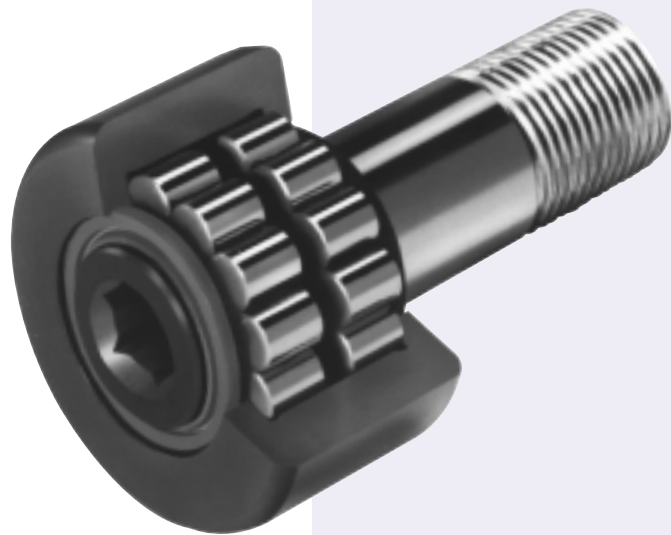


**The Cylindrical Roller
Cam Follower —
A Superior Product
for a New Century of
Industrial Applications**



Werner Guilford
Director of Engineering
RBC Bearings



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RBC Roller® Cylindrical Roller Bearing Cam Follower
 U.S. Patent Number 5531137

RBC Roller®

In response to strong market demand for a more durable cam follower capable of higher operating speeds and reliable, maintenance-free operation, RBC developed and patented the cylindrical roller bearing cam follower — the RBC Roller Long Life™ cam follower.

This technical paper presents an itemization of the engineering design features that afford this superior level of performance and compares these characteristics to the classic needle bearing cam follower design.

The RBC Roller provides an important and measurable step forward toward the goal of maintenance-free reliability in harsh operating environments.



Needle Roller Cam Follower (Classic Design)

Comparison of Cylindrical Roller to Needle Roller

A look at the internal design of a standard needle bearing cam follower versus a cylindrical roller bearing cam follower tells an important story. Compare the accompanying section figures of a typical full complement needle roller cam follower (*Figure 2*) with the full complement cylindrical roller cam follower (*Figure 3*). It is quite obvious that in the latter design, 2 rows of cylindrical rollers replace a single row of small diameter needle rollers. In addition, contacting lip seals replace the combination gap seal and thrust washer. Typically, the cylindrical roller bearing cam follower is lubricated for life and, therefore, eliminates the need for lubricating holes.

Switching to cylindrical rollers delivers other benefits, as well. Dynamic capacity is primarily a function of the roller diameter, thus dynamic capacity increases and is, therefore, greater per unit of O.D. size (*Figure 1*). This means better fatigue endurance. To make room for the larger roller diameter, the wall thickness of the outer ring has been reduced to comply with standard boundary dimensions of the series.

