engineered solutions in plastic

Bearings design guide

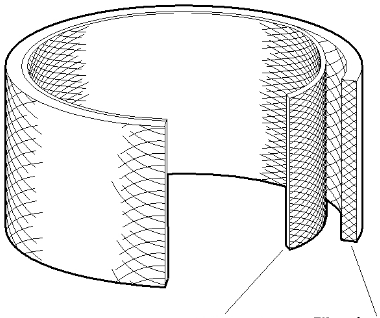
Innovation Beyond Metals

Introduction

Versatile high load, low friction composite bearings.

What Is A Composite Journal (CJ) Bearing?

MAC-CJ bearings use continuous fiberglass filaments incorporated into a proprietary epoxy resin matrix for a very high strength bearing that is naturally concentric with no seam or overlap. This high strength laminate construction allows for a thin wall (2.5mm to 5.0mm) bearing,reducing the size and weight of the assembly. The resulting bearing exhibits a very low coefficient of friction coupled with high load-bearing capacity.



MAC-CJ Liner Design

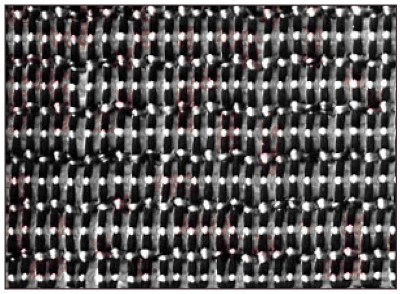
MAC-CJ bearings utilize a proprietary design that ensures the anti-friction lining is locked into the composite material with more than a simple adhesion effect. This proprietary design also drives excellent resistance to impact fatigue and cavitation problems.

MAC-CJ MRP series bearings have their liners applied in a dry manufacturing mode. They are inherently very resistant to impact because the liner backing has high strength fiberglass filaments interwoven into the liner backing.

The differences in liner construction can be seen most dramatically during three periods: first, how coefficient of friction and wear change during the break-in period, second, how the bearing handles contamination in a dirty or unsealed environment, and third, long term bearing life. Differences in liner construction can also impact performance in the following areas:

- Coefficient of Friction—The required breakaway torque & startup forces required.
- Impact Fatigue—How the bearing handles shock or impact loading.
- Amount of Wear—The orientation of the PTFE in relation to the mating surface as well as the content of the PTFE will impact the amount of wear the finished journal bearing will exhibit.
- Time for Achieving Sufficient PTFE Film Transfer—The liner construction will impact the length of time as well as the operating conditions required to have the PTFE film properly transfer from the inner diameter of the bearing to the outer diameter of the mating surface.

Although not required, a dry lubricant can be used at installation to improve performance during the break-in period.



MAC-CJ MRP Wear Surface

"This high strength laminate construction allows for the use of a thin wall bearing."

introduction

Versatile high load, low friction composite bearings.

Go Greaseless!

MAC-CJ bearings not only exhibit excellent load capacities, low frictional values and resistance to corrosion, they also allow for true self-lubrication.

> ***"The PTFE super-filaments used in the bearing wear surface exhibit tensile strengths 20 times greater than traditional PTFE resins."***

What Are The Desired Characteristics Of Journal/Plane Bearing Materials?

In general, journal/plane bearing materials should have the following characteristics in order for the bearing assembly to be properly designed:

1. Truly Self-Lubricating. Many materials claim to offer some level of self-lubrication; however, many (especially sintered metal structures) lose their self-lubrication properties quickly during operation. When the lubrication fails, metal-on-metal contact results. Premature bearing failure generally quickly follows.

2. Contamination Resistance. The contamination is allowed to deflect the lower modulus bearings and eventually work its way out of the joint without damaging the pin.

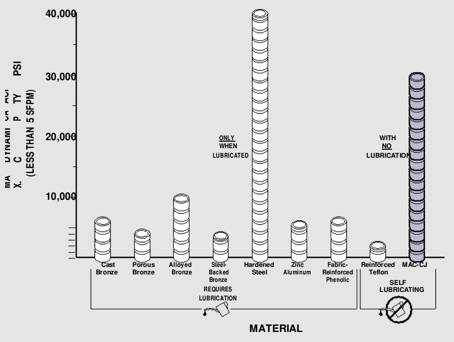
3. PV Rating. The PV rating should be easy to understand, and fit most application environments with a good match between the bearing pressure and surface velocity capabilities.

4. Quick Transfer of PTFE Film to Shaft. The key to self-lubricating bearings is the rapid transfer of PTFE from the bearing ID to the shaft surface during the initial break-in phase. The film of PTFE on the shaft functions as a dry lubricant, which reduces the friction and wear rate.

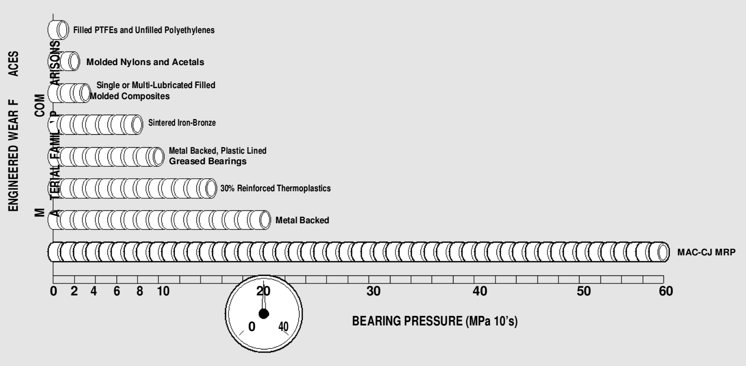
5. Fiber Orientation to Minimize Friction. In a properly designed self-lubricating bearing, the bearing will exhibit a low coefficient of friction when the contact surface is on the ends of the PTFE fibers.

6. High Percent of PTFE Near the Surface. It is not sufficient to simply have PTFE fibers on the wear surface. A high percent of PTFE is desirable near the surface of the bearing to provide an ample amount of dry lubricant for wear and friction reduction.

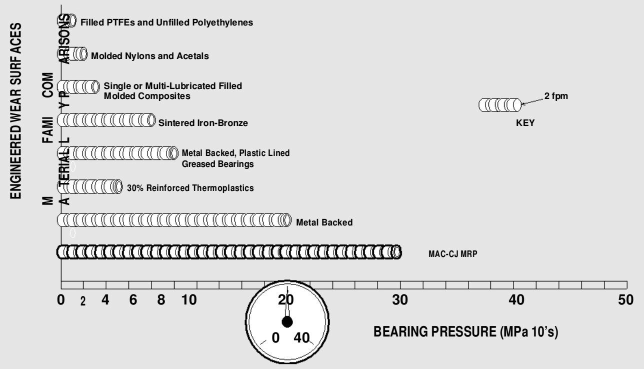
