KAMATICS KARON® Design Guide

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Contents:

1. Kamatics in General:

Kamatics Corporation manufactures self-lubricating bearings from common and exotic materials. The liner materials used in the bearings are designated as **KAron** for temperatures to 400°F (204°C), **KAtherm** for temperatures to 600°F (315°C), and **KAcarb** for temperatures to 1200°F (635°C). These three systems encompass a family of self-lubricating bearing liners providing low friction, high load capacity, long life with low rates of wear and a large temperature range. They were developed solely by Kamatics to be used primarily as self-lubricating bearing liners in a variety of applications. This design guide will concentrate on the KAron system.

KAron is a combination of thermosetting resin and filler materials in particle or fiber form. This differs significantly from other self-lubricating materials in that there are no continuous interconnecting fibers or weave that can provide a moisture path to the bonding substrate. A moisture path may either promote corrosion under the liner or significant liner swelling when used in a moisture-laden environment.

KAron liner systems are homogenous in nature, a mixture of resin, polytetrafluoroethylene (PTFE) and other special fillers. Because of this, consistent friction and extremely low, linear, rates of wear can be expected throughout the life of the liner. Other self-lube materials are generally made up of a fabric blanket with different strata of PTFE, fiberglass, nylon, resin etc. and consistent performance cannot be anticipated throughout its thickness.

Characteristics considered in the formulation of KAron include load carrying capability, operating temperature, coefficient of friction, sliding/rubbing velocities or any combination of these.

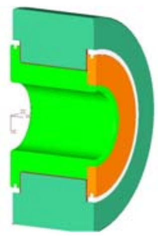


Figure 1
Typical KAron Lined Roller

In addition to typical bearing applications, a KAron liner has other valuable uses including:

- **Salvaging Components** – KAron can be applied in various thicknesses providing a method of salvaging components with oversize bores, undersize OD's, worn or damaged surfaces, etc. Such applications can be rapidly addressed by a Kamatics representative as to the suitability of Karon as a solution.
- **Fretting Protection** – KAron can be used as an inexpensive barrier to eliminate/prevent damaging contact between expensive components. In many cases, KAron can be used as "applied" without any subsequent machining
- **Corrosion Protection** – KAron has demonstrated limited protection against corrosion while providing a bearing material that can be machined to very close tolerances.

KAron is well accepted throughout the industry. Oil exploration, aircraft, space, marine, nuclear power, hydropower, are just some of areas successfully using

KAron. The operating conditions and parameters vary widely. For example:

- Temperature ranges from cryogenic to over 400° F (205° C).
- Static contact pressures in excess of 100,000 psi (690 mPa).
- Short term operating velocities of 100 feet/minute (30 meters/min) or higher.
- Liner thickness up to 0.060" (1.5 mm).
- Operation with contaminates such as oil, grease, sand, grit, deicer, hydraulic fluid and cleaning fluids, and others.
- Requirement to adhere to various materials including stainless and carbon steels, titanium, copper, nickel and aluminum alloys, fiberglass, carbon fiber and others.
- The need to operate against various materials, hardnesses, and surface finishes.

KAron has definite thickness associated with it. It is not a thin "dry film lubricant" that can be applied after final machining without affecting dimensions. Therefore, space must be provided for the liner when designing components that will include KAron. Liner thicknesses normally range between 0.010 to 0.015 inches (0.25 to 0.38mm). Liner thickness is also a function of the amount of wear or clearance a system can tolerate and continue to operate as intended. For applications where clearance is not an issue, the liner thickness can be increased.

Liner Application

Prior to its application, the surface to be lined should be abraded (roughened) and cleaned to insure optimum adhesion. The abrading is accomplished by spraying special abrasive media at precise velocities and distances. If the surface to which the liner is to be applied has been shotpeened, the roughening will be kept to a minimum. This is to minimize any adverse effects to the shotpeening. Cleaning of the pre-lined surface is accomplished with chemicals that will not affect the properties of the base material. The liner is applied and cured at temperatures that will not affect the mechanical properties of the substrate.

Applications such as pistons, complex housings, or similar, require design considerations that may not be readily apparent. This is especially true in cases where the customer intends to fabricate the part ***minus the liner*** and then send it to Kamatics for liner application.

Surfaces that are not KAron lined may require protection from the abrading process. This can be a labor-intensive process involving masking. Cost savings can be realized by providing extra material on the non-lined surfaces allowing them to be roughened along with the lined area and later machined to the final dimensions. As KAron is normally machined after application, the extra time to machine the adjacent surface is minimal. **Figure 2** illustrates this technique. The substrate material and KAron liner will be machined in the same setup, resulting in an excellent blending of the two. Kamatics provides the customer with guidance and/or "pre-liner" configuration drawings to coordinate this concept.

Blank **KAron Lined** **Final Machined**

Figure 2

Frequently Kamatics will require the same machining datum the customer used to generate the pre-lined surface. This is for proper tolerance and position of the final KAron lined surface. Any such datum should be identified and agreed upon in advance of any part fabrication.

Design Comments:

- Unless the bearing is molded to size, the KAron liner is normally machined after its application. Therefore, the requirement to hold very close pre-liner dimensions and smooth surface finishes prior to lining is not necessary. Tolerances of ± .002" (0.05 mm) and 125-250 rms (0.8-1.6 um) surface finish on the area to be lined is adequate.
- KAron is unaffected by chromium, cadmium, anodize, and alodine solutions. It is not necessary to protectively mask the liner during these operations. Because of this, the intersection between the plating and liner is virtually gap free. KAron is considered an electrical insulator where plating is concerned. Normal electrical conductivity through the liner to substrate is extremely difficult and cannot be relied upon in normal liner thicknesses.

2. Journal Bearings

Kamatics Corporation has been designing and manufacturing self-lubricating journal bearings for over 30 years. The original self-lube bearing was manufactured from compact carbon sleeves shrunk-fit into metallic housings. Operating capability of this combination exceeded 1000°F (538°C) and is still in use. They are offered as "KAcarb" bearings. Since then, technological advancements have extended Kamatics products into a larger family of self-lube liner systems, all exhibiting low friction, low rates of wear, and temperatures ranging from cryogenic to over 1000°F (538°C).

The majority of journal bearings (flanged or non-flanged) are manufactured with a **metallic backing**. The backing can be just about any metal but it is predominately stainless steel and aluminum. However, most composite structures require that the bearing be compatible with the structure. Kamatics Corporation manufactures a large size range of KAron lined bearings with **composite backings.** Carbon/epoxy and fiberglass/epoxy are the most common composite combinations used.

Composite Bearings

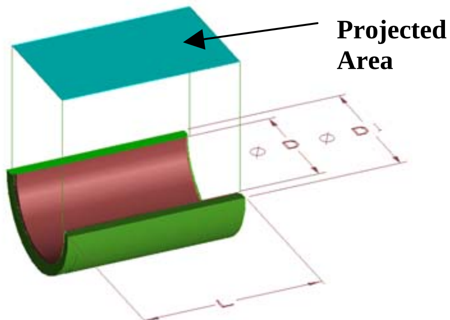
Kamatics has "state-of-the-art" computer controlled filament winding and braiding capabilities. Composite backed bearings in excess of 40 inches (1 meter) have been produced. Kamatics KAron lined/composite backed bearings are qualified to MIL-B-85560. Composite bearings for operation at temperatures to 600°F (315°C) are possible with our KAtherm technology.

Kamatics also produces bearings made from **solid KAron**…without any backing for those applications where space is limited. Solid KAron bearings are normally pressed in, or bonded to, a housing and when installed have similar load and performance capabilities of metal or composite backed KAron bearings.

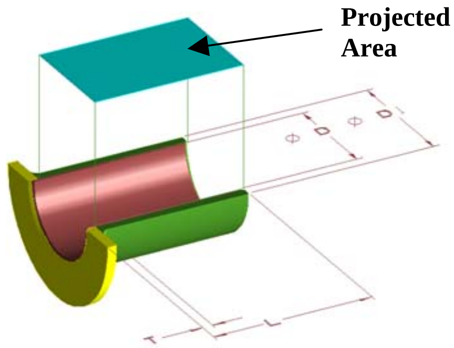
Journal Bearing Design:

A suggested approach to the design of both flanged and non-flanged KAron self-lubricating journal bearings is offered below.

The bearing pressure distribution used in the following equations is in a simplified form. Forgoing extensive discussion on actual pressure distribution and for calculation purposes, assume the area supporting the load to be a "projected area" pressure as defined in **Equation 1.**



<u>Figure 3</u>, (Non-flanged Journal)



<u>Figure 4</u>, (Flanged Journal)

<u>Equation 1</u>; Journal bearing pressure;
S=P/A, where;

- **S** = Pressure (projected area)
- **P** = Applied load (force)
- **A** = D x L_{EFF}
- D = Nominal journal ID
- L = Nominal length of the journal (including the flange if there is one)
- L_{EFF} = L minus "edge effects"

The "edge effects" are the non-load supporting chamfers and the area under the flange, in the case of flanged journals. The "Projected Area" concept defined is widely used in the bearing industry and most published load ratings are based on this concept.

Sizing of the journal bore is based upon a combination of load, shear and tensile allowables of the bolt/pin material plus any bending under load. The bearing stress on the bearing should be checked once the bolt/pin diameter has been established.

It is important to be as accurate as possible when determining forces and both normal operating and maximum forces are required. For instance, supplying and calculating size based only on the maximum force coupled with an operation or flight spectrum may cause the bearing to be larger than necessary or the amount of calculated wear to be unrealistically high. (Obviously, the bolt/pin has to be selected based on maximum loading among other things.) If the operating time at maximum load is relatively low and cycles are few, it may be overlooked for the initial sizing. This is assuming the loads are within the liner materials capability (below static limit load value). Once initially sized, the amount of wear attributed to the operating extremes can be added to the amount of wear attributed to the normal operating conditions. All movement under load has some contribution to the total wear.

The length of the journal bearing should be kept to a length-to-diameter (L/D) ratio of less than 1.5 to keep both pin bending and edge loading to a minimum. Edge loading can lead to more than anticipated wear. Larger L/D ratios can be designed but only after careful consideration to pin bending is given. Bell-mouths (shallow tapers) machined into the bore will minimize edge loading due to large L/D ratios.

Things to consider in the design of a KAron lined self-lube journal bearing:

- KAron liner material is machineable using conventional turning, reaming or honing procedures. Appendix A explains these techniques. Bearings can be supplied with thicker liner material to allow final machining of the ID after installation.
- Consideration should be given to the type of installation fit between the bearing OD and housing. A press fit will reduce the operating clearance between the bore and mating shaft, and if not addressed, may create an interference with the shaft. **Tables 2** & **3** offer housing dimensions for use with Karon journal bearings.
- As in the case of many journal bearing applications, the bearing manufacturer supplies only one half of the bearing system. The end user supplies the other half (the inner race) in the form of a bolt, sleeve, pin, or similar.
- As noted, the user supplies the mating part and the installation of this part must be carefully controlled. The shaft must be accurately aligned to minimize liner damage during insertion into the bearing. It should have a smooth chamfer or radius on the end that enters the bearing. Fortunately, Kamatics self-lube liners have a significant advantage over fabric self-lube liners in that in the event of localized damage during shaft installation, the damage remains local. There are no interconnecting fibers or weave that will allow the damage to progress and propagate under load until loss of liner or jamming of the shaft has occurred in the bore.
- It is important to select the most corrosion resistant and hardest material with the smoothest surface finish possible *for the application under consideration*. Consider the use of hard chrome plate to further enhance the shaft finish.
- The selection of mating materials can be a difficult decision and in order not to “over-design”, the amount of wear and the type and number of expected operating cycles should be known.
- **Table 4** lists the potential trade-off relative to life with various mating shaft hardnesses and surface finishes. Table 4 displays general “trend” type of information and should not be taken as an absolute value. Kamatics engineering is available for guidance if necessary.

3. Spherical Bearings

Kamatics Corporation has designed and manufactured self-lubricated spherical bearings since 1966. The original Kamatics spherical bearing was made from compacted carbon matrix liners operating against a chrome oxide coated and polished surface. This was known as a “**KAcarb**” bearing and is still in use today for applications operating at temperatures up to 1200°F degrees F (635°C). Today, as mentioned previously, Kamatics manufactures spherical bearings with **KAron** self-lube liners for temperatures to 400°F (204°C) and **KAtherm** for temperatures to 600°F (315°C). Contact your Kamatics representative for further information for KAtherm and KAcarb applications.

Spherical Bearing Design:

The design criterion for a KAron lined spherical bearing is similar to the criteria for a journal bearing. The major difference is that the inner race is supplied within the bearing assembly and its hardness, surface finish and corrosion resistance is normally left up to the bearing manufacturer.

Equation 2 provides a method for calculating bearing pressures for spherical bearings and is similar to the journal bearing "projected area" approach.

Important Note: Kamatics Karon lined spherical bearings incorporate a unique "cathedral" shaped cavity between the ball OD and outer race ID. This feature "locks" the liner within the bearing overcoming the familiar problem of liner loss suffered with many fabric lined bearings. **Figure 5** shows the "cathedral" feature.

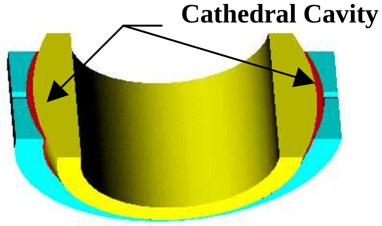


Figure 5

Some other important design considerations relative to the design of spherical bearings follow:

- It is imperative that the spherical surface of the ball be as hard, smooth and corrosion resistant as possible.
- There should be sufficient clamp-up torque applied to the ball faces to insure that motion takes place between the ball OD and outer race liner unless movement within the bore is required.
- For applications where it is difficult to generate enough preload on the ball to prevent rotation between the bore and bolt/shaft, Kamatics can supply the bearing with a KAron liner in the bore and side faces. This will eliminate damage to mating surfaces in the event that motion takes place in the bore.
- Consideration should be given to the type of installation fit between the bearing OD and housing. A press fit will reduce the operating clearance between the ball and outer race and increase the breakout torque if there is initial torque. Either condition may be acceptable for the application. The designer is just cautioned to consider the consequences of the fit.
- Similar consideration should be given to the fit between the ball bore and bolt as noted above. A designer is cautioned not to use an interference fit between the ball and bolt if the ball is hardened 440C stainless steel or other materials that may be prone to stress cracking when under tensile loads.
- Like the previous suggestions for journal bearing installations, for those applications where the user intends to use a thermal fit technique (shrink fit) to install a KAron spherical bearing, a solution of dry ice and solvent in which to immerse the bearing is recommended.

