Bearings and Tribology Affect Inline Skating

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Background

Inline skating can be an enjoyable and highly effective fitness training activity. It has approximately the same calorie burn rate as running with less than half the impact load. There are four broad categories of inline skating: aggressive, hockey, fitness/recreational, and speed skating. While this categorization is not exhaustive and omits cross-over styles (like exhibition) it does include the most distinct types. This article will focus on equipment selection in the context of applying mechanical engineering (ME) principles to avoid marketing traps and satisfy functional needs. We will begin with a brief history of the product then describe, in summary form, the styles of blading and how this impacts equipment selection and finally discuss the issue of bearings, lubricants and wheel selection. These three machine elements are the primary differentiator between price points and have the largest impact on the products' performance characteristics.

The earliest known conceptualization of an inline skate dates back to the 1700's when a Dutchman attempted to simulate ice skating by nailing wooden spools to strips of wood attached to his shoes. Versions of the in-line skate resurfaced periodically, but the concept did not catch on. Given the technology of the time, in-line skates could not be designed to function as well as conventional roller-skates. By 1930, roller skates had found a permanent place in society. In 1980, two hockey players chanced upon a set of inline skates and found them to be ideal for off-season training. They subsequently formed the Rollerblade® company re-introducing inline skates to the mainstream. Beginning in the 1990's, inline skating has enjoyed immense, and growing, popularity and has moved to entirely new market segments. While still having a strong hockey following, the sport now has cross-overs from skate boarders (aggressive) and, most importantly, has penetrated the fitness market.

The four identified styles are described as follows:

<u>Aggressive</u>
This style is characterized by brazen stunts including half pipe (a U-shaped trough that bladers jump in, on or through), sliding down railings, jumping stairs and "wall walking". These blades are generally very rugged, have grind plates on the frame (to protect the frame and allow easier sliding on railings) and smaller softer wheels.

<u>Hockey</u>
As noted, this is where inline skating evolved. It allows hockey players to train off season and without recourse to an indoor ice skating rink.

<u>Recreational/Fitness</u>
This is the largest market segment because it captures the fitness crowd. When one goes to a sporting goods store, the majority of the skates available usually fall into this category. Price points are anywhere from $25 to about $200. Above $200 lies the more specialized equipment (mostly speed skating).

Speed Skating

Speed skating is really a separate category because the equipment is more specialized (and expensive). For example, a speed blade will have one additional wheel (five wheels instead of four) on each frame, larger wheels and mid cut boots.

There is a lot of equipment that can be used for the first three categories but when we talk about high-end fitness or speed then the selection becomes more specialized. For example, speed blades would not be suitable for aggressive skating.

Machine Elements: Engineering Reality vs. Marketing

Bearings, lubricants, and wheels are the three primary determinants of product performance. Other factors such as boot ergonomics, stiffness and frame geometry are not to be ignored, however. There is lots of mythology in the sport literature but not much product performance data. For example, what is the traction torque of a "really fast" bearing? What is the viscosity of that "super slick" lube? And, why does it cost $7/oz instead of $.10/oz for 80W-90 gear oil? Some basic engineering fundamentals will help keep money in your pockets and the wheels on the ground (except for aggressive skating).

Bearings

Inline skates use rolling element radial ball bearings. The standard size is the "608" (common in vacuum cleaner motors) which is 8mm ID, 22mm OD by 7mm wide and are of a steel (typically 52100) construction. There are other sizes available like the "688" mini, but the 608 is the standard. When shopping for these bearings, the marketing "value proposition" usually centers around its ABEC rating. It is said that the higher the ABEC rating the better.

The ABEC (Annular Bearing Engineering Committee) standards control the manufacturing tolerance of the bearing. The higher the ABEC rating the tighter the tolerance. For example, a 608 ABEC 1 bearing has an OD tolerance of .0000" to -.0004" while an ABEC 7 is .0000" to -.0002". Take note, this is not related to IRC (Internal Radial Clearance) it is only the production tolerance band. The relevant question is whether a higher ABEC rating (and higher cost) equates to lower traction torque (what you feel when you blade) and the short answer is no.

For low DN (bore ID, mm x RPM) bearings, less than 100,000 DN, the manufacturing tolerance does not have a significant impact. The ABEC rating becomes more important at high DN (around 1 million) where dynamic considerations (like ball excursion) come into play. For comparison, a blader doing around 12 mph on 80MM OD wheels would be at 10,000 DN. This is essentially a static load case. A high ABEC rating is important for bearings used in high precision instruments where the bearings would add tolerance stack that degrades instrument precision.