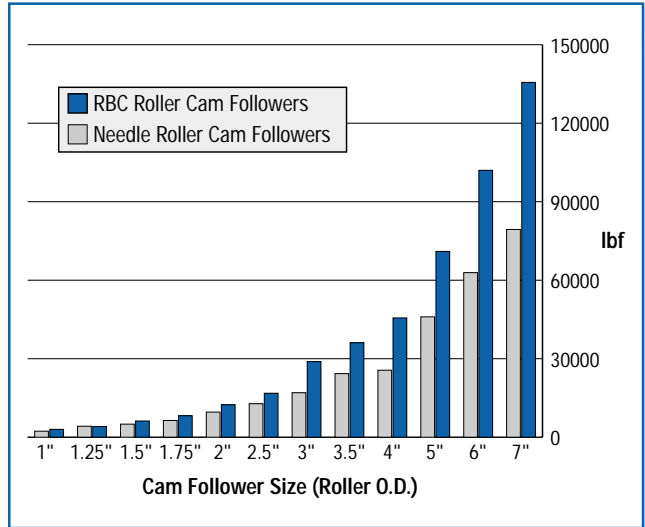


Figure 1: Comparison of Dynamic Capacity

Axial Guidance of the Outer Ring

There are additional design differences between cylindrical roller and needle roller cam followers. The most significant is the axial guidance of the outer ring. In *Figure 2*, we see a typical needle roller cam follower design. The outer ring is guided between the two flanges and will rub against one or both of them under thrust load. To avoid direct metal-to-metal contact between the outer ring faces and these retaining flanges, the seal typically has an extension reaching into the gap between outer ring and flange. The radial extension then functions as a plastic thrust washer. To fulfill such a function, the seal material must have good load carrying ability and must be reasonably stiff.

These requirements demand material properties that are contrary to effective seal materials, where pliability is a desirable characteristic. Consequently, these seals operate as gap seals and depend on a grease barrier and frequent relubrication for survival. A very weak link in the design.

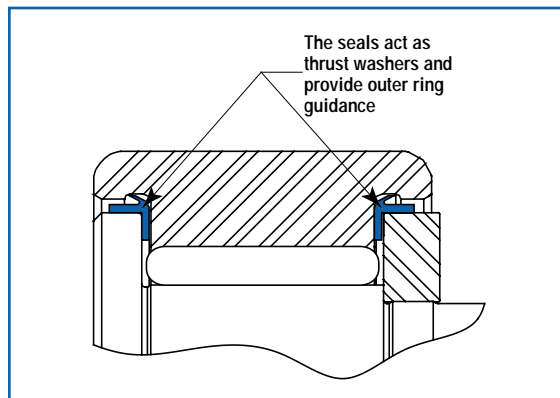


Figure 2: Needle Roller Cam Follower

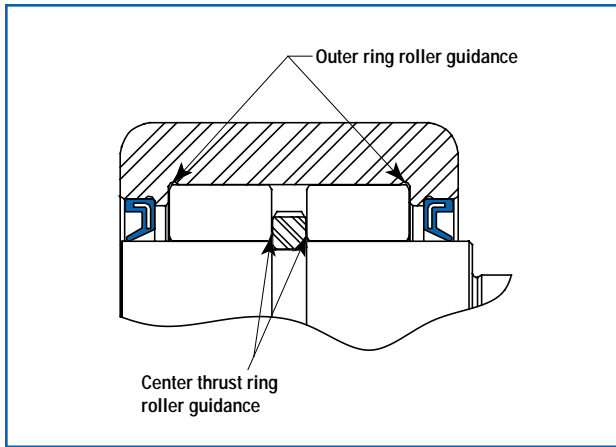


Figure 3: Cylindrical Roller Cam Follower

On start-up, these cam followers purge excess amounts of grease through the gap seals. Once that process is completed, the lubricant flow stops until relubrication. The thrust washer portion of the seal itself has only limited capabilities to support thrust forces. If they are too high, the washer wears or, in a worst case scenario, melts. Then metal-to-metal contact occurs which, in the absence of a lubricant flow, will quickly cause abrasive or adhesive wear on the contact surfaces.

In contrast, the faces of the rollers provide the guidance for the outer ring of a cylindrical roller cam follower (Figure 3). While this is still a steel-on-steel sliding contact with comparable sliding velocities and contact pressures, it achieves superior performance primarily due to better lubrication conditions. The rolling action of the rollers carries new lubricant into the contact area during each revolution, and the flanges at both ends of the outer ring keep the centrifugal force from purging the grease. Additionally, the contacting lip seals keep grease inside the bearing, and seal on ground bearing quality surfaces.

Roller Guidance

Roller bearing maximum operating speed is very much dependent on the guidance of the rollers as they enter the load zone. Roller guidance differs radically between needle roller and cylindrical roller cam followers. By definition, face guidance and the capability of transmitting thrust through the roller requires a rolling element with a length-to-diameter ratio of 2.8 or less. Needle rollers, on the other hand, have a length-to-diameter ratio of greater than 2.8 and can be neither face guided nor can they carry thrust load. A face guided cylindrical roller can enter the load zone in nearly perfect alignment. Needle rollers depend on the curvature of the outer ring raceway to correct misalignment acquired while traveling through the unloaded zone of the bearing. This simply means that cylindrical roller cam followers can operate at higher speeds than their needle roller counterparts.