- To assist in housing size selection, **Tables 5 and 6** offer typical housing dimensions for use with Karon lined spherical bearings.

Equation 2; Spherical bearing pressure; S=P/A, where;

- **S** = Pressure (projected area)
- **P** = Applied load (force)
- **A** = $D_{(ball)} \times H_{EFF}$
- $\mathbf{D}_{(ball)}$ = Nominal ball OD
- **H** = Nominal width of the outer race

- $\mathbf{H_{EFF}}$ = H minus "edge effects"

The "edge effects" are the possible non-load supporting liner setback allowances at each side face of the outer race. In the case of KAron lined spherical bearings, assume the setback at each side to be 0.025 inches (0.63mm) or 0.050 inches (1.27mm) total "edge effect".

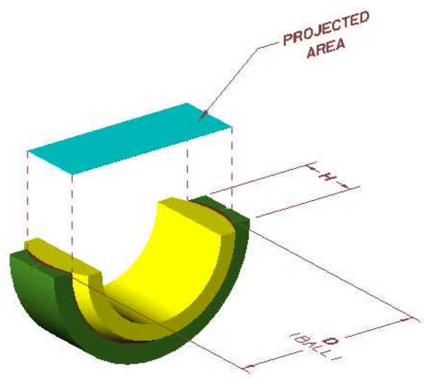


Figure 6,
(Spherical Bearing Projected Area)

Rod End Bearing Design:

Kamatics has over 35 years of experience manufacturing rod end assemblies. Materials range from carbon steel to high nickel alloys. Bore sizes range from 0.060 inch (1.5mm) to 3.00 inches (75mm) and larger. They are used in applications from farm equipment to space shuttles. Kamatics rod ends operate at temperatures ranging from cryogenic to 1000°F (538°F) with KAron, KAtherm, and KAcarb liner systems. "Kamatics KAron Bearing Catalog – Spherical, Rod End, and Journal Sleeve Bearings" (KR-M series) offer some of the more standard sizes of rod ends available. Special sizes are produced upon request. **Figure 7** shows a typical male threaded rod end assembly.

The design of a rod end assembly requires a thorough understanding of the loads it will be subjected to. For example, if the loads are predominately compression (in the direction of the threads or shank), the banjo diameter (the hoop of metal around the bearing insert) can be thinner than if the rod end were used in tension. A tension load on the rod end body causes the hole in the body containing the bearing insert to become elongated (ovalized). Obviously, this elongation does not happen if the load is in compression (in the direction of the shank/threads) as the hole is not "stretched" in this direction.

The elongation creates a "pinching" force on the bearing insert in the 3-9 o'clock position relative to the shank. This can have two significant effects on the assembly. First is that it tends to increase the torque required to rotate the ball. If the magnitude of the torque increase is high enough, coupled with the normal operating torque, frequent oscillation or rotation of the ball may produce unanticipated bending stresses on the rod end body and possibly lead to a fatigue failure at the banjo/shank intersection.

The second effect is relative micro motion between the housing ID and bearing OD at the 3-9 o'clock position as a consequence of the hole elongation. Frequent load reversals between tension and compression can lead to fretting between the bearing and rod end body…and eventual metal fatigue of the rod end. Classic rod end failures occur approximately 15-20 degrees below the 3-9 o'clock position.

A light interference fit between the bearing and rod end body is recommended to minimize the possibility of fretting. Kamatics manufactures spherical bearings to be installed in the rod end body with internal clearance designed to accommodate an interference fit without adding additional ball rotational torque. The rod end body should be completely analyzed to insure that; the shank/thread size is large enough to support the loads; the banjo diameter is thick enough to react applied forces and minimize hole elongation; the fillet radius between the banjo and shank/threads is of sufficient size and with as good a surface finish as possible to minimize stress concentrations.

Kamatics is available to assist in the design of your rod end application.

Figure 7 (male rod end assembly)

4. "KRP" Track Roller, Cam Follower and Pivot Bearings:

The design and manufacture of self-lubricating track rollers, cam followers and typical airframe pivot bearings was and continues to be pioneered by Kamatics Corporation. It was obvious that there was an unfulfilled need for this type of bearing that would not be subject to the effects of corrosion, brinnelling, ball/roller/needle fracture and difficulty to grease that is common to conventional anti-friction bearings. The need to continually re-lubricate, the manpower required, not being sure that the lubricant ever reached the bearing, was and continues to be a concern. Also, by eliminating the grease requirement, the environment around the bearing remains much cleaner and not subject to the collection of grit, dirt etc. that is also common around greased assemblies. Looking under the wing or at a landing gear of a greased aircraft is enough to make one aware of the potential benefits of non-greased self-lubricated bearings.

Track Rollers & Cam Followers:

For the majority of track roller/cam follower applications the "**KRP**" design incorporates a KAron liner applied to the OD of the inner race and. Either KAron or PTFE filled Acetal resin is inserted between the side faces of the outer race and thrust members. This provides an additional benefit to the roller by providing a thrust capability not usually found in an anti-friction bearing of the same type. The outer race is made from a hard corrosion resistant stainless steel material, normally Custom 455, 440C or Cronidur 30 stainless steel, and a 17-4 PH stainless steel inner race and thrust member(s). Depending upon the operating conditions, seals are included to minimize the entry of abrasive particles and contaminating fluids. The assembly is then either electron beam welded or swaged to keep the components together as an assembly. **Figure 8** illustrates this Kamatics design approach.

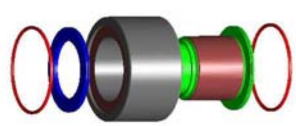


Figure 8 (clevis mounted roller)

The design and load carrying capability of track rollers and cam followers depends heavily on the installation. That is, whether the bearing is installed between a clevis arrangement or is cantilevered off of structure. Of concern for a cantilevered (studded) roller is determining where the roller will contact the mating track or cam. **Figure 9** shows a studded roller assembly.

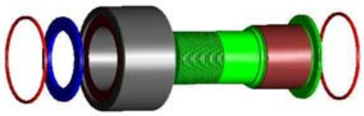


Figure 9, (stud mounted roller)

The worst-case scenario is when the roller contact is at the extreme end of the outer race, away from the threaded end. The bending moment arm is the longest at this point, imparting maximum stress on the stud. This is not a problem unless the stud is not of sufficient size to safely react the implied stress. There are various methods to analyze the bending stresses in a cantilevered roller and this is normally the responsibility of the bearing user. The same concern as to where the outer race will contact the mating surface exists with a clevis-mounted assembly, however, the bending consideration is at a minimum. The concern here is more of track/cam contact and bolt shear stresses. Bolt shear is usually not a major concern as there is double shear involved with a clevis arrangement.

There are ways to minimize the bending concern on a studded roller. One is to incorporate a "crown" radius on the OD of the roller in an attempt to bring the contact point nearer the center of the outer race width. This is the most common approach with anti-friction bearings, however, this ensures that the contact stresses on the track or cam will be high because of the more localized contact area. This is not a problem as long as the stresses are within the material's capabilities.

A second approach to minimizing both the bending and contact stress considerations is the patented Kamatics **self-aligning roller**. This design incorporates a KAron lined spherical inner race that operates against the same hardened outer race material as the more common "KRP" design. The spherical feature allows the roller to conform/align to the mating track/cam surface without the high contact stresses and with a reduced bending moment arm that can be considered to pass through the centerline of the outer race width. **Figure 10** illustrates the self-aligning design.

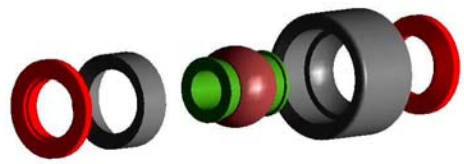
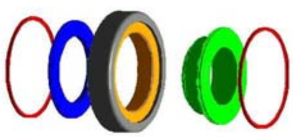


Figure 10, (self-aligning roller)

Extensive testing and field results have shown that a KAron lined track roller will operate successfully for an extended duration at dynamic bearing pressures as high as 20,000 psi (140 mPa). **For most commercial aircraft flap/slat roller applications or similar, by keeping the bearing pressures to a maximum of 12,000 psi (85mPa), the roller can yield in excess of 200,000 revolutions of useful life with liner wear less than 0.004 inches (0.10mm).** As is obvious, if as many as 200,000 revolutions are not required, the bearing pressures can be increased. This is normally the case of military aircraft, where space is small, loads are higher but the number of cycles is lower. Kamatics engineering is available to assist in sizing the roller for any application under consideration.

"KRP" Linkage/Bellcrank Pivot Bearings:
Prior to the Kamatics self-lube KRP design, the typical linkage/bellcrank pivots bearings were mainly limited to ball bearings or greased journal bearings. The "KRP" design for these applications

also incorporate a design similar to the track roller/cam follower with an internal self-lube liner, but without the hardened outer race. Because this type of bearing is contained/pressed within a housing the need for a hardened outer race does not normally exist. In "linkage/bellcrank" KRP, the self-lube liner is applied to the ID and side faces of the outer race and the inner race is of sufficient hardness to provide the hard, abrasion-resistant surface necessary for optimum performance. **Figure 11** illustrates this design.



<u>Figure 11</u>
("KRP" Linkage/Bellcrank Bearing)

Table 8 offers some recommended housing and shoulder dimensions for installation.

Kamatics "KRP" catalog offers self-lubricated designs that are dimensionally equivalent to many of the more commonly used ball, needle and roller bearings used in the industry today. They all feature the benefit of a liner system that is not prone to problems associated with anti-friction bearings. Problems such as race brinnelling, rolling element failure, greasing difficulties (including the requirement to get the grease to the bearing) and the manpower needed to maintain the bearing.

For load-carrying capability of a KRP bearing, calculations based on the projected area concept, similar to that previously discussed for Kamatics journal bearings should be used. A KRP linkage/bellcrank bearing normally experiences race oscillation as opposed to race rotation for track roller/cam follower bearings. The data in **Table 7** along with **Equations 3 or 4 and 5** can be used to determine probable liner wear.

5. Wear Strip Material:

Kamatics Corporation offers a unique method of obtaining the KAron liner system in sheet or strip form for special applications. To date, the majority of applications for this material have been in problem areas involving unintentional rubbing, scuffing or fretting. It can also be used when the component to be lined is either too large or too costly to transport to Kamatics for the conventional liner application. **Figure 12** shows some typical wear strip configurations.

The Kamatics KAron wear strip material is in the form of a fiberglass/epoxy backing of variable thickness, with the KAron V liner system applied to one or both sides of the fiberglass. The normal operating temperature range for KAron lined wear material is –65°F (-54°C) to +250°F (+120°C). Operating temperatures up to +500°F (+260°C) are possible with KAtherm T87. Consult Kamatics engineering for further information on the use of high temperature wear material.

Wear strip products are applied by bonding the material onto the substrate with no further machining of the KAron surface anticipated. If necessary, Kamatics can supply complete data for the bonding process along with suggested structural adhesives. Wear strip products consisting of KAron applied onto both surfaces of the fiberglass/epoxy backing are not bonded onto a substrate. These products are generally stamped to size for use as thrust washers.

Light Duty and Medium Duty KAron lined wear strip material is stocked at Kamatics for immediate delivery. Light Duty material, KAron applied to one side, is approximately 0.018 inches (0.46mm) thick with a nominal KAron thickness of 0.008 inches (0.20mm). Medium Duty material, KAron also applied to one side, is approximately 0.036 inches (0.91mm) thick with a nominal KAron thickness of 0.016 inches (0.41mm). Maximum width length dimensions are 12 inches (300mm) x 48 inches (1200mm). Other thickness/size combinations can be manufactured in an expeditious manner to support programs under consideration.

Unless directed otherwise, the typical wear strip material is supplied with a "peel-ply" removable release film on the side opposite the KAron surface. Once removed the surface is ready for bonding. Removal of the peel-ply leaves a clean, roughened textured surface, perfect for the bonding operation.

Data sheets explaining the properties of **KAron V Wear Strip** material is shown in Addendum A.

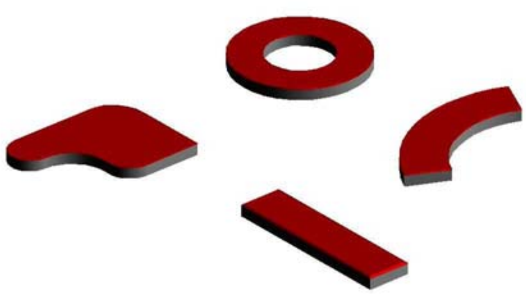


Figure 12
Typical Wear Strip Shapes

6. Bearing Motion;

After the bearing pressures have been arrived at, the rubbing velocity of the bearing surfaces and total rubbing distance traveled should be determined. There are several equations to do this and the units are normally expressed in feet per minute (FPM) for velocity and feet for distance.

Equation 3; velocity - oscillation

$V_{(Oscillation)} = ((\alpha * CPM) / (360)) * ((D * \pi) / 12))$, where;

- **V** = Velocity in feet per minute
- α= Number of degrees per cycle
- **CPM** = Cycles per minute
- **D** = Journal ID or ball OD
- **360** = 360° per revolution
- **12** = 12 inches per foot

Calculating the number of degrees per cycle should be calculated using the method shown in **Figure 13**. Figure 13 graphically shows what is understood when the oscillation angle is stated to be ±α° (α indicating any arbitrary angle). It is generally understood that ±α° means "α° times 4", i.e. ±25° = 100° total per cycle. It is not the total included angle times 4. It is extremely important to be accurate on this point otherwise we may have doubled or halved the motion, leading to erroneous wear approximations.