The other choice to make is whether to buy conventional steel bearings (the most common) or go to the extra expense of a hybrid ceramic. A typical bearing, for inline skates, will be made from 52100 steel (a high carbon steel) which is quite adequate. A hybrid ceramic has Silicone Nitride (SiN) balls within a steel inner and outer race. Hybrids have far superior characteristics at higher speeds (> 1.5 million DN) than steel bearings. The reasons are that SiN is lighter than steel so the centrifugal loads (and hence contact stress) is lower resulting in a longer fatigue life. SiN has a lower thermal expansion coefficient so the IRC does not change much, reducing the thermal pre-load effect. As an added bonus, SiN is impervious to corrosion and appears to be more damage tolerant. It is possible that hybrid ceramics may provide a marginal benefit in a skate application in spite of the 50% to 300% cost increase. The marketing literature claims that hybrids require less lubrication. Personal test experience with hybrid ceramics (for missile engine applications) does not support this assertion. It is likely that this claim is based on the fact that hybrids can run at higher temperatures (lower thermal expansion) and is simply more forgiving of lubrication deprivation. However, this would not be noticeable to a blader.

In conclusion, for aggressive and hockey bladers, an ABEC 1 is more than sufficient. Also, the quality levels on all the reputable brands is at ABEC 3 or better in any case (even if marked ABEC 1). For a casual fitness blader (20 minutes typical session) an ABEC 3 or 5 will suffice. For the hardcore fitness types (>1 hrs per trip) an ABEC 5 or hybrid would be suitable.

The primary drivers for traction torque will be the internal geometry like race/ball finish, ball diameter to race curvature, and the number of rolling elements. These are not controlled by the ABEC rating.

Lubricant: To Grease Or Not To Grease

The purpose of a lubricant in the bearing is to provide a fluid film for elasto-hydrodynamic lubrication (EHL), convey heat out of the bearings and guard against contaminants. For inline skating there are two choices (if not buying pre-packed grease bearings); grease or oil lube. Each has it's advantages.

Grease lubing has the following benefits: it is really cheap and lasts a long time between maintenance intervals. Greases also provides superior contamination resistance which is good for those who blade in wet or sandy conditions. The downside (from personal experience) is that a grease packed bearing feels very "draggy", almost like one put taffy in all 16 bearing sets.

Oil lubing is best for those who need the absolute lowest running torque and are willing to tolerate a higher maintenance level for their hobby. The question is what lubricant to select? The lubricants available sold specifically for inline skating applications typically sell for $5-$7/oz compared to less than $.11/oz for a premium motor or gear oil. What is the difference? Typically for a low load, low speed application such as blading, one would want a high viscosity oil with a tackiness additive and perhaps a demulsifier (to get water out of the oil). The high viscosity is mandatory since the EHL film thickness is proportional to the ball entrainment velocity (not very high) and viscosity. Should the film be too thin then adhesive wear, from boundary lubrication, will cause accelerated bearing wear and lower life. Tackiness is important for lube retention in the bearing. Unfortunately, this data is not available for lubes marketed for the inline skate market. It is available for the popular motor and gear oils. So what to do?

80W-90 gear oil was tested and confirmed to be the optimum lubricant. The reason is that this oil is very cost effective (allowing for very frequent servicing that will keep hard particle contamination out) with a high viscosity. During testing, careful attention was paid to signs of discoloration indicating lube deprivation and high running temperature.

The bottom line is that each user will have to evaluate their own blading style and choose according to their needs. Those desiring low maintenance and high contamination resistance should use grease. Most others should use oil.

Wheel Selection

This is a simpler topic. There are only two things that need consideration and the rest is marketing. That is wheel size and durometer. Make sure the wheel is polyurethane (most are) or one could take a ride on the fleecing railroad! Durometer refers to the wheel's hardness, very important! Softer wheels like 78A provide better traction but wear much quicker and have a higher rolling resistance. Harder wheels last longer, have a lower rolling resistance but have slightly less traction. The authors experience (2X a week at 1hr 45min average) is that with higher durometer wheels, longer life is noticed but not reduced traction. So, for distance and speed, the higher durometer wheels (85a or 88a) are better. For the hockey or aggressive skater, the softer wheel (75a durometer or lower) is better.

Size refers to the wheel OD. A speed or fitness blader will want a larger wheel (preferably 80MM) since these offer a lower rolling resistance. This is true because the larger wheels have a smaller contact area for a given load and have the added benefit of enabling the blader to roll through more debris. But, keep in mind, an inline skate that can accept a large wheel will need a longer frame. This is good for speed and distance since it is more stable but makes them sluggish for hockey or aggressive skating.

The author's recommendation for wheels are:

Recreation/fitness and speed skaters: 80MM (or 84MM if possible) and 82a (fitness) and 88a (for the Forrest Gump on blades crowd). The latter for frequent long journeys; the 85a or 88a will have a noticeably longer life and the reduced drag really is noticeable.

Aggressive: The author notes that 72mm x 90a seems to be typical for this category.

Conclusion

This article was not meant to be a definitive guide to inline skating equipment selection but rather a guide to how one can attempt to apply basic mechanical engineering principles when buying inline skating equipment.

The user should evaluate their skating style and training needs against what is available. With the proper equipment (especially protective gear!) inline skating can be extremely beneficial to personal fitness and weight-loss programs, is fun, and is a cool way to show machine design in action!

About the author:

Fred Ahrens, PE is also an adjunct instructor at both the University of Cincinnati College of Applied Science and Cincinnati State Technical and Community College where he teaches courses in mechanical engineering technology. Mr. Ahrens' industry experience specializes in the design, analysis and test of bearings, seals and drives.