Alignment by curvature alone is not very efficient. The needle rollers may still maintain a small amount of misalignment as they move through the load zone, resulting in sliding and heat generation.

Relative Rotation of Rollers

In full complement bearings, adjacent rollers rub against each other in opposing directions. As a result, the grease film on the roller surface experiences a shearing action, which tends to deteriorate the quality of the grease through oxidation. The amount of shear is directly related to the number of rolling elements, which determines at how many places shear occurs. The relative velocity of adjacent rollers is also a determining factor in the generation of shear forces. With fewer rolling elements of larger diameter, the cylindrical roller cam follower has fewer locations of shear and the relative velocity between rollers is lower than in a needle roller cam follower (Figure 4). That means the grease charge in cylindrical roller cam followers does not oxidize as quickly, which makes a "lubricated for life" cam follower feasible.

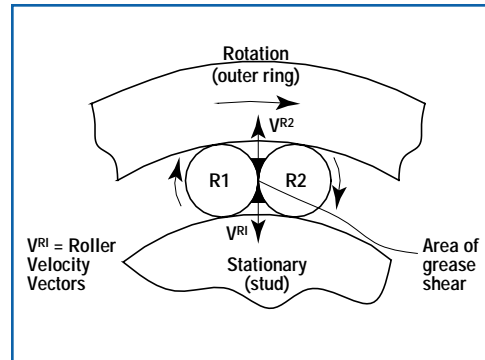


Figure 4: Grease Shear in Full Complement Roller Bearings

Grease Charge

The maximum amount of grease a bearing can contain is simply a function of the free space available inside the bearing. In other words, it is the volume bounded by the outer raceway, the inner raceway, and the width minus the volume of the rolling elements, plus whatever additional space there may be. In standard needle roller cam followers, the multitude of needle rollers occupies most of the available space, leaving a scant amount of room for grease. The grease charge primarily fills the void between adjacent rollers and the inner or outer raceway (Figure 5). The primary mode of failure of these products is a lack of lubrication resulting from deferred maintenance practices. The greater the grease charge, the longer the product will perform in most common applications.

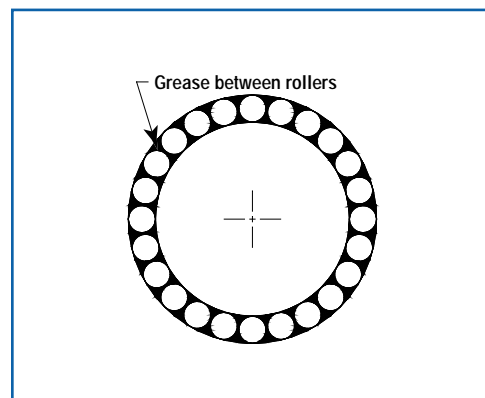


Figure 5: Free Space for Grease – Needle Roller Design

In a cylindrical roller cam follower, these voids between rollers and raceways become larger, although there will be fewer of them. But additional space for lubricant is provided in the area between the two rows of rollers and between rollers and seals. This results in up to four times more grease in like-sized cylindrical roller cam followers than needle roller cam followers (Figure 6). In 95% of all applications, more grease supply means longer service life.