Equation 4; distance - oscillation

$d_{(Oscillation)} = ((\pi * D * \alpha / 360) * N) / 12$, where;

- **d** = Rubbing distance traveled in feet
- **D** = Journal ID or ball OD
- α = Total degrees per cycle
- **N** = Number of cycles (oscillations)
- **12** = 12 inches per foot
- π = 3.14159…

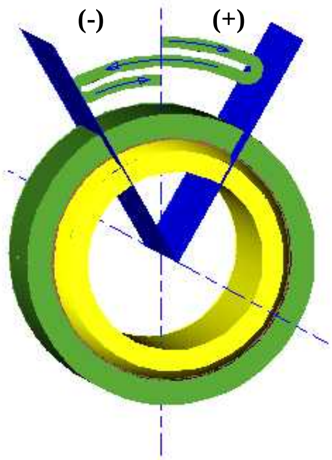


Figure 13,
Oscillation Angle (α) Definition

Equation 5; velocity - rotation

$V_{(Rotation)}$=(D∗π∗RPM)/ 12, where;

- **V** = Velocity in feet per minute
- **RPM** = Revolutions per minute
- **D** = Journal ID or ball OD
- π = 3.14159…
- **12** = 12 inches per foot

Equation 6; distance - rotation

$d_{(Rotation)}$ = ((π∗D∗N)/12
where;

- **d** = Rubbing distance traveled in feet
- **D** = Journal ID or ball OD
- **N** = Number of revolutions
- π = 3.14159 …
- **12** = 12 inches per foot

PV Values, (Pressure x Velocity)

When both bearing pressure (**P**) and velocity (**V**) are determined, the product of the two is a quantity known as "**PV**". This is a value that is used to assist in determining liner wear at various operating conditions.

At Kamatics, many years of endurance test data have been generated for Karon liner materials at various pressures, velocities, and temperatures.
Table 7 displays typical rates of liner wear at various PV levels based on a laboratory environment. The rate of wear is given in inches of wear, per inch of liner travel, at various bearing pressures.

It should be emphasized that when considering PV values, one realizes that a self-lube liner is normally used at velocities less than 20 FPM…and at relatively low bearing pressures at this velocity.

For example, a typical helicopter tail rotor pitch bearing may operate at bearing pressures of 2000 psi (14 mPa) and at a velocity of 20 fpm. This equates to a PV value of 40,000. Similarly, an aircraft slat actuator may operate at a bearing pressure of 20,000 psi (140 mPa) and at a velocity of 2 fpm for a PV value of 40,000. Both are within acceptable PV limits however you would not use the same liner material for both applications. You would use a liner grade that is formulated for either high speed or high load. It would not be advisable to operate at a pressure of 20000 psi and at a velocity of 20 fpm (a PV of 400,000) for any appreciable amount of time.

For most applications, keeping the PV to 50,000 or less will yield relatively long bearing life.

"Life" itself has to be carefully considered as to how long the bearing must operate without exceeding an acceptable amount of wear/clearance. If the application under consideration is required to operate for a relatively short period of time, it is quite conceivable that PV values in excess of 100,000 can be acceptable...again, depending on the duty requirements of the bearing. Any time the requirement is for a PV in excess of 50,000, Kamatics engineering should be contacted for advice.

7. Wear Calculations:

Equation 7 incorporates values obtained from Table 7 to arrive at a predicted amount of liner wear after an assumed operation sequence.

Equation 7; Wear Calculation

W = k ∗ d

where;

W = total liner wear in inches

k = wear rate from **Table 7**, in inches of liner wear per foot of liner travel.

d = total liner distance traveled in feet obtained from Equations 4 or 6.

Example: Assume a typical application is operating at a bearing pressure (P) of 25,000 psi, at an average rubbing velocity (V) of 1.5 feet per minute and for a distance of 5000 feet. The product of the "P" and "V" is well within the allowable range noted earlier. From Table 7, locate the point where the 25,000 psi ordinate intersects the "wear" curve, and follow this intersection point to the left, parallel to the "x" axis and obtain the "**k**" wear factor of 3800 E^{-10} or 3.8 E^{-7}. Multiply this "k" factor times the number of feet traveled and obtain the amount of liner wear of 0.002 inches (0.05mm) of liner wear. To this add 0.0005 inches (0.013mm) of "liner seat-in" that may occur within the first 100 feet of travel, for a potential total liner wear of 0.0025 inches (0.063mm).

8. Bearing Installation:

There has been much written pertaining to bearing installation and many companies have established their own preferences. MIL-STD-1599 offers some excellent basic recommendations relative to fit-up and dissimilar metal considerations. The following is offered to complement MIL-STD-1599 with respect to Kamatics bearings.

Journal Bearing Installation:

The self-lube liner on a journal bearing is normally supplied unprotected other than standard wrapping and packaging. Once removed from its packaging, handling and installation damage can be a major concern.

It is important to protect and not subject the liner from external damage during the installation process. The tool used to insert the bearing into the housing must be free of sharp corners with smooth beveled edges where it enters the bearing. The edges of the housing into which the bearing is being assembled should be chamfered to assist in centering the bushing.

In the case of a journal with a lined flange, the insertion tool should have a surface as large as the flange OD to apply the insertion force against. This will protect the liner on the flange as well as the liner within the bore. The force applied to the bearing should be firm, steady and in one continuous effort. Pausing before complete insertion may cause galling of the bearing OD, housing bore or both. **Figures 14 and 15** offer installation suggestions and **Tables 2 and 3,** housing and shaft sizes. **Figure 16** shows various methods used to retain journal bearings.

In applications where the user intends to use a thermal fit technique (shrink-fit) to install a KAron journal bearing, Kamatics recommends a solution of dry ice and an environmentally safe solvent in which to immerse the bearing. If the housing is to be heated to increase the bore size for easier entry of the bearing, the temperature used to heat the housing should not cause the bearing temperature to exceed 325°F (163°C).

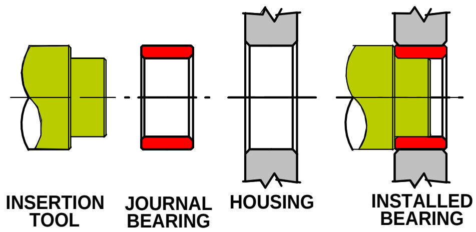


Figure 14
(Non-flanged Journal Bearing)

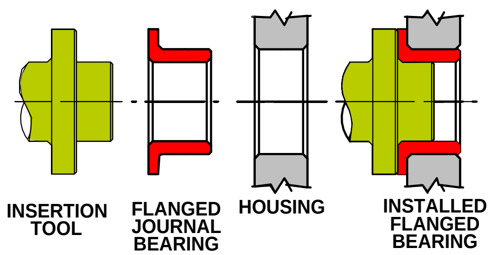


Figure 15
(Flanged Journal Bearing)

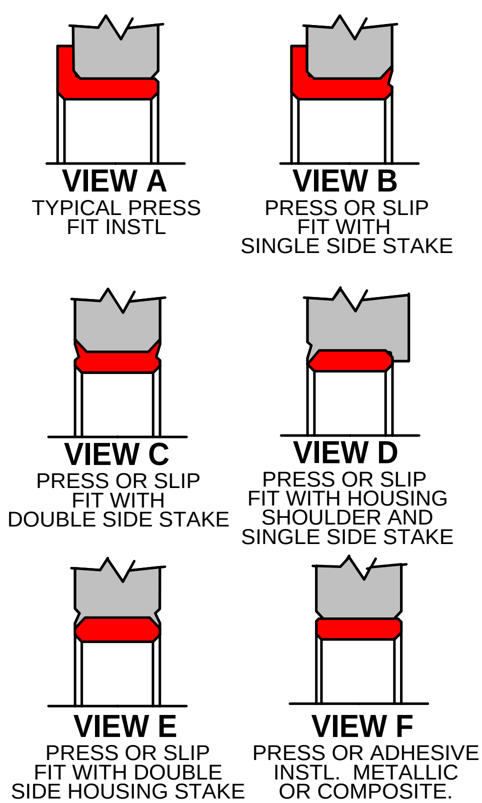


Figure 16
(Typical Journal Bearing Installation)

Note: When a bearing is retained axially within the housing, the fit between the bearing and housing can be either a slip or press fit. The choice depends upon, among other things, the load applied to the bearing and the possibility of it chucking or rotating within the housing. A slip fit should be considered if there is concern that the bore will reduce too much as a result of the fit and interfere with the motion of the shaft. **In the case of Kamatics lined bearings, this concern can be eliminated as the liner can be precisely machined after a press fit installation.**

View A, Figure 16 depicts the most common method of installing a flanged journal bearing with an interference fit. The designer is cautioned to remember that the interference will reduce the ID of the bearing. It is assumed that there is a thrust force in one direction only.

View B (Fig 16) depicts an installation similar to View A, however, with the addition of a swaging groove on the side opposite the flange. The lip of the groove is deformed into a chamfer in the housing, preventing possible migration of the bearing from the housing.

View C (Fig 16) depicts a non-flanged bearing installed with a swaging groove on both sides of the bearing. This will prevent the bearing from migrating out of the housing in either direction. Axial retention of the bearing is important especially if the shaft translates within the bore.

View D (Fig 16) depicts a non-flanged bearing retained by a housing shoulder on one side and a single-side housing stake on the other.

View E (Fig 16) depicts a bearing retained by two side housing staking grooves.

View F (Fig 16) depicts a bearing installed by either a press fit or a slip fit with a retaining adhesive to assist in maintaining position. The adhesive installation is very common with the use of composite bearings.

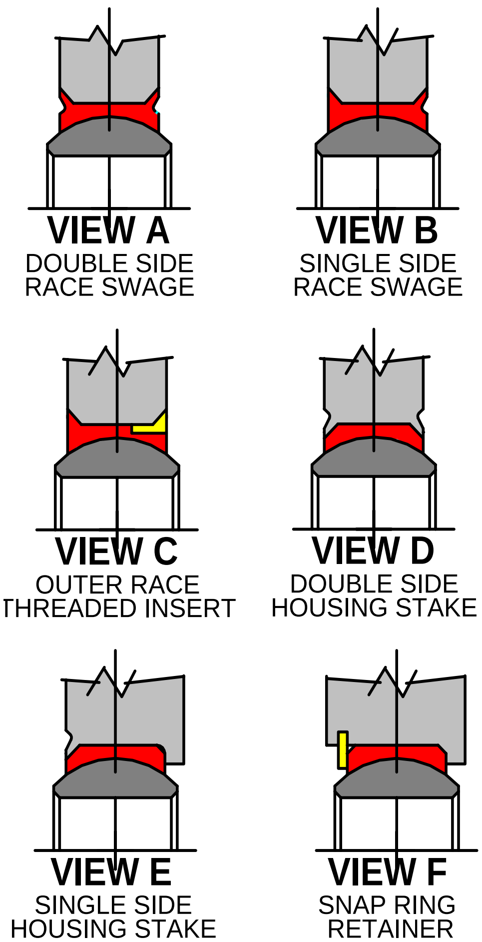


Figure 17
(Typical Spherical Bearing Installation)

Spherical Bearing Installation

There are various methods used to install spherical bearings. **Figure 17** illustrates some of the more common installations. When installing a spherical bearing into its mating housing it is important to apply the force against the side face of the outer race and not against the ball. Pressing on the ball face may tend to "wedge" the ball into the outer race and affect the bearing torque. Similarly to journal bearings, the force to insert should be firm, steady and complete in one attempt. Use tooling to position the bearing before insertion if necessary to insure that the OD enters the housing properly. On those installations where the bearing is retained axially, the use of a small amount of lubricant to aid in the assembly process is acceptable. This is assuming it does not interfere with either the function of the bearing or any sealant application around the circumference of the joint after installation.

View A, Figure 17 depicts the more standard outer race double swaged groove installation. This method provides axial retention and allows multiple bearing replacements without damaging the housing. Roll or anvil swaging tools accomplish the swaging or deforming of the groove into the housing chamfers. Kamatics Tech Note 18 offers roll swaging information as well as instructions as to how to manufacture swaging tools.

View B (Fig 17) depicts another common installation where one side of the outer race has a pre-machined lip that nests into a housing chamfer and a groove on the opposite side to be swaged into a housing chamfer. This method assists in accurately positioning the bearing in the axial direction and requires only one swaging operation.

View C (Fig 17) depicts an installation where the bearing is captured in a housing by a pre-machined lip on one side and a removable threaded insert on the other. The insert is retained within the bearing via a nylon plug, or similar, that is deformed into the threads during assembly. This design is used for those applications where the bearing may have to be removed on site where the more normal swaging is difficult or impossible.

View D (Fig 17) shows an installation where the bearing is retained within the housing with a line of housing stakes around both sides of the bearing. This type of installation should be used only when absolutely necessary. Cost may be a driver for this type of installation. Generally, three or four stakes on each side are required for low-load non-critical applications. The major problem with this option is that the housing is damaged during the staking operation and great care must be taken so that the bearing is not deformed and unnecessarily tightened.

View E (Fig 17) depicts an installation similar to View D except only one line of housing stakes is used along with a housing shoulder. This type of installation does not provide the same ease of bearing replacement that View F does and damage occurs to the housing during each installation.

View F (Fig 17) depicts an installation where a shoulder on one side and a snap ring on the other retain the bearing. This type of installation is used when it may be necessary to remove the bearing and swaging or staking is not feasible. The snap ring is easily removed and allows replacement of the bearing.

Track / Cam Roller Installation

There are various methods used to install and attach a roller to structure. Figure 18 depicts some of the more common methods including Kamatics self-aligning roller bearings. A key to proper performance with track/cam rollers is the alignment of the roller OD with the track or cam. The typical non-self-aligning roller must be accurately positioned both relative to the track itself and in the direction of travel. Abnormally high contact stresses between the roller and track can occur if the roller axis is tilted resulting in point contact instead of line contact. If the roller is "skewed" relative to the direction of travel, outer race skidding and high thrust loads can occur. Fortunately, the Kamatics "KRP" roller has a significant thrust capacity that is virtually non-existent with the needle roller equivalent.

The Kamatics "KRP" self-aligning roller basically eliminates the concern for precision alignment both with respect to axis tilt and skewing. The outer race will "track" as required, following track wander and structure deflections or irregularities.

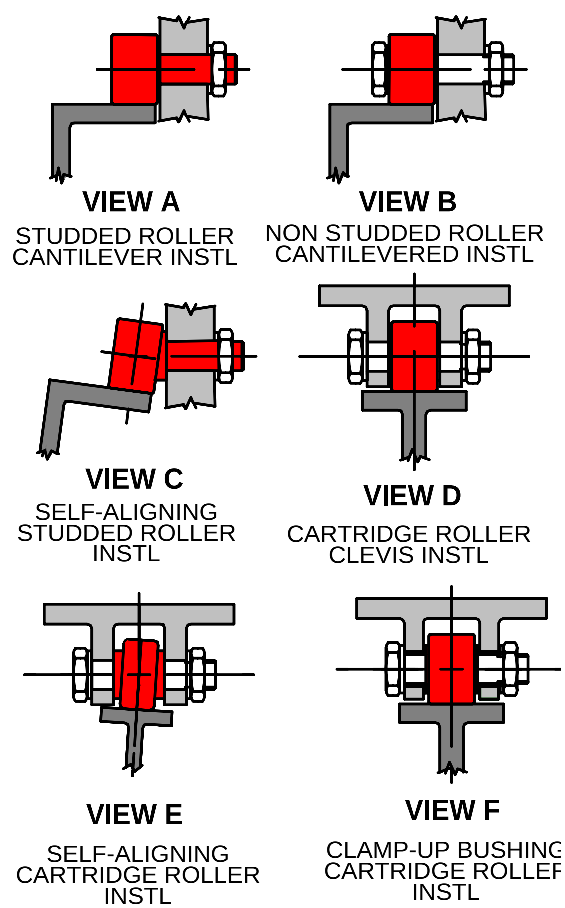


Figure 18
(Typical Track Roller/Cam Follower Installation)

View A, Figure 18 depicts a typical studded roller installation where the roller is attached to firm structure capable of reacting the moment loads applied during operation. The nut must be torqued to the point where the shoulder of the roller is firmly in contact with the structure.

