Radius of Hollow (mm) | 15.88 | 12.70 | 19.05 | 12.70 | 9.53 | 15.88 | 15.88 | 12.70 | 19.05 |
| Radius of Curvature (m) | 3.048 | 2.743 | 3.353 | 3.353 | 2.743 | 3.962 | 3.048 | 2.743 | 3.353 |
| Point of Tangency (cm) | 0.00 | -1.27 | 1.27 | 0.00 | -1.27 | 1.27 | 0.00 | -2.54 | 2.54 |

Table 1. Current and adjusted radii of hollow, radius of curvature, and point of tangency of three test subjects.

Player #1 originally had a radius of hollow of 15.88mm and tested hollows of 12.70mm and 19.05mm respectively. To the first test, the subject responded that the blade was too sharp and had too much of a groove, causing the blade to get caught on the ice frequently. To the second test, the subject responded that the blade was too dull and the groove was not deep enough. In addition, he stated that stopping was difficult and he had decreased traction in his movements. Player #1 originally had a radius of curvature of 3.048m and tested radii of 2.743m and 3.353m. The subject responded that the radii of 2.743m did not allow enough of the blade to come in contact with the ice at any given point. He responded that the radius of 3.353m allowed too much blade to come in contact with the ice, making turning difficult and accelerating awkward. Player #1 originally had a centered point of tangency and tested tangent points 1.27cm toward the toe of the blade and 1.27cm toward the heel of the blade. The subject responded that the tangent closer to the toe caused him to feel as though he was going to fall forward and caused him pain in his lower back. In addition, the tangent closer to the toe caused him to feel as though he was going to fall backward and greatly hindered his ability to skate forward.

Player #2 originally had a radius of hollow of 12.70mm and tested hollows of 9.53mm and 15.88mm respectively. The subject responded that the radius of 9.53mm caused the blade to be unusably sharp and difficult to use. He responded that the radius of 15.88mm caused the blade to feel flat in comparison to his original setting. Player #2 originally had a radius of curvature of 3.353m and tested radii of 2.743m and 3.962m,. Similar to Player #1, the subject responded that the radius of 2.743m did not allow enough of the blade to come in contact with the ice and the radius of 3.962m allowed too much blade to come in contact with the ice. Player #2 originally had a centered point of tangency and tested tangent points 1.27cm toward the toe and 1.27cm toward the heel. He responded that the tangent closer to the toe made it difficult for him to skate backwards while making skating forwards an entirely different experience from his original setting. The tangent closer to the heel made him feel unbalanced, thus hindering his ability to skate forward and backward.

Player #3 originally had a radius of hollow of 15.88mm and tested hollows of 12.70mm and 19.05mm. He responded that the radius of 12.70mm was too sharp and cut the ice too deep. The subject responded that the radius of 19.05mm caused the blade to feel smooth and dull, making every aspect of skating difficult for him. Player #3 originally had a radius of curvature of 3.048m and tested radii of 2.743m and 3.353m respectively. The subject responded that the radius of 2.743m made him feel as though he was not accelerating as well and made turning awkward. He responded that the radius of 3.353m did not affect his acceleration but hindered turning. Player #3 originally had a centered point of tangency and tested tangent points 2.54cm toward the toe and 2.54cm toward the heel. Similar to the other two subjects, he responded that the tangent closer to the toe made skating backward more difficult while the tangent closer to the heel made skating forward more difficult. He also responded that the tangent closer to the toe caused him slight lower back pain for the duration of the test.

## Data Analysis and Discussion

The data collected were inconclusive in terms of the original idea of the project, to improve and standardize the sharpening style of ice hockey skate blades. The data gathered show that the sharpening style of a user's hockey skates depends on the individual, not the position they play in the game of hockey or, for recreational skaters, preference of skating style. The only trends noticeable in the data were in the players' responses to the altered sharpening. When a radius of hollow was decreased, a deeper cut in the ice and more prominent groove were reported; when it was increased, a shallower cut in the ice and difficulty in stopping were reported. A decreased radius of curvature caused reports of an uncomfortably small amount of blade touching the ice at any point; an increased radius of curvature caused reports of difficulty in turning. A point of tangency nearer to the toe caused an uncomfortable forward lean; a point of tangency nearer the heel caused an uncomfortable backward lean. Each of the three test subjects exhibited these trends in every trial with no anomalous data.

# Conclusions

The data collected lead to the conclusion that the sharpening style of ice hockey skate blades cannot be standardized; therefore, the current objective to improve the blades in relation to the sharpening style cannot be achieved. As stated above, the determination of the style of sharpening that best fits an individual by their position in the game of hockey or by a given set of preferences is impossible. As a result, the original method of trial and error of individual settings remains the preferred method of achieving the most suitable overall sharpening style of an ice hockey skate blade.

## Limitations and Assumptions

For the experiment to be designed, several assumptions were made and constants were set. First, air resistance was determined to be negligible. Second, it was accepted that the responses to the given survey were both accurate and honest. Third, the tester assumed that the instruments used to measure the sharpness of the blades were accurate. The ambient temperature and humidity of the room and the temperature of the ice were kept constant for every test. In addition, the sharpness of the blades was maintained throughout the testing period. The sources of error present in the work were the actual presence of air resistance, inaccurate measurement of the aspects of the sharpening, and inaccurate responses to the administered survey.

## Applications and Future Experiments

The work completed will improve a vital aspect of the game of hockey. It will remove the doubt from which style of sharpening best suits a player by dramatically narrowing down the scope of possibilities. The current style of sharpening leaves the user to a process of trial and error to discover the settings that fit his or her own preferences, leaving much room for imperfection. The suggested style will find the exact settings or approximate settings for each user depending on the position they play in the game of hockey or by request of traits they would like their skate blades to exhibit. With the suggested style, the user can find his or her preferred settings with ease, allowing for better precision while ice skating and more control over individual movements. After the completed work, further testing could commence to refine the sharpening method. Then, the style could be employed for use by professional ice hockey players. Future research could include automated sharpening of ice hockey skates using the suggested method, allowing for more precise sharpening and, in turn, the ability to fine-tune the blades.

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