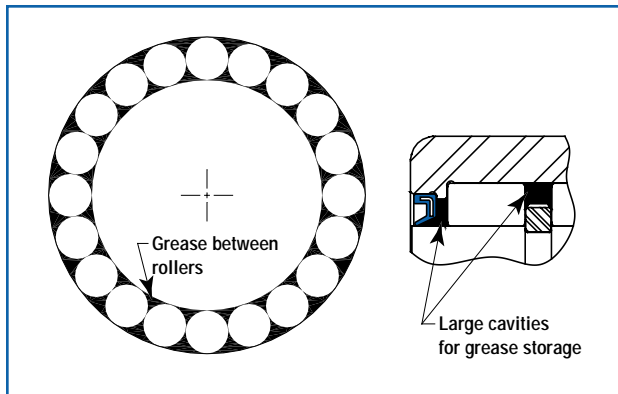


Figure 6: Free Space for Grease – Cylindrical Roller Design

Seals

The function of seals is to keep the lubricant in the bearing and to keep contaminants out. It has already been demonstrated that gap seals by themselves do not do a convincing job at either of these tasks and typically need help from a grease barrier to be effective (Figure 7). In

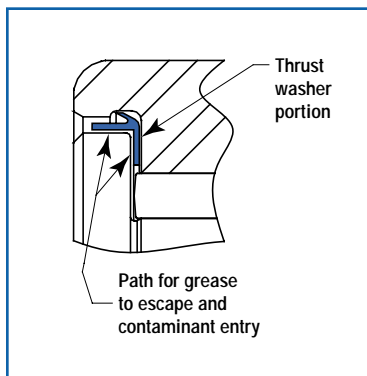


Figure 7: Non-contacting Gap Seal – Needle Roller Design

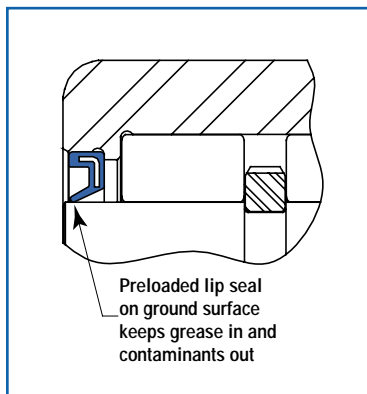


Figure 8: Contacting Lip Seal – Cylindrical Roller Design

addition, there are limited choices concerning materials, since the seal is also required to fulfill the function of a thrust washer in typical needle roller cam follower designs.

Contacting lip seals as used in the RBC Roller have only one function: to seal the bearing (Figure 8). This makes it possible to adapt the seal material to a wide variety of requirements — resistance to chemicals, ozone, salt water, and elevated temperatures, to name a few. While the standard seal of an RBC Roller is not meant to seal against pressure, it is also possible to employ a spring loaded lip seal for that purpose.

Origin of Thrust Forces

This section will briefly examine the origin of thrust forces with which a cam follower must contend. It can be assumed that the cam follower outer ring is not axially constrained (e.g., by running in a channel, a condition that would introduce unpredictable thrust forces). In a typical application, the cam follower runs on a track parallel to its axis and its surface can only support perpendicular forces. Under these constraints, thrust forces will be generated by misalignment, either because the cam follower axis is not parallel to the track (called **Type I Misalignment – Figure 9**), or the cam follower axis is not perpendicular to the direction of motion (called **Type II Misalignment – Figure 10**). Naturally, there can be a combination of the two to make things more difficult. Additionally, misalignment is not easy to detect by inspection.

As seen in **Figure 9**, the axis of the cam follower is tilted with respect to the raceway. The amount of thrust is a function of the tilt angle and is typically fairly small. The outer ring rests on the track over its full length and the misalignment takes place internally, as long as the angle falls within the diametral clearance of the bearing. The misalignment can thus not be detected by trying to shine a light through the contact, but is immediately apparent by looking at the contact area on the outer ring OD after a short period of operation. This condition produces internal roller end loading, which can be accommodated by using a crowned outer ring. Since cam followers are cantilevered devices, Type I misalignment occurs as the stud deflects under load. Type I misalignment is