View B (Fig 18) depicts an option to a studded roller where a standard cartridge roller is cantilevered off of structure and secured with a bolt and nut. There must be adequate room for the bolt head in the installation. A benefit of this installation is that it may be easier and timelier to obtain a bolt with the proper grip length than a studded roller with the grip needed.

View C (Fig 18) depicts a studded roller in a self-aligning configuration. It is installed exactly as any studded roller however, as shown, it has the unique capability of aligning to compensate for both track alignment and skew.

View D (Fig 18) depicts an installation of a cartridge (non-studded) roller in a clevis arrangement. In this installation, care in not putting too high a bending load on the clevis lugs is necessary. A better option to View D, if enough room exists, is shown in View F where no bending stress is put on the lugs.

View E (Fig 18) depicts a self-aligning cartridge roller. It is installed exactly as any non-studded roller, however, similar to the studded version shown in View C, it also has the capability of aligning to compensate for both track alignment and skew.

View F (Fig 18) depicts a cartridge roller installed in a clevis arrangement that employs the use of two clamp-up bushings. A flanged bushing is pressed into one lug. A second, non-flanged bushing is slip fit into the opposite lug and is of sufficient length to protrude beyond the lug when assembled. This protrusion insures that bolt clamp-up will not create bending forces in either lug. The load path is through the straight bush, through the bearing inner race, through the flanged bushing and finally through the lug opposite the straight bushing and reacted by the bolt head (or nut).

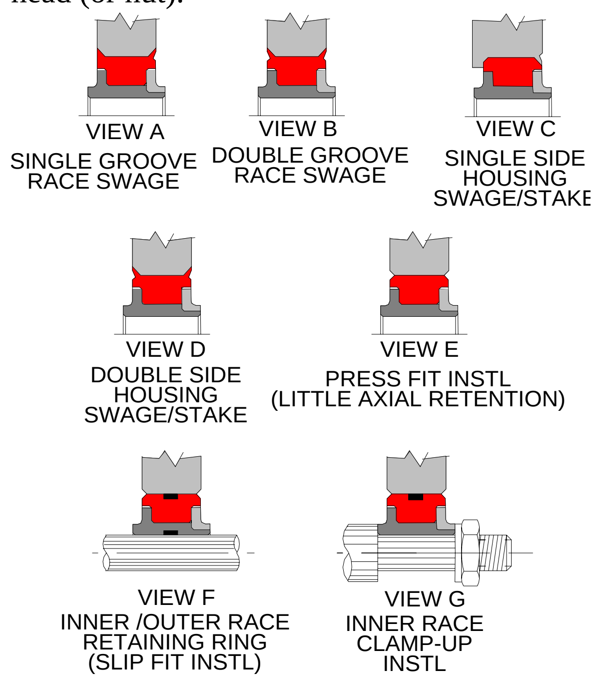


Figure 19
(Typical Pivot Bearing Installation)

View A, Figure 19 depicts a bearing installed with a press or slip fit. The outer race is incorporates an integral machined lip on one side and a swaging groove on the opposite. As in most installations of this type, including spherical bearings, the swaged lip is primarily for axial retention. It is not intended to prevent outer race rotation in the housing. If there is concern about bearing rotation in the housing, consider the use of a press fit in addition to the grooves or an adhesive. Suggested press fits are presented in this document. Bearings installed with swaging grooves can be replaced without damage to the housing.

View B (Fig 19) depicts a double outer race swaging groove installation. The bearing can be either a press or slip fit into the housing. All comments listed above for the View A installation are applicable to this installation.

View C (Fig 19) depicts a single housing swage/stake installation coupled with an integral housing shoulder. Similar to the previous two installations, the bearing may be either a press or slip fit. If intermittent line staking is chosen, the number of bearing replacements is normally limited to two. This installation provides thrust capability only in the direction of the shoulder.

Note: Intermittent line staking should be employed only in those cases where the staking is to contain the bearing during handling and assembly…not for any axial retention during operation.

View D (Fig 19) depicts a double housing swage/stake installation. Those comments listed for View C installations are also applicable here except there is no thrust capability in either direction.

View E (Fig 19) depicts an installation where the only axial retention device is the interference fit between the outer race and housing. The amount of retention is a function of the press fit. This type of installation should be used only after careful consideration.

View F (Fig 19) depicts an installation that uses a novel Kamatics innovation to retain a slip fit bearing. It incorporates the use of a polymer retaining ring in the outer race OD and/or the inner race ID. The polymer ring protrudes approximately .002 inches (0.05 mm) above the metallic surface, deforms and grips the mating surface during assembly. The slip fit shaft shown is typical of many torque tube bearing installations that had traditionally used ball bearings.

The polymer retaining ring should be considered for those applications where the possibility of unwanted relative motion exists between the outer race and housing or the inner race and shaft.

View G (Fig 19) depicts an installation that employs a familiar method on retaining the mating shaft to the inner race of the bearing. The shaft, with a "shoulder" or similar, is slipped into the bearing bore and secured to the inner race with the use of a nut or other threaded fastener. This approach can be used with any of the outer race retention methods previously shown.

TABLE 1
KAron and KAtherm Self Lubricating Systems

Liner	Approximate Physical Properties	Characteristics	Typical Applications
KAron B High Load	Density – 1.51 gm/cc Hardness Rockwell M 95 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures to 50,000 psi (345 MPa). Velocities to 3 fpm (1 M/min.) Temp Range –100° to 400° F (-73° to >205°C) SAE AS81820 & SAE AS81934 Qualified	Aircraft controls, landing gears etc. Highly loaded linkages. Jet engine controls. Other high loaded demanding, maintenance free applications.
KAron V High Load / Low Friction	Density – 1.36 gm/cc Hardness Rockwell M 85 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures to 40,000 psi (276 MPa). Velocities to 10 fpm (3 M/min.) Temp Range –100° to 300° F (-73° to 150°C) Mil-B-8943 Qualified	Track rollers. Cam followers. Marine/naval applications. Aircraft shock struts. Other high loaded, low friction applications.
KAron F Low Friction	Density – 1.36 gm/cc Hardness Rockwell M 85 Thickness Range .003” – min. (.076 mm min.)	Rubbing surface is a predominately PTFE enriched outer surface, providing low coefficient of friction at low loads and at low temperatures. The general operating parameters are the same as KAron V. A minimum thickness liner of .003” (.076 mm) can be obtained.	Spherical bearings Track rollers. Cam followers Other moderately high loaded, low friction applications
KAron VS Low Friction	Density – 1.56 gm/cc Hardness Rockwell 15X 88 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures up to 15,000 psi (103MPa), excellent low temperature friction capabilities. Temp Range –100° to 300° F (-73° to 150°C)	Spherical bearings Track rollers. Cam followers Other moderate loaded, low friction applications
KAron SP Ductile	Density – 1.44 gm/cc Hardness Rockwell 15X 77 Thickness Range .005 - .060” (.127 – 1.5 mm)	Dynamic Operating Pressures up to 25,000 psi (145MPa), excellent low temperature friction capabilities. Temp Range –100° to 250° F (-73° to 121°C) Designed for Mil-B-8943	Landing gear shock struts. Other applications requiring low friction and low rates of wear along with a degree of ductility to accommodate system deflections.
KAtherm T87S High Speed / Low Friction **500°F (260°C)**	Density – 1.39 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 15,000 psi (103 MPa). Velocities 50 fpm (15 M/min.) Temp Range –100° to 500° F (-73° to 260°C) Designed for SAE AS81819	Formulated for helicopter pitch link, pitch change, lead lag, scissors bearings requiring long life/low wear with very low friction. Also used for commercial/industrial oscillatory and continuous direction applications.
KAtherm T87 High Speed / High Temperature **500°F (260°C)**	Density – 1.37 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 20,000 psi (140 MPa). Velocities to 30 fpm (9 M/min.) Temp Range –100° to 500° F (-73° to 260°C) Designed for SAE AS81819	Formulated for high temperature applications to 500°F (260°C) such as variable guide vane bushings, engine linkages, thrust reverser bearings, engine controls, high temperature cam followers, high speed track rollers, helicopter rotor control bearings, and industrial pulleys.
KAtherm T88 High Speed / High Temperature **600°F (316°C)**	Density – 1.30 gm/cc Hardness Rockwell M 80/90 Thickness Range .005 - .030” (.127 – .75 mm)	Dynamic Operating Pressures to 10,000 psi (70 MPa). Velocities to 30 fpm (9 M/min.) Temp Range –100° to 600° F (-73° to 316°C)	Formulated for high temperature applications to 600°F (316°C) such as VG bushings, engine linkages, thrust reverser, cam followers, track rollers and helicopter rotor control bearing
KAtherm T10 High Load / High Temperature **600°F (316°C)**	Thickness .010” (.254 mm)	Dynamic Operating Pressures to 20,000 psi (140 MPa) Velocities to 30 ft/min (9 M/min) Temp Range –100° to 600° F (-73° to 316°C)	High temperature/high load fabric for applications to 600°F (316°C) such as high temperature cam followers and spherical bearings used in aircraft gas turbine engines, high

NOTE: Kamatics also produces a variety of low to high temperature materials for wear strip, wear pads, wear bars, and bumper pad applications. Contact Kamatics Corporation for more information.

TABLE 2a (inch) Stainless Steel Journal Bearings

KAMATICS P/N	SAE AS81934 P/N	BEARING OD +0.0000, -0.0005	HOUSING ID +0.0010, -0.0000	MAX. SHAFT DIAMETER *
KRJ4-S	M81934/X-04C	0.3760	0.3743	0.2485
KRJ5-S	M81934/X-05C	0.4386	0.4369	0.3110
KRJ6-S	M81934/X-06C	0.5012	0.4995	0.3735
KRJ7-S	M81934/X-07C	0.5638	0.5621	0.4360
KRJ8-S	M81934/X-08C	0.6265	0.6248	0.4985
KRJ9-S	M81934/X-09C	0.6892	0.6875	0.5610
KRJ10-S	M81934/X-10C	0.8142	0.8125	0.6235
KRJ11-S	M81934/X-11C	0.8767	0.8750	0.6860
KRJ12-S	M81934/X-12C	0.9393	0.9376	0.7485
KRJ14-S	M81934/X-14C	1.0645	1.0628	0.8735
KRJ16-S	M81934/X-16C	1.1898	1.1881	0.9985
KRJ18-S	M81934/X-18C	1.3148	1.3131	1.1235
KRJ20-S	M81934/X-20C	1.4398	1.4381	1.2485
KRJ22-S	M81934/X-22C	1.5648	1.5631	1.3735
KRJ24-S	M81934/X-24C	1.7523	1.7503	1.4989
KRJ26-S	M81934/X-26C	1.8773	1.8753	1.6239
KRJ28-S	M81934/X-28C	2.0023	2.0003	1.7489
KRJ32-S	M81934/X-32C	2.2523	2.2503	1.9989

- *Maximum shaft diameter is based on 0.001 inch resultant clearance between the shaft OD and bearing ID after bearing installation in its housing.

TABLE 2b (millimeter) Stainless Steel Journal Bearings

KAMATICS P/N	SAE AS81934 P/N	BEARING OD +0.0000, -0.0127	HOUSING ID +0.0254, -0.0000	MAX. SHAFT DIAMETER
KRJ4-S	M81934/X-04C	9.5504	9.5072	6.3119
KRJ5-S	M81934/X-05C	11.1404	11.0973	7.8994
KRJ6-S	M81934/X-06C	12.7305	12.6873	9.4869
KRJ7-S	M81934/X-07C	14.3205	14.2773	11.0744
KRJ8-S	M81934/X-08C	15.9131	15.8699	12.6619
KRJ9-S	M81934/X-09C	17.5057	17.4625	14.2494
KRJ10-S	M81934/X-10C	20.6807	20.6375	15.8369
KRJ11-S	M81934/X-11C	22.2682	22.2250	17.4244
KRJ12-S	M81934/X-12C	23.8582	23.8150	19.0119
KRJ14-S	M81934/X-14C	27.0383	26.9951	22.1869
KRJ16-S	M81934/X-16C	30.2209	30.1777	25.3619
KRJ18-S	M81934/X-18C	33.3959	33.3527	28.5369
KRJ20-S	M81934/X-20C	36.5709	36.5277	31.7119
KRJ22-S	M81934/X-22C	39.7459	39.7027	34.8869
KRJ24-S	M81934/X-24C	44.5084	44.4576	38.0721
KRJ26-S	M81934/X-26C	47.6834	47.6326	41.2471
KRJ28-S	M81934/X-28C	50.8584	50.8076	44.4221
KRJ32-S	M81934/X-32C	57.2084	57.1576	50.7721

- *Maximum shaft diameter is based on 0.0254 millimeter resultant clearance between the shaft OD and bearing ID after bearing installation in its housing.

TABLE 3a (inch) Aluminum Alloy Journal Bearings

KAMATICS P/N	SAE AS81934 P/N	BEARING OD ±0.0005	HOUSING ID +0.0010, -0.0000	MAX. SHAFT DIAMETER *
KRJ4-Y	M81934/X-04A	0.3760	0.3748/0.3753	0.2485
KRJ5-Y	M81934/X-05A	0.4386	0.4374/0.4379	0.3110
KRJ6-Y	M81934/X-06A	0.5012	0.5000/0.5005	0.3735
KRJ7-Y	M81934/X-07A	0.5638	0.5626/0.5631	0.4360
KRJ8-Y	M81934/X-08A	0.6265	0.6253/0.6258	0.4985
KRJ9-Y	M81934/X-09A	0.6892	0.6880/0.6885	0.5610
KRJ10-Y	M81934/X-10A	0.8142	0.8130/0.8135	0.6235
KRJ11-Y	M81934/X-11A	0.8767	0.8755/0.8760	0.6860
KRJ12-Y	M81934/X-12A	0.9393	0.9381/0.9386	0.7485
KRJ14-Y	M81934/X-14A	1.0645	1.0628	0.8735
KRJ16-Y	M81934/X-16A	1.1898	1.1881	0.9983
KRJ18-Y	M81934/X-18A	1.3148	1.3131	1.1233
KRJ20-Y	M81934/X-20A	1.4398	1.4381	1.2483
KRJ22-Y	M81934/X-22A	1.5648	1.5631	1.3733
KRJ24-Y	M81934/X-24A	1.7523	1.7503	1.4983
KRJ26-Y	M81934/X-26A	1.8773	1.8753	1.6233
KRJ28-Y	M81934/X-28A	2.0023	2.0003	1.7483
KRJ32-Y	M81934/X-32A	2.2523	2.2503	1.9993

- *Maximum shaft diameter is based on 0.001 inch resultant clearance between the shaft OD and bearing ID after bearing installation in its housing.

TABLE 3b (millimeter) Aluminum Alloy Journal Bearings

KAMATICS P/N	SAE AS81934 P/N	BEARING OD ±0.0127	HOUSING ID +0.0254, -0.0000	MAX. SHAFT DIAMETER*
KRJ4-Y	M81934/X-04A	9.5504	9.5200/9.5326	6.3119
KRJ5-Y	M81934/X-05A	11.1404	11.1010/11.1227	7.8994
KRJ6-Y	M81934/X-06A	12.7305	12.7000/12.7127	9.4869
KRJ7-Y	M81934/X-07A	14.3205	14.2900/14.3027	11.0744
KRJ8-Y	M81934/X-08A	15.9131	15.8826/15.8953	12.6619
KRJ9-Y	M81934/X-09A	17.5057	17.4752/17.4879	14.2494
KRJ10-Y	M81934/X-10A	20.6807	20.6502/20.6629	15.8369
KRJ11-Y	M81934/X-11A	22.2682	22.2377/22.2504	17.4244
KRJ12-Y	M81934/X-12A	23.8582	23.8277/23.8404	19.0119
KRJ14-Y	M81934/X-14A	27.0383	26.9951	22.1869
KRJ16-Y	M81934/X-16A	30.2209	30.1777	25.3568
KRJ18-Y	M81934/X-18A	33.3959	33.3527	28.5318
KRJ20-Y	M81934/X-20A	36.5709	36.5277	31.7068
KRJ22-Y	M81934/X-22A	39.7459	39.7027	34.8818
KRJ24-Y	M81934/X-24A	44.5084	44.4576	38.0568
KRJ26-Y	M81934/X-26A	47.6834	47.6326	41.2318
KRJ28-Y	M81934/X-28A	50.8584	50.8076	44.4068
KRJ32-Y	M81934/X-32A	57.2084	57.1576	50.7822

- *Maximum shaft diameter is based on 0.0254 millimeter resultant clearance between the shaft OD and bearing ID after bearing installation in its housing.

Table 4

Mating Bearing Surface	
Surface Finish	
Roughness-μin.	Life Factor
4-10 (.025-.25 μm)	1.00
16 (0.4 μm)	.75
32 (0.8 μm)	.40
Surface Hardness	
Hardness Rc	Life Factor
50+	1.00
40	.60
30	.40

TABLE 5a (inch) Spherical Bearings (Narrow Series)

KAMATICS P/N	SAE AS81820 P/N	Bearing OD +0.0000, -0.0005	Housing ID +0.0000, -0.0005	Housing Chamfer x 45°±5°(inches)	Recommended Housing Width +0.010, -0.000
KR3-CNG	MS14101-03	0.5625	0.5618	0.020-0.025	0.218
KR4-CNG	MS14101-04	0.6562	0.6555	0.020-0.025	0.250
KR5-CNG	MS14101-05	0.7500	0.7493	0.020-0.025	0.281
KR6-CNG	MS14101-06	0.8125	0.8118	0.020-0.025	0.312
KR7-CNG	MS14101-07	0.9062	0.9055	0.020-0.025	0.343
KR8-CNG	MS14101-08	1.0000	0.9993	0.040-0.045	0.390
KR9-CNG	MS14101-09	1.0937	1.0930	0.040-0.045	0.437
KR10-CNG	MS14101-10	1.1875	1.1868	0.040-0.045	0.500
KR12-CNG	MS14101-12	1.4375	1.4368	0.040-0.045	0.593
KR14-CNG	MS14101-14	1.5625	1.5618	0.040-0.045	0.703
KR16-CNG	MS14101-16	1.7500	1.7493	0.040-0.045	0.797
KR20-CNG	MS14101-20	2.0000	1.9993	0.040-0.045	0.942

TABLE 5b (millimeters) Spherical Bearings (Narrow Series)

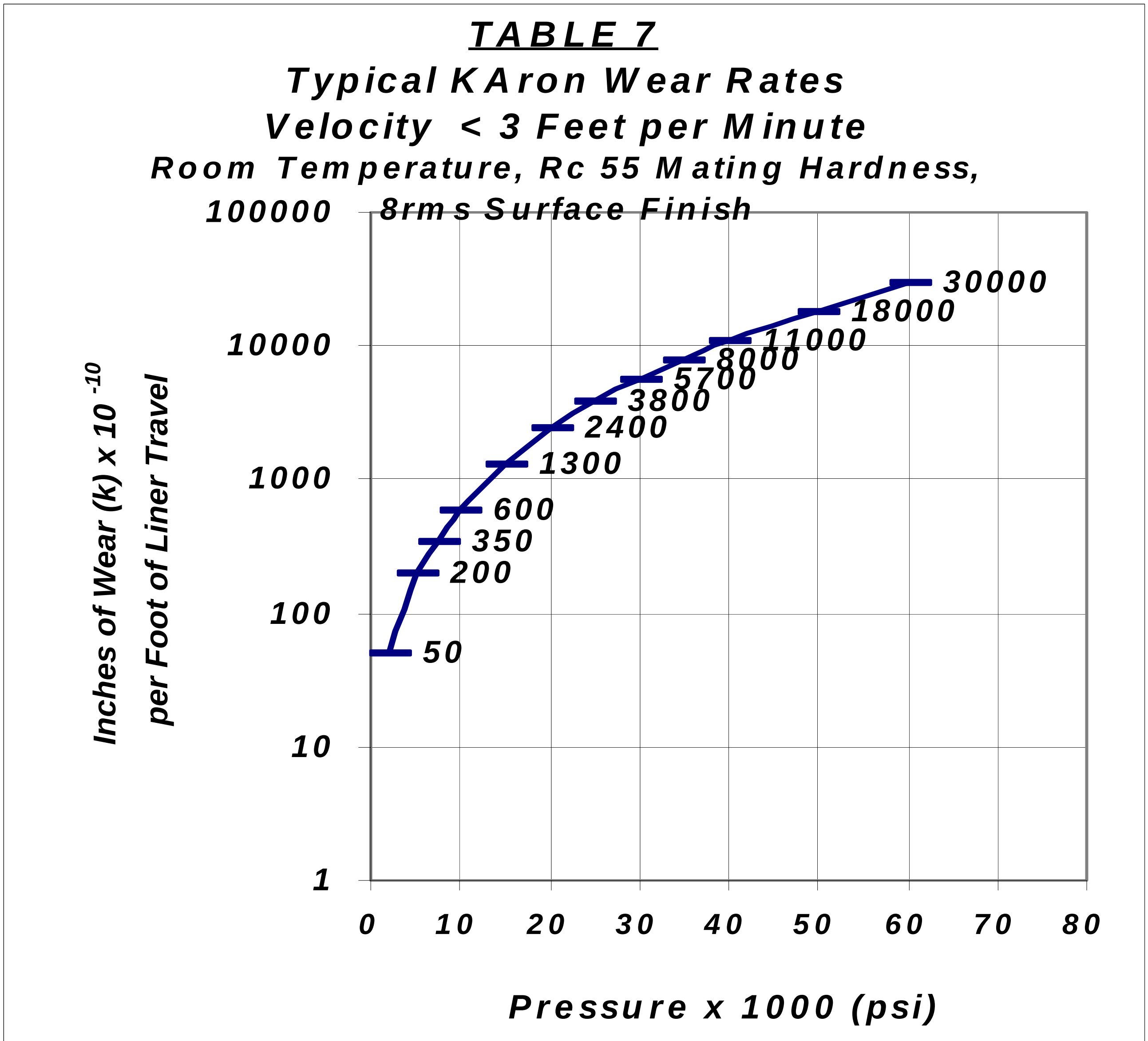
KAMATICS P/N	SAE AS81820 P/N	Bearing OD +0.0000, -0.0127	Housing ID +0.0000, -0.0127	Housing Chamfer x 45°±5°	Recommended Housing Width +0.250, -0.000
KR3-CNG	MS14101-03	14.2875	14.270	0.51-0.64	5.5372
KR4-CNG	MS14101-04	16.6675	16.650	0.51-0.64	6.3500
KR5-CNG	MS14101-05	19.0500	19.032	0.51-0.64	7.1374
KR6-CNG	MS14101-06	20.6375	20.620	0.51-0.64	7.9248
KR7-CNG	MS14101-07	23.0175	23.000	0.51-0.64	8.7122
KR8-CNG	MS14101-08	25.4000	25.382	1.000-1.140	9.9060
KR9-CNG	MS14101-09	27.7800	27.762	1.000-1.140	11.0998
KR10-CNG	MS14101-10	30.1625	30.145	1.000-1.140	12.7000
KR12-CNG	MS14101-12	36.5125	36.495	1.000-1.140	15.0622
KR14-CNG	MS14101-14	39.6875	39.670	1.000-1.140	17.8562
KR16-CNG	MS14101-16	44.4500	44.432	1.000-1.140	20.2438
KR20-CNG	MS14101-20	50.8000	50.782	1.000-1.140	23.9268

TABLE 6a (inch) Spherical Bearings (Wide Series)

KAMATICS P/N	SAE AS81820 P/N	Bearing OD +0.0000, -0.0005	Housing ID +0.0000, -0.0005	Housing Chamfer x 45°±5°	Recommended Housing Width +0.010, -0.000
KR3-CWG	MS14103-03	0.6250	0.6243	0.020-0.025	0.327
KR4-CWG	MS14103-04	0.6250	0.6243	0.020-0.025	0.327
KR5-CWG	MS14103-05	0.6875	0.6868	0.020-0.025	0.317
KR6-CWG	MS14103-06	0.8125	0.8118	0.020-0.025	0.406
KR7-CWG	MS14103-07	0.9375	0.9368	0.020-0.025	0.442
KR8-CWG	MS14103-08	1.0000	0.9993	0.020-0.025	0.505
KR9-CWG	MS14103-09	1.1250	1.1243	0.020-0.025	0.536
KR10-CWG	MS14103-10	1.1875	1.1868	0.020-0.025	0.567
KR12-CWG	MS14103-12	1.3750	1.3743	0.040-0.045	0.630
KR14-CWG	MS14103-14	1.6250	1.6243	0.040-0.045	0.755
KR16-CWG	MS14103-16	2.1250	2.1243	0.040-0.045	1.005
KR20-CWG	MS14103-20	2.3750	2.3743	0.040-0.045	1.130

TABLE 6b (millimeters) Spherical Bearings (Wide Series)

KAMATICS P/N	SAE AS81820 P/N	Bearing OD +0.0000, -0.0127	Housing ID +0.0000, -0.0127	Housing Chamfer x 45°±5°	Recommended Housing Width +0.254, -0.000
KR3-CWG	MS14103-03	15.8750	15.857	0.051-0.064	8.306
KR4-CWG	MS14103-04	15.8750	15.857	0.051-0.064	8.306
KR5-CWG	MS14103-05	17.4625	17.445	0.051-0.064	8.052
KR6-CWG	MS14103-06	20.6375	20.620	0.051-0.064	10.312
KR7-CWG	MS14103-07	23.8125	23.795	0.051-0.064	11.227
KR8-CWG	MS14103-08	25.4000	25.382	0.051-0.064	12.827
KR9-CWG	MS14103-09	28.5750	28.557	0.051-0.064	13.614
KR10-CWG	MS14103-10	30.1625	30.145	0.051-0.064	14.402
KR12-CWG	MS14103-12	34.9250	34.907	1.000-1.140	16.002
KR14-CWG	MS14103-14	41.2750	41.257	1.000-1.140	19.177
KR16-CWG	MS14103-16	53.9750	53.957	1.000-1.140	25.527
KR20-CWG	MS14103-20	60.3250	60.307	1.000-1.140	28.702

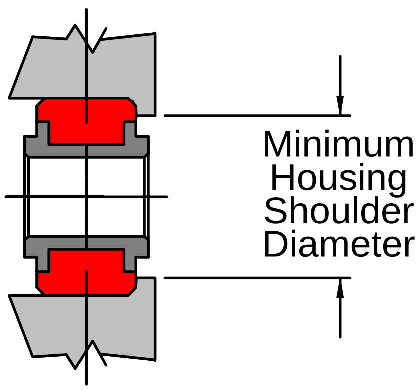


The values above are to be considered as a guide only for initial sizing of a bearing under consideration. Other contributing factors such as mating surfaces hardness, finish, contamination, temperature and type of bearing motion (oscillation, translation or rotation) have an effect on the amount of liner wear. After sizing the bearing, consult Kamatics engineering for review and comments.