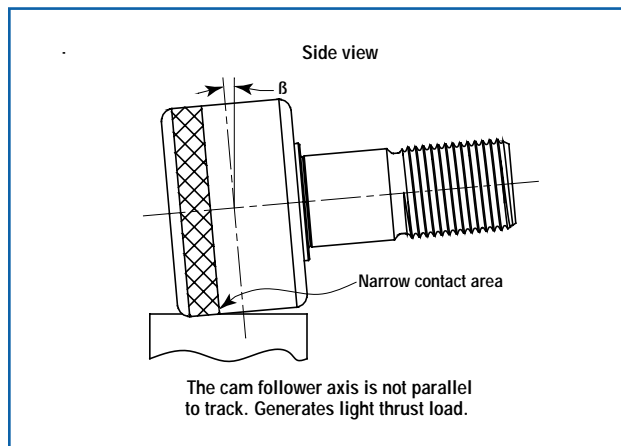


Figure 9: Type I Misalignment

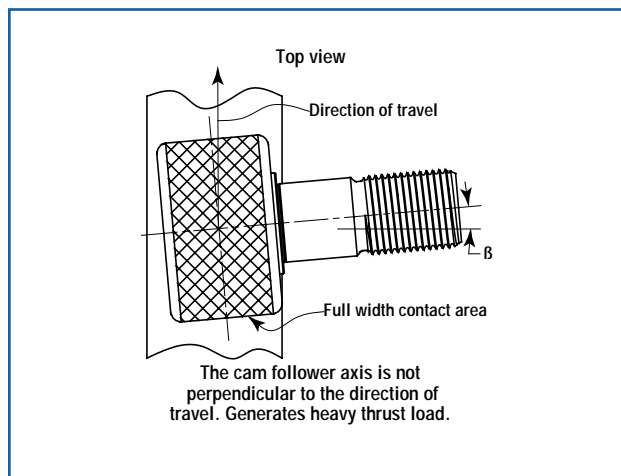


Figure 10: Type II Misalignment

unavoidable and shortens the life of needle bearing cam followers and compromises the sealing capability. The cylindrical roller cam follower was developed to remedy this problem by providing more positive roller end support. This improves the cam follower's ability to sustain and manage thrust loads resulting from Type 1 misalignment.

Figure 11 shows the Type II misalignment with the cam follower axis not perpendicular to the direction of motion. In this case, the outer ring wants to roll from point A to B, but is forced to point C by the equipment. The cam follower gets to C by a simultaneous rolling and sliding action consisting of rolling from A to B and sliding from B to C. The thrust force generated by the sliding motion is the radial load times the coefficient of friction between outer ring and track. Note that the angle of misalignment does not enter into this equation, therefore the magnitude of the thrust force is independent of the angle. However, the work done on the system and the amount of wear generated on the outer ring and the track is very much a function of the angle of misalignment. To minimize the wear from Type II misalignment, it is imperative that the track be lubricated to keep the coefficient of friction as small as possible.

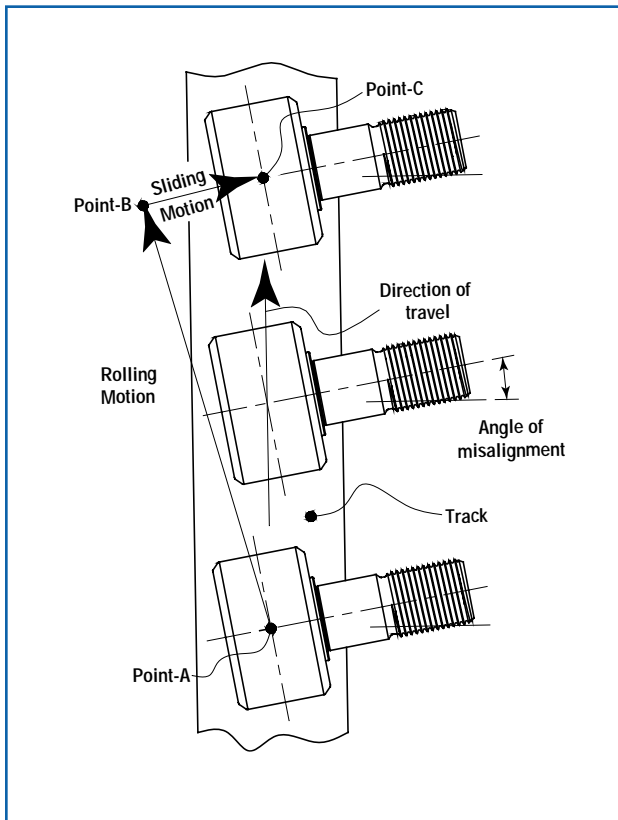


Figure 11: Sliding Motion in Cam Followers with Type II Misalignment

Limits of Thrust Carrying Capability

The cylindrical roller cam follower has superior thrust capability, compared to a simple needle roller cam follower (demonstrated above). However, there are some practical limitations.

Ratio of Radial to Thrust Load

The first limitation is the ratio of radial to thrust load. In dynamic applications, the thrust load should not exceed 10% of the radial load applied. In static applications that ratio can be as high as 20%.

Transmission of thrust load through the rollers is shown in **Figure 12**. In any case, cylindrical roller cam followers are much more capable of sustaining thrust loads than needle roller cam followers. Typically, needle roller cam followers will demonstrate early failure when subjected to thrust loads.

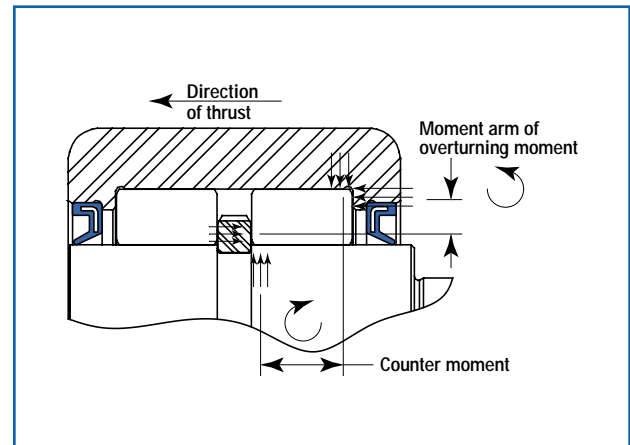


Figure 12: Thrust Support in Cylindrical Roller Cam Follower

Heat Generation

The second limit-to-thrust carrying capability is the amount of heat generated between the roller faces and the flanges. Even if the radial-to-thrust ratio is fine, there are some high-load, high-speed applications where the amount of heat generated is sufficient to break down the grease and cause bearing failure. Extensive testing in RBC's laboratory has shown that cylindrical roller cam followers can run 30 – 50°F cooler than their needle roller bearing counterparts (**Figure 13**). A cooler running bearing is a bearing that lasts longer.

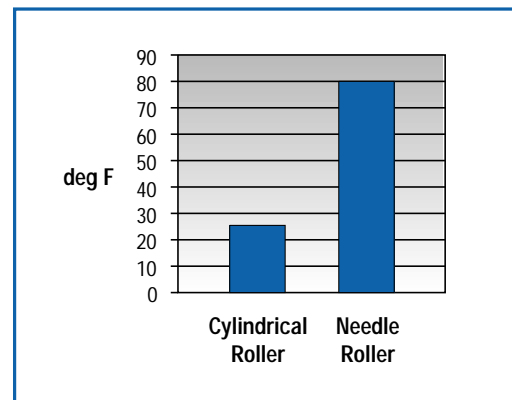


Figure 13: Operating Temperature Increase

Importance of Track Lubrication

In most cases, standard needle roller cam followers with their gap seal/thrust washer combination operate acceptably in cases with small angles of Type I misalignment. Under Type II misalignment, the RBC Roller cylindrical roller cam follower clearly provides superior service. To meet the radial-to-thrust load limitation, the coefficient of friction between outer ring and track should be kept to 0.1 or less, which requires track lubrication. On unlubricated tracks, the coefficient can reach as high as 0.3 which, under heavy load, can overwhelm even a cylindrical roller cam follower.

Speed Limits and Operating Temperature

The speed limit of a rolling bearing depends largely, but not exclusively, on roller guidance and lubrication. Oil lubricated bearings can usually be operated at a speed 50% higher than grease lubricated bearings. However, roller guidance has a much more profound effect on the maximum permissible speed. Typically, the speed limit for full complement needle bearings ranges from 50,000 to 80,000 $d \cdot n$, where $d \cdot n$ is the bearing inside diameter in millimeters times the rotational speed in rpm. The speed limit for unsealed cylindrical roller bearings ranges from 200,000 to 400,000 $d \cdot n$. However, in the case of a sealed cylindrical roller cam follower like the RBC Roller, the speed is limited by the maximum permissible surface speed of the seal, usually around 1,000 to 1,200 ft/min. (Figure 14).