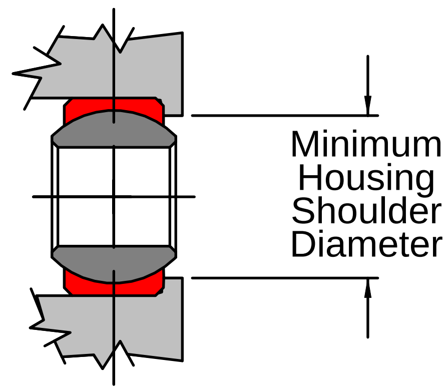
Table 8a

Recommended Minimum Housing Shoulder Diameters

(Inches)



"KRP" Design



Spherical Design

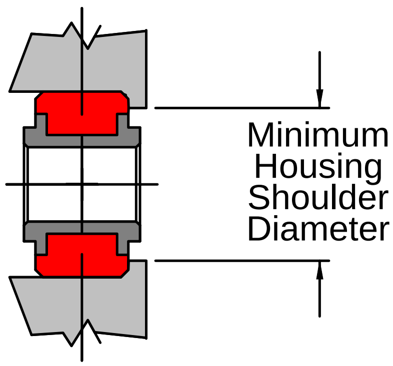
Bearing Number	Minimum Housing Shoulder Diameter
KRP3	.62
KRP4	.73
KRP5	1.01
KRP6	1.23
KRP8	1.45
KRP10	1.65
KRP3A	.52
KRP4A	.62
KRP5A	.68
KRP6A	.75
KRP8A	.98
KRP10A	1.21
KRP12A	1.46
KRP16A	1.76
KRP20A	2.03
KRP16B	1.59
KRP16BS	1.72
KRP21B	1.89
KRP23B	2.02
KRP25B	2.13
KRP29B	2.37
KRP33B	2.67
KRP37B	2.91
KRP47B	3.60
KRP49B	3.77
KRP49BK	3.69

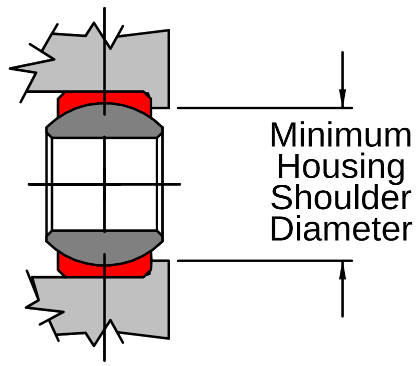
Bearing Number	Minimum Housing Shoulder Diameter
KRP21BS	2.10
KRP23BS	2.16
KRP25BS	2.28
KRP29BS	2.54
KRP33BS	2.79
KRP37BS	3.04
KRP47BS	3.85
KRP48BS	3.97
KRP49BS	3.97
KRPB538	.92
KRPB539	1.04
KRPB540	1.16
KRPB541	1.36
KRPB542	1.60
KRPB543	1.84
KRPB544	2.12
KRPB545	2.43
KRPB546	2.68
KRPP3	.63
KRPP4	.72
KRPP5	1.08
KRPP6	1.25
KRPP8	1.47
KRPP10	1.64

Bearing Number	Minimum Housing Shoulder Diameter
KR3CN	.39
KR4CN	.48
KR5CN	.53
KR6CN	.59
KR7CN	.64
KR8CN	.72
KR9CN	.80
KR10CN	.87
KR12CN	1.07
KR14CN	1.15
KR16CN	1.31
KR20CN	1.55
KR3CW	.46
KR4CW	.50
KR5CW	.54
KR6CW	.60
KR7CW	.69
KR8CW	.76
KR9CW	.89
KR10CW	.94
KR12CW	1.08
KR14CW	1.19
KR16CW	1.63
KR20CW	1.81

Bearing Number	Minimum Housing Shoulder Diameter
KR3CE	.43
KR4CE	.58
KR5CE	.58
KR6CE	.74
KR8CE	.96
KR10CE	1.16
KR12CE	1.27
KR14CE	1.72

Table 8b
Recommended Minimum Housing Shoulder Diameters
(Millimeters)





"KRP" Design

Spherical Design

Bearing Number	Minimum Housing Shoulder Diameter
KRP3	15.80
KRP4	18.59
KRP5	25.76
KRP6	31.34
KRP8	36.93
KRP10	41.81
KRP3A	13.21
KRP4A	15.75
KRP5A	17.38
KRP6A	19.16
KRP8A	24.80
KRP10A	30.84
KRP12A	37.19
KRP16A	44.81
KRP20A	51.46
KRP16B	40.46
KRP16BS	43.64
KRP21B	48.11
KRP23B	51.21
KRP25B	54.15
KRP29B	60.25
KRP33B	67.87
KRP37B	73.91
KRP47B	91.44
KRP49B	95.71
KRP49BK	93.78

Bearing Number	Minimum Housing Shoulder Diameter
KRP21BS	53.29
KRP23BS	54.74
KRP25BS	57.96
KRP29BS	64.40
KRP33BS	70.79
KRP37BS	77.19
KRP47BS	97.69
KRP48BS	100.89
KRP49BS	100.89
KRPB538	23.47
KRPB539	26.47
KRPB540	29.51
KRPB541	34.54
KRPB542	40.59
KRPB543	46.69
KRPB544	53.75
KRPB545	61.82
KRPB546	68.02
KRPP3	16.10
KRPP4	18.24
KRPP5	27.38
KRPP6	31.70
KRPP8	37.29
KRPP10	41.61

Bearing Number	Minimum Housing Shoulder Diameter
KR3CN	9.80
KR4CN	12.07
KR5CN	13.34
KR6CN	14.86
KR7CN	16.13
KR8CN	18.16
KR9CN	20.32
KR10CN	22.10
KR12CN	27.18
KR14CN	29.21
KR16CN	33.27
KR20CN	39.37
KR3CW	11.68
KR4CW	12.57
KR5CW	13.72
KR6CW	15.11
KR7CW	17.40
KR8CW	19.18
KR9CW	22.48
KR10CW	23.88
KR12CW	27.43
KR14CW	30.23
KR16CW	41.28
KR20CW	45.85

Bearing Number	Minimum Housing Shoulder Diameter
KR3CE	10.80
KR4CE	14.61
KR5CE	14.61
KR6CE	18.80
KR8CE	24.38
KR10CE	29.34
KR12CE	32.13
KR14CE	43.69

9. APPENDIX A

- Photographs of Kamatics Products
- KAron Characteristics
- KAron Fluid Compatibility
- Customer Conducted Humidity Testing
- KAron V Coefficient of Friction
- Journal Bearing Construction Comparison
- Spherical Bearing Construction Comparison
- Honing, Machining Cleaning and Measuring KAron and KAtherm, Data Sheet 131
- KAron V Wear Strip Product Data Sheet, Data Sheet 134
- KAron Wear Strip Bonding, Tech Note 15
- Roller Swaging KAron Lined Bearings, Tech Note 18

Photo showing the scope and size-range of Kamatics capabilities. Bearings shown are made from stainless steel, aluminum, bronze, titanium and composites. KAflex driveshaft couplings made from stainless, titanium, and maraging steels.

Photo showing KAron lined sleeve and journal bearings for use in landing gears, actuators, pivot joints and similar.

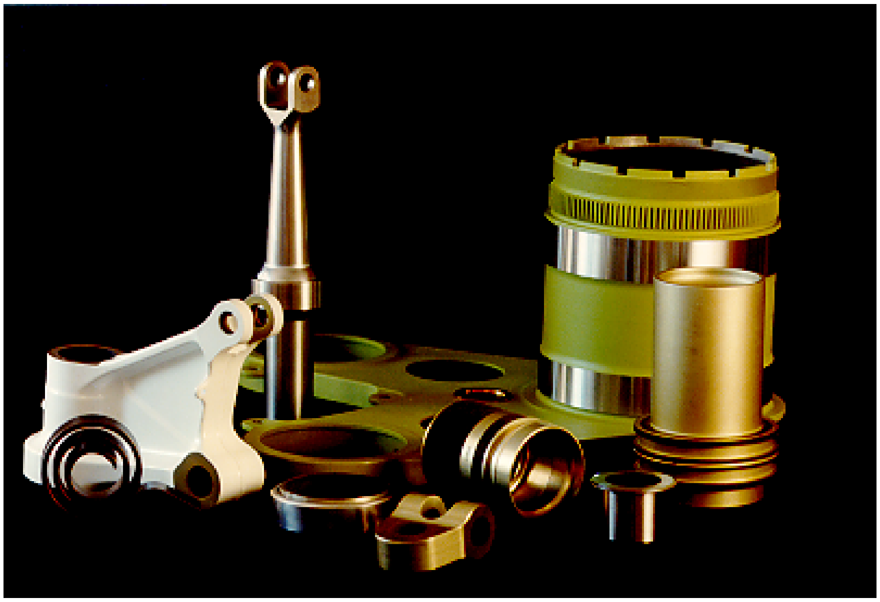


Photo showing complex configurations to which the KAron liner is applied. Pictured are landing gear bearings, helicopter rotor bearings, actuator glands, flaperon spherical bearings and a KAron lined door spring.

Photo showing various sizes of spherical bearings produced by Kamatics. Pictured are bearings for hydropower turbines, submarine linkages, nuclear power generator supports and landing gear trunnion pivots.

KAMATICS CORPORATION

KAMAN

Pictured above are typical KAron lined track rollers, cam followers, and track sliders. Bearings shown are used on large commercial, business and regional aircraft track, slat and door mechanisms among other places.

Composite bearings; filament wound, braided and laminated construction all with a KAron liner applied are depicted above. Sleeves, thrust washers, flanged journals, guide strips and bars are shown. Glass, carbon, polyester and other fibers are combined with various resins including epoxy and polyester.

Typical KAron Characteristics

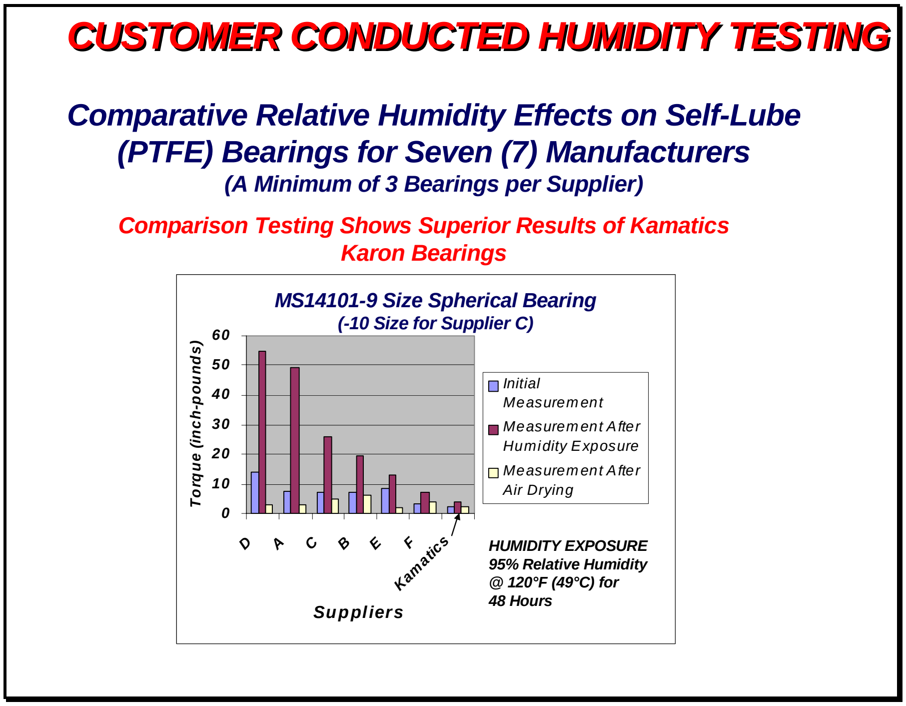
- ***Self adhering - No secondary bonding***
- ***Large thickness range…up to.060"***
- ***Excellent fluid compatibility***
- ***Excellent abrasion resistance***
- ***Homogenous - uniform wear & friction***
- ***Ability to refurbish components***
- ***It is Machinable***

The slide above lists significant attributes for KAron liner systems. All KAron formulations are made from the same basic resin system, insuring consistent performance.

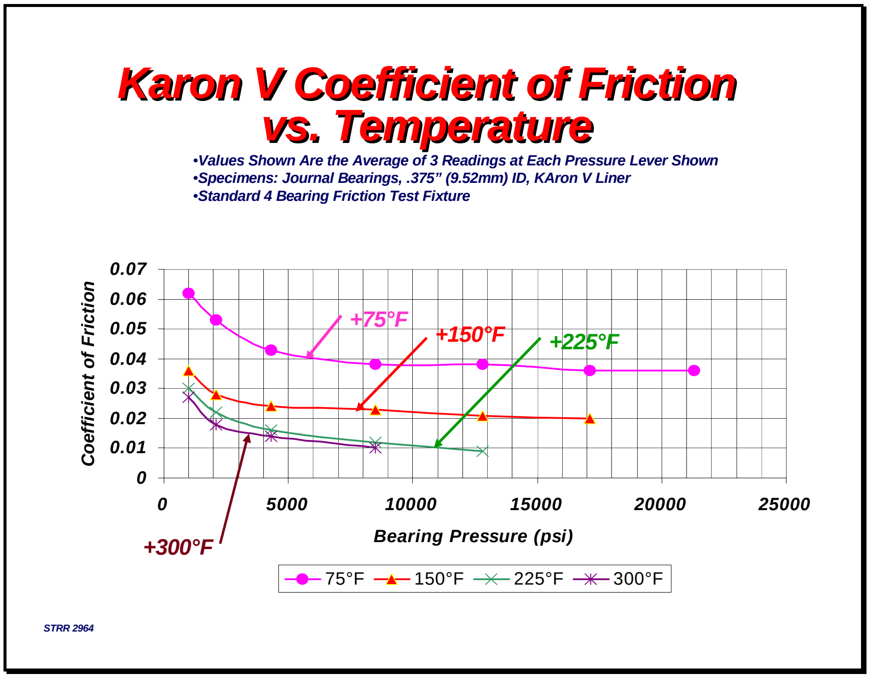
KAron Fluid Compatibility

- ***Skydrol 500A/500B-Hydraulic Fluid***
- ***MIL-H-5606-Hydraulic Fluid***
- ***MIL-PRF-83282-Hydraulic Fluid***
- ***MIL-PRF-7808-Lubricating Oil***
- ***MIL-L-2104 Grade 10-Lubricating Oil***
- ***MIL-L-23699-Lubricating Oil***
- ***MIL-A-8243-Anti-icing Fluid***
- ***O-A-548-Ethylene Glycol***
- ***MIL-DTL-5624-JP-4, JP-5 & JP8 Jet Fuel***
- ***TT-S-735 Type VII-Standard Test Fluid***
- ***MIL-L-25769-Cleaning Compound***
- ***TT-T-548-Toluene***
- ***TT-B-846-Butyl Alcohol***
- ***Water (both fresh & salt)***
- ***Many Other Fluids..Contact Kamatics***

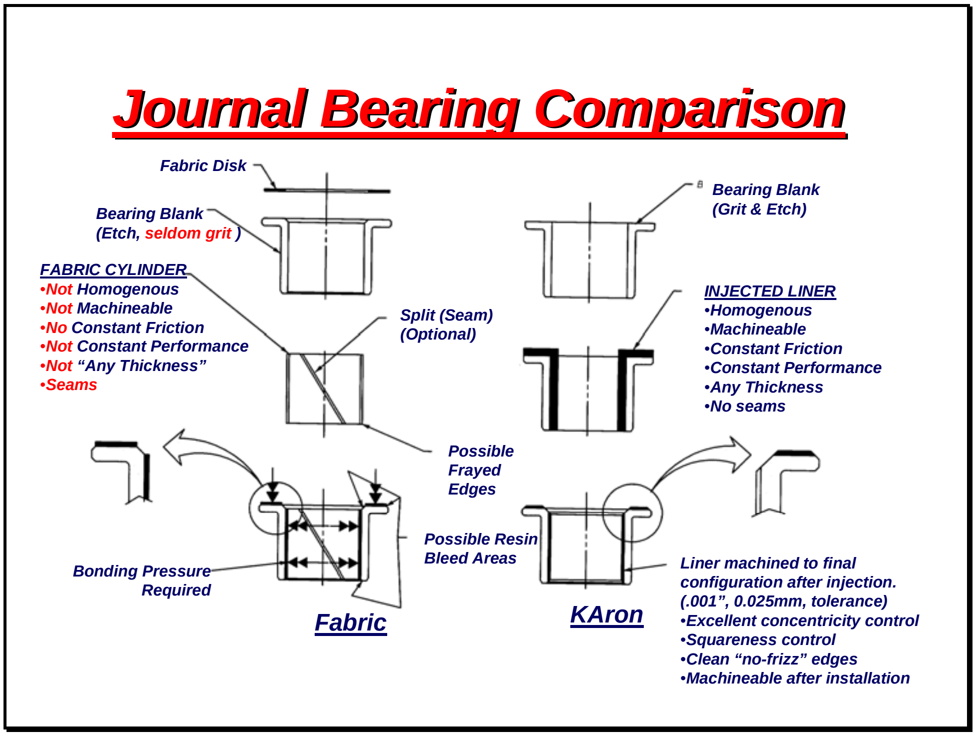
It is important that a liner system be capable of operating in hostile environments. This includes the ability to function in various fluids without degrading, softening or swelling. The KAron liner system operates exceptionally in most industrial and aerospace fluids, including those listed above.



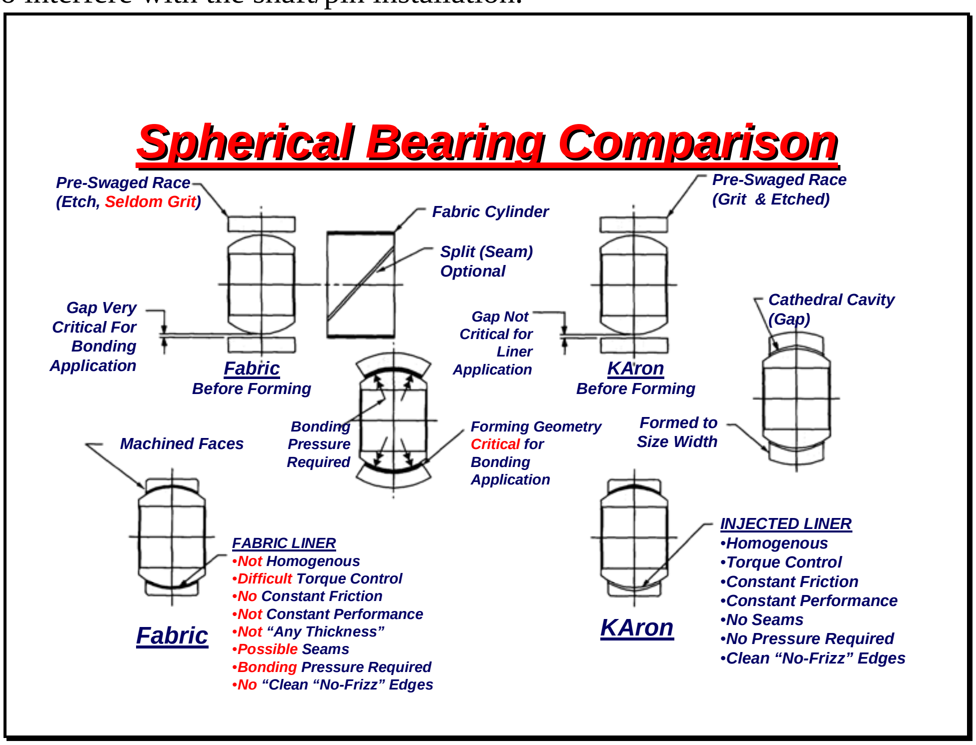
The results shown above were obtained from testing conducted by a major aerospace company. It clearly shows that the KAron liner system was affected the least of the seven suppliers submitting specimens.



The slide above offers typical coefficient of friction values for the KAron V liner system at various temperatures and bearing pressures. If information as to the coefficients of other KAron liners is required, contact a Kamatics representative at 860-243-9704



The slide shown above graphically depicts the difference in the manufacture of a KAron lined journal bearing and that of a fabric lined journal bearing. It is readily apparent that a KAron lined bearing will allow trouble-free installation and provide constant operating performance. There is no the concern the realistic possibility of raised and/or frayed liner edges to interfere with the shaft/pin installation.



Similar to the slide above, this slide also depicts the differences in manufacture between a KAron lined spherical bearing and a fabric lined spherical bearing. The Kamatics cathedral cavity and no requirement for bonding pressure sets the KAron bearing apart

HONING, MACHINING, CLEANING & MEASUREING KARON and KATHERM

Honing:

The following information is supplied as an aid in KARON or KATHERM honing operations. A honing machine, Sunnen or similar, should be used and the finished ID be sized with standard GO\NO-GO plug gages. Tooling may be required to properly position the part being honed to insuring alignment, squareness, and/or position.

- **Stone -** Sunnen K6-A63 or K6-A65 or similar (280 grit medium hard aluminum oxide).
- **Speed -** 300 to1000 rpm, depending upon the diameter of the bushing being honed.
- **Coolant -** Sunnen MB30 (oil base) or similar.

After honing, ultrasonic clean the bushing in any of the cleaners noted below, to remove honing stone debris.

Machining:

The following information is supplied as an aid in KARON or KATHERM machining operations. The finished ID should be sized with standard GO\NO-GO plug gages. Tooling may be required to properly position the location of the ID.

- **Inserts -** Diamond inserts for best results, Carbide inserts acceptable. 0.030” nose radius minimum.
- **Speed -** 1000 surface feet per minute (300 meters per minute) minimum.
- **Depth of Cut -** as required.
- **Feed Rate -** 0.001/. 003 inches (0.025/0.075 mm) per revolution.
- **Coolant –** water-soluble coolant (if necessary).

Depending on size and the degree of accuracy required, special fixtures and/or holding devices may be required (as would be the case for machining any material). KAron is easily machined and therefore the use of a coolant is not necessary. The machining debris will be in the form of small chips and powder.

Cleaning:

Cleaning of the Kamatics bearings can be accomplished with practically any normal factory cleaner or solvent. Obviously those that do not leave a undesirable residue are preferred. Suggested is Turco 4215 alkaline detergent followed with a fresh water rinse, or Citrikleen XPC citric based solvent followed with a methanol rinse. Nitrosol, alcohol, acetone, and Tri-chlor 111 (when/if environmentally acceptable) can also be used. Avoid acids (hot or cold) and caustic “paint removers” as these can be a problem if left on the liner for an extended period of time (over 3 minutes).

Dimensional Inspection:

Dimensional inspection of KAron and KAtherm lined surfaces requires special consideration. Because or the fibrous nature of the material and its hardness relative to metals, we suggest the use of “GO-NO GO” gages when inspecting inside diameters. Light pressure on micrometer measurements on external surfaces readily measured with this type of instrument, should be used.

If conventional dial bore indicators are used, where there are several small pressure probes employed, it has been established that the reading on the gage should allow .00015 inches (0.0038 mm) for the probe penetration into the liner.

For example, if the high limit dimension on an inside diameter is 1.0000 inches (25.40 mm), a “dial bore” reading of 1.0003 inches (25.408 mm) would be an acceptable reading. The low limit value would be similarly affected.

Kamatics Data Sheet 134

KAron® V Wear Strip

Product Data Sheet

Description:

Kamatics KAron® V Wear Strip consists of standard KAron Grade V self-lubricating bearing material applied onto a thin fiberglass substrate. It is designed to be bonded onto surfaces that are subjected to light to medium duty rubbing pressure, or as a fretting resistant barrier.

Physical Properties:(1)

Coefficient of friction:	.04 - .08	
Compressive strength:	30,000 psi	(207 mPa)
Max dynamic load:	10,000 psi	(69 mPa)
Max operating temp:	250°F	(120°C)

Available Sizes:

Standard KAron V Wear Strip material is available in cut sheets of 12" x 48" (305 x 1219 mm), 3/4" and 1" (19mm and 25.4mm) wide strips, washers of various sizes, and custom die cut shapes. The material is available in two thicknesses:

KAron V Wear Strip Grade	*Product Description*	*Nominal Thickness*
KWS100	Light Duty Wear Strip	.018" ± .003 (.46 mm ± .075)
KWS200	Medium Duty Wear Strip	.036" ± .003 (.91 mm ± .075)

Standard Part Numbering System:

For standard cut strip dimension parts, Kamatics uses the following part numbering system:

KWS*[M]xxx[T] - yyy - zzz*

Where:

M = Metric dimensions
xxx = Wear strip grade, i.e. KWS100 = Light Duty Wear Strip, .018" (.46mm) nominal thickness
T = 3/8" (9.5mm) pull tab included along edge (pull-tab allows for easy removal of peel ply backing)
yyy = Part width in 1/8" increments up to 12", i.e. 024 = 3" wide
(Metric: 5mm increments up to 300mm, i.e. 020 = 100mm wide)
zzz = Part length in 1/4" increments up to 48", i.e. 096 = 24" long
(Metric: 10mm increments up to 1200mm, i.e. 050 = 500mm long)

Bonding Procedure:

KAron V Wear Strip comes with a woven nylon peel-ply on the back of the fiberglass to protect the bonding surface from dirt and debris. When the pull-tab (T) option is called out in the part number, a 3/8" (9.5mm) long breakaway tab will be provided for easy removal of the peel ply backing. With the peel-ply removed and the back surface exposed, the KAron V Wear Strip is prepared for bonding onto a suitable surface. A room temperature curing structural epoxy adhesive (2) is recommended for bonding KAron V Wear Strip material.

Notes:

1. Above reported values based on wear strip only. Physical properties in service will be largely dependent upon the adhesive bond integrity, the substrate material, and surface preparation of the substrate.
2. Suggested structural adhesives: EA9460, EA9309, EA9394 (Dexter Hysol), Scotchweld 460 (3M Co.), Araldite 2011 (Ciba Specialty Polymers).

Kamatics KAron Wear Strip
Bonding Procedure for General
Purpose Installations, <160°F (<70 °C)

Introduction

Kamatics KAron coated Wear Strips offer the capability to coat and protect moving parts by field application of self lubricating bearing materials. When attaching the Kamatics Wear Strip, care should be taken in the field bonding procedure to assure adequate adhesion of the Wear Strip to the substrate to be protected. The Kamatics Engineering Technical Note provides a procedure for general purpose bonding of Kamatics Wear Strips where operating temperature will not exceed 160°F (70°C) and operating loads are low.

General

A reliable bonding procedure requires care in the following:

⇒ - Adhesive selection and control
⇒ - Substrate cleaning
⇒ - Substrate preparation
⇒ - Bond line thickness control
⇒ - Curing procedure.

This Engineering Technical Note addresses each of the above elements to provide the user with a step-by-step procedure for general purpose bonding of Kamatics Wear Strips .

Adhesive Selection and Control

For bonding Wear Strips, Kamatics recommends the use of Hysol Epoxy Adhesive EA 9309.3 NA, or equivalent. Important characteristics of the adhesive are:

⇒ - Adequate working time for the particular installation
⇒ - 160°F (70°C) operating temperature
⇒ - Integral bond line control (suspended glass beads or fabric carriers)

The final bond quality can be adversely affected by improper handling and storage of the adhesive. Therefore, all adhesives must be stored and handled strictly in accordance with the manufacturer's instructions and must not be used beyond their published shelf life.

Substrate Cleaning

The substrate should be thoroughly cleaned to remove all traces of dirt, oils, and other contaminants.
For substrates which are heavily contaminated, the surfaces to be bonded should first be cleaned using a detergent cleaner and thoroughly rinsed with hot water.

Cleaning of the surface to be coated should be by washing or wiping with trichloroethane, acetone, or alcohol.

No cleaning of the Kamatics Wear Strip is required. The surface of the Wear Strip to be bonded is protected by an integral "peel ply" applied to the surface to be bonded. Removal of this "peel ply" exposes a surface which is clean, roughened, and ready for bonding.

All parts, following cleaning, should be handled only by personnel using clean, lint free gloves. Contamination of cleaned surfaces must be avoided, and any such contamination requires re-cleaning of the parts.

Substrate Preparation

In order to achieve a reliable bond between the Kamatics Wear Strip and the substrate, both surfaces should be mechanically roughened to provide a surface most receptive to adhesion.

As mentioned previously, the "peel ply" applied to the back of the Wear Strip, when removed exposes a surfaces which is already clean, properly roughened, and ready for bonding.

The substrate should be mechanically roughened using an alumina grit paper (80-200 grit is adequate) or using alumina grit in a grit blast operation, to remove all surface deposits. Re-clean the surfaces after roughening. Bond as soon as possible.

Proper Bond Line Thickness Control

In order to achieve the highest possible bond strength, the bond line thickness must be controlled. The best method for controlling the bond line thickness is to use an adhesive with an integral method of bond line control.

Adhesive EA 9309.3 NA is a liquid which incorporates 0.005" diameter glass beads for bond line control. The liquid is applied to one or both surfaces to be bonded, and the surfaces are pressed together until the excess adhesive is squeezed out from between the surfaces. The glass beads prevent the surfaces from being pressed closer together than 0.005" (0.125 mm), providing the optimum bond line thickness.

Proper Curing Procedure

The final bond quality can be adversely affected by improper curing of the adhesive. Therefore, all curing operations must be performed strictly in accordance with the manufacturer's instructions. EA 9309.3 NA provides optimum strength when cured at 70°-80°F (20°-25°C) for 5 to 7 days. The bond will develop sufficient strength for handling after 6 hours at room temperature, and fixturing to hold the part pressed together should be used until handling strength is developed. Time to develop handling strength can be greatly reduced by application of heat (do not exceed 250°F for this purpose).

Kamatics Wear Strip
Bonding Procedure Summary

Adhesive:

- Hysol EA9309.3 NA or equivalent.

Cleaning:

- Clean heavily contaminated surfaces using a detergent cleaner and thoroughly rinse with hot water.
- Clean the surface by washing in trichloroethane, acetone, or alcohol.

Surface Preparation (Substrate):

Mechanically roughen using an alumina grit paper (80-200 grit is adequate) or using alumina grit in a grit blast operation, to remove all surface deposits. Re-clean after roughening.

- Handle only with clean, lint free gloves.
- Apply adhesive as soon as possible.

Surface Preparation (Wear Strip):

Remove the "peel ply" from the back of the wear strip (a sharp object such as a knife is useful for initiating separation of the "peel ply" from the Wear Strip).

- Handle only with clean, lint free gloves.
- Apply adhesive as soon as possible.

Bond Line Control:

Apply a thin coat of adhesive to both the surface and to the back surface of the Wear Strip (or, if using a film adhesive, apply the pre-cut adhesive film to the back of the Wear Strip).

Press the Wear Strip against the substrate until excess adhesive no longer is squeezed from between the parts. (Wiping the excess adhesive from the parts at this point will reduce the effort required for cleanup of the parts.)

Bond Curing:

Keeping the parts pressed together, cure the bond to handling strength at room temperature 70°-80°F (20°-25°C) for 6 hours. Fully cure the bond at room temperature for 5 to 7 days.

- Clean up excess adhesive as required.

ROLLER SWAGING KARON LINED SELF-LUBRICATED SPHERICAL BEARINGS

General:

The information given in Tech Note 18 is offered as a guide when designing a tool to roll swage a bearing into a housing. The data pertains to the manufacture of a tool for any particular bearing size. It is obvious that a “basic” tool can be designed with interchangeable spacers, sleeves, and rollers that would accommodate a family of bearing sizes. The user is encouraged to consider this option when designing tooling.

Introduction

Installation of KAron lined self lubricated spherical bearings is best performed by using a roller swaging tool similar to that shown in Figure 1 or the Appendix. Roller swaging requires less force than anvil staking, is easier to adjust to variations in swaging groove geometry, and allows finer control of the actual swaging process. Because the sleeves (or pilots) and adjustable spacers allow one basic rolling tool to be adapted to a variety of bearing sizes, roller swaging tools are also more economical than anvil staking tools.

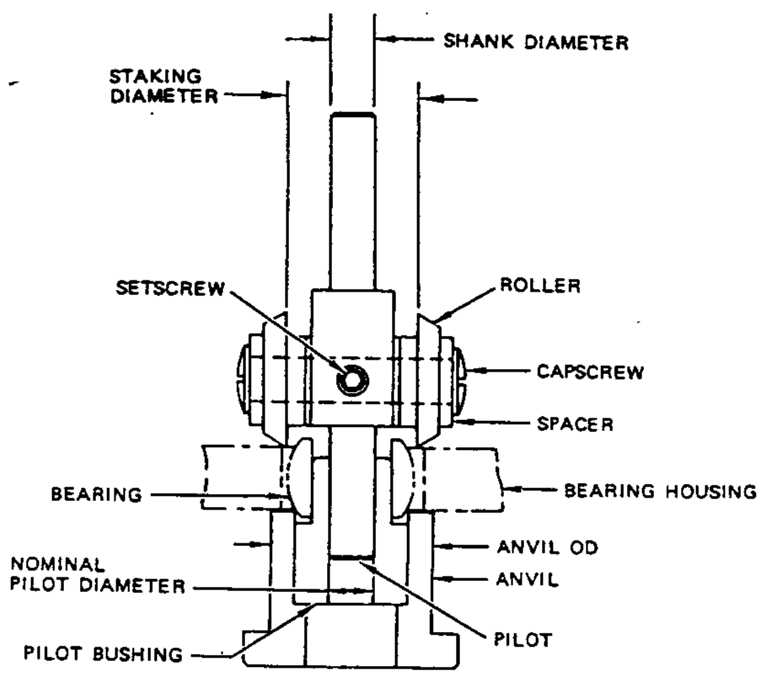


Figure 1 - Typical Roller Staking Tool Set Up

Most users find it easier and more convenient to manufacture their own roller swaging tools in accordance with the formula and drawings contained in the Appendix or similar designs. In addition, Kamatics can provide individual tools or sets for users without the facilities to easily produce their own tools.

Procedure

The following step-by-step procedure provides the instructions needed to successfully install KAron-lined self lubricated spherical bearings in a shop environment. Installation of KAron-lined self lubricated spherical bearings in parts which are mounted on the aircraft require modified versions of the roller swaging tool, but the basic procedure is the same.

(1) Use a heavy duty drill press with a quill diameter of not less than 2 inches, and gearing that will give not less than 200 pounds of force at the chuck with usual operator input. Set the drill press for approximately 80 rpm for 1 inch or smaller bore diameters, or proportionately slower for larger bearings.

(2) Set the rollers of the swaging tool to agree with the diameter of the bearing swage groove. The distance between the inside edges of the rollers should be .005-.010” larger than the diameter of the center of the groove, as a starting point. Tighten all the parts, making sure the rollers turn freely. The fit of the pilot in the guides of the primary and the secondary anvils should be tight without binding.

(3) Install the swaging tool in the chuck of the drill press.

(4) Apply the specified installation finish (primer, sealant, etc.) to the ID of the housing and the OD of the bearing.

(5) Install the bearing centered in housing. Make sure the outer race of the bearing is flush to 0.010 inch above the housing surface, or as specified on the installation drawing.

(6) Apply a thin layer of general purpose grease to the swaging groove to prevent galling. Try not to let the grease get on the KAron surfaces of the inner race.

CAUTION: MINIMIZE THE AMOUNT OF GREASE OR OTHER LUBRICANTS WHICH MIGHT GET INTO KARON-LINED BEARINGS. LUBRICANTS CAN COLLECT CONTAMINATION AND THUS SHOULD BE AVOIDED.

(7) Set the surface to be swaged perpendicular to the axis of the spindle.

(8) Swage the first side of until the lip is swaged out into the swaging groove. Inspect the swaging lip to insure that sufficient swaging has occurred. There should be less than .005” gap between the outside of the lip and the housing, which can be checked with a wire feeler gage. If the lip has not swaged over adequately after two attempts, increase the distance between the inside edges of the rollers an additional .005” and re-swage.

(9) Turn the assembly over and swage the second side.

NOTE: Do not let the rollers touch the bottom or the inner face of the swaging groove in the bearing outer race. This can cause binding of the bearing to the extent that the ball cannot be turned in the housing.

(10) Clean the lubricant from the bearing with a rag wet with a small amount of methyl ethyl ketone, acetone, or similar solvent. Protect the inner race from the solvent and all lubricants.

(11) Examine the swaged lip for clearance and galling. Gall marks should be avoided, and is caused when the rollers did not turn or the roller lubrication was insufficient.

(12) The stake is completed when the swaged lip touches the housing chamfer and the gap at the outer edge is less than .005”.

(13) Unless specified by the overhaul instructions, the no-load breakaway torque of an installed KAron-lined spherical bearing must not be more than two times the uninstalled maximum breakaway torque specified in the bearing specification or standard.

(14) If required, give the bearing a push-out load test. Apply the load only to the outer race. The bearing must not move in the housing or come loose.

DIMENSIONS FOR ROLLER SUPPORT,

A DIA = AS REQ TO FIT DRILL OR MILL CHUCK (BEARING I.D. MIN)
B DIA = SLIP FIT IN BEARING I.D.(PRESS FIT ON SUPPORT)
C MIN = (BALL WIDTH - RACE WIDTH)/2 + MAX BRG GROOVE DEPTH + .020

C MAX = C MIN + .005
D DIA = B-.06 (PRESS FIT WITH SLEEVE LD.)
E MIN = NOMINAL BOLT DIA
E MAX = E MIN + .010
F MIN = C MAX + E MAX {2 ROLLERS REQUIRED, O.D. MUST BE WITHIN .001 OF EACH OTHER}
F MAX = F MIN + .010
G MIN = MAX BRG GROOVE DIA + .005
G MAX = G MIN + .005
H DIA = SLIP FIT WITH BOLT DIA
L MIN = C + (1.5 x BRG BALL WIDTH)
L MAX = L MIN + .030
W MAX = G MIN - .06 (ALLOWS 2 .030 THICK SPACERS) SEE NOTE 3

<u>DIMENSIONS FOR ROLLER BASE</u>

J MIN = MAX BRG I.D. + .005
J MAX = J MIN + .005
K MIN = G MIN
K MAX = MIN BRG O.D.
M MIN = SUGGEST 1.00 MIN (TO SUIT USER EQUIPMENT)
N MIN = ((BRG BALL WIDTH - RACE WIDTH)/2) + .030
N MAX = N MIN + .030

P MIN = (2 x $\sqrt{(\text{BRG BALL DIA}/2)^2 \ @\ (\text{RACE WIDTH}/2)^2}$) + .020
P MAX = P MIN + .010
R MIN = K MAX + .25 (MAX = TO SUIT CUSTOMERS EQUIPMENT)

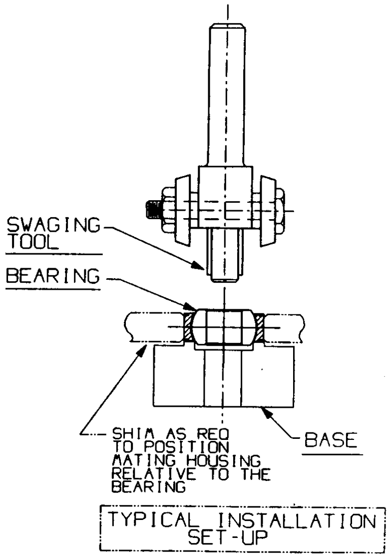
<u>NOTES:</u>

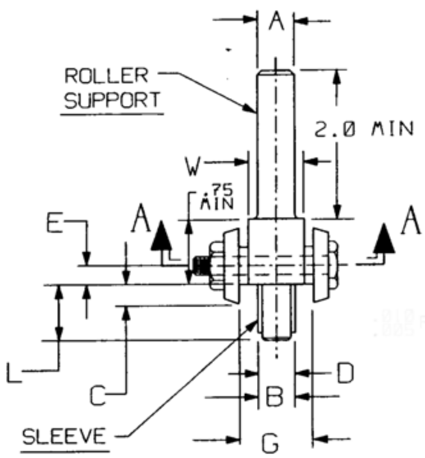
1. REFER TO MIL-STD-1599 REQUIREMENT 202, PARA.6 FOR INSTALLATION AND SUBSEQUENT INSPECTION OF INSTALLED BEARINGS.
2. ASSEMBLE NUT AND BOLT AS SHOWN. TIGHTEN THE NUT SUCH THAT THERE IS APPROXIMATELY .005* LOOSENESS TO ALLOW THE ROLLERS TO ROTATE WITHOUT CATCH OR BINDING.
3. SPACER THICKNESS *AS REQUIRED TO OBTAIN PROPER WIDTH TO MATCH DIM. “G” (BEARING GROOVE DIAMETER). THE SUPPORT CAN BE MANUFACTURED WITHOUT THE NEED FOR SPACERS BUT THE TOOL IS THEN LIMITED TO THAT ONE SIZE UNLESS MODIFIED LATER.

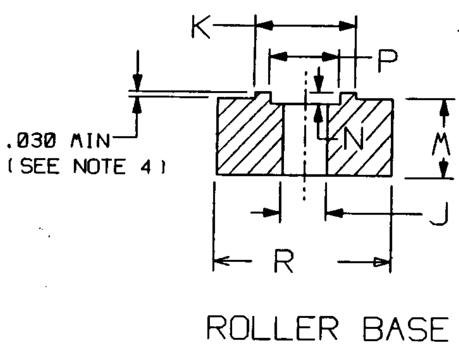
4. THE UNDERCUT IS NOT MANDATORY BUT THE POTENTIAL FOR INTERFERENCE WITH MATING HOUSING WILL EXIST.

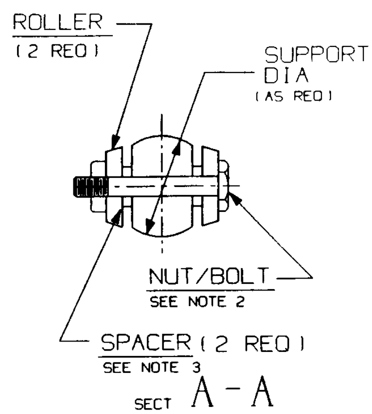
<u>ROLL SWAGING TOOL - MATERIAL</u>

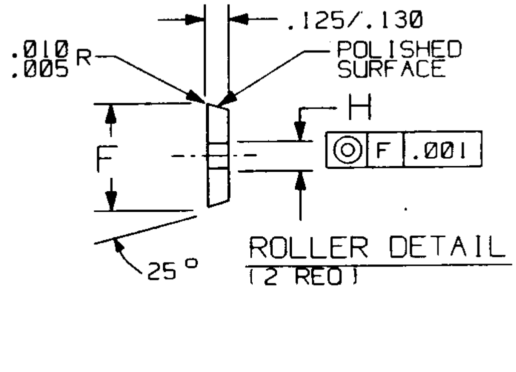
ROLLER SUPPORT- STEEL,Rc4O MIN
ROLLER (2) - TOOL STEEL,Rc55 MIN
SLEEVE- ACETAL RESIN., PTFE, NYLON, ETC
SPACER (AS NEEDED, 2 MIN)- STEEL,Rc25 MIN
BOLT- .250 DIA.CLOSE TOLERANCE. HARDENED (Rc35 MIN) (SUGGESTED)
NUT- .250 THREAD (SELF-LOCKING SUGGESTED)
ROLLER BASE- STEEL,Rc4O MIN


SWAGING TOOL
BEARING
SHIM AS REQ TO POSITION MATING HOUSING RELATIVE TO THE BEARING
BASE
TYPICAL INSTALLATION SET-UP


A
ROLLER SUPPORT
2.0 MIN
W
.75 MIN
E
A
A
L
C
SLEEVE
B
D
G


K
P
.030 MIN
(SEE NOTE 4)
N
M
J
R
ROLLER BASE


ROLLER
(2 REQ)
SUPPORT DIA
(AS REQ)
NUT/BOLT
SEE NOTE 2
SPACER (2 REQ)
SEE NOTE 3
SECT A - A


.125/.130
.010 .005 R
POLISHED SURFACE
H
F
F .001
25°
ROLLER DETAIL
(2 REQ)

Notes

Notes