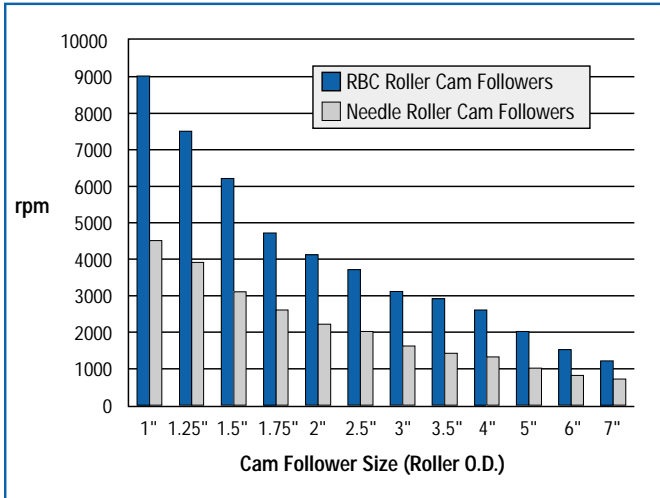


Figure 14: Cam Follower Speed Limit

The maximum permissible operating temperature for a standard needle roller cam follower is typically based on the temperature limit of the seal material, usually a variation of Nylon 6.6. For high-temperature applications, the choice generally means eliminating the seal altogether. The maximum operating temperature for the cylindrical roller bearing cam follower depends on the choice of grease and the seal material. Both may be selected within limits without endangering functionality.

Relubrication Requirements

Highly effective seals and larger initial grease charge enable RBC Roller cylindrical roller cam followers to operate far longer than needle roller cam followers that have not been relubricated. Without relubrication, the initial grease charge in needle roller cam followers is consumed by oxidation and loss through purging at initial start-up. To ensure maximum life, these cam followers should be relubricated after 2 million revolutions. Operation in contaminated environments requires even more frequent relubrication. Comparative laboratory tests confirm the exceptional life advantage delivered by RBC Roller cam followers over needle roller cam followers when relubrication is not performed. Figure 15 shows comparative life on 1" diameter cam followers when run at 25% of their dynamic load capacity. RBC Roller cam followers delivered over 12 million revolutions, compared to 3 million revolutions for the needle roller cam follower.

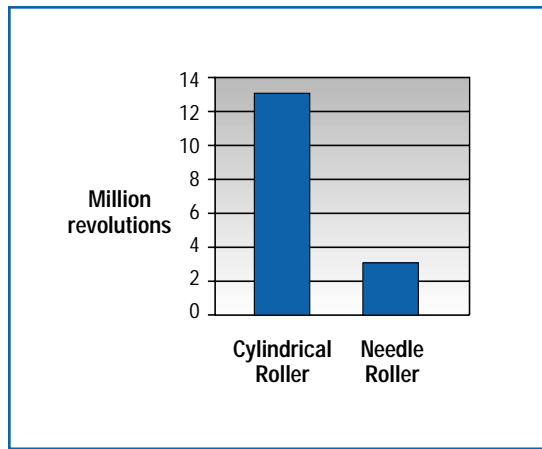


Figure 15: Cylindrical roller cam follower life compared to needle roller cam follower – without relubrication

Operating Torque

By now there is familiarization with the two forces acting on a track: the force perpendicular to the track surface as a result of the operating load, and the friction force acting tangentially on the cam follower outer ring in the plane of the track. The friction force is of particular interest for two reasons, it has to be large enough to overcome the friction torque of the cam follower itself, and it must be able to accelerate the cam follower.

Required Radial Load to Overcome Torque

Cylindrical roller cam followers with contacting lip seals feel tight when compared to standard needle roller cam followers. The source of this tightness is the friction torque generated by the seals. On a typical 2-in. cam follower, the moment to overcome seal friction could be around $M_S = 18 \text{ in} \cdot \text{oz}$ or $1.13 \text{ in} \cdot \text{lbf}$. Assuming a coefficient of friction of 0.1, the required radial load to overcome the seal drag is thus $F_r = M_S / ((d/2) \cdot \mu) = 1.13 / (1 \cdot 0.1) = 11.3 \text{ lbf}$. Considering that the capacity of a 2-in. cam follower is 12,400 lbf, it is reasonable to assume that the actual operating load will be much higher than the small force required to overcome seal drag (Figure 16).

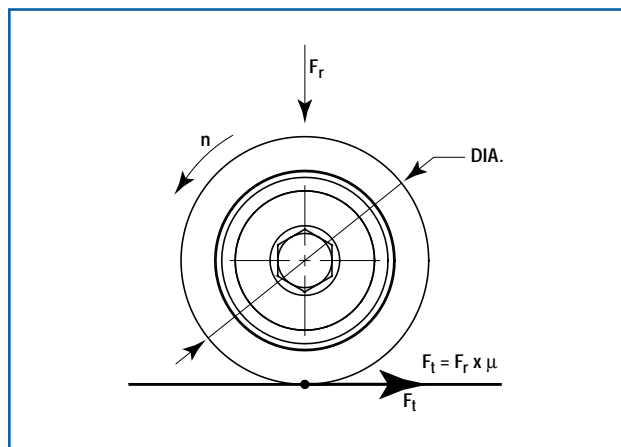


Figure 16: Origin of Tangential Forces

Summary

The RBC Roller represents a superior alternative to the classic needle bearing cam follower design (circa 1950). This product has been developed to achieve higher reliability in the demanding operating

environments of modern machinery and is produced from the finest bearing quality steels. The table below summarizes those important design features that achieve this superior performance level.

Comparison of RBC Roller Cylindrical Roller Cam Followers and Needle Roller Cam Followers	
Dynamic Capacity	Cylindrical roller cam followers are rated 30% to 70% higher than like-sized needle roller cam followers.
Fatigue life	Increased dynamic load capacity directly influences a design operating life that can be over five times that of needle roller cam followers.
Operating Speed	Superior guidance of short cylindrical rollers in the RBC Roller cam follower permits operating speeds that are nearly twice those of needle roller cam followers.
Sealing	The contacting lip seals of the RBC Roller cylindrical roller cam follower provides more effective grease retention and exclusion of contaminants, running on a ground surface.
Lubed For Life	The combination of highly-effective seals and up to four times the internal grease volume mean that periodic relubrication can be eliminated.
Running Temperature	Reduced roller skewing and lower roller rotating speeds mean that RBC Roller cam followers generate up to 50°F less heat than needle roller cam followers.
Thrust Loads	The combination of a center thrust ring and positive roller retention by the outer ring internal shoulders enable the RBC Roller to withstand higher thrust loads.
Interchangeability	RBC Roller cylindrical roller cam followers are produced in sizes and configurations that are directly interchangeable with needle roller cam followers. This means easy drop-in replacement on existing needle roller cam follower installations.

RBC Bearings designs and produces precision bearings in 12 facilities in North America and Europe. Founded in 1919, the corporate headquarters is in Fairfield, Connecticut, USA. Products produced by RBC include **QuadLube**[®] and **ImpactTuff**[®] spherical plain bearings, **Pitchlign**[®] heavy-duty needle roller bearings, **Tyson**[®] tapered roller bearings, **Heim**[®] rod ends, precision ground ball screws, thin section radial bearings, **Nice**[®] ball bearings, **Fiberglide**[®] self-lubricating plain bearings, needles and rollers, and a wide variety of cam followers.

Since RBC first produced cam followers in 1939, numerous design enhancements have been implemented by the company. The patented RBC Roller cylindrical roller cam follower described in this report is a major improvement over traditional needle roller cam followers in numerous performance areas.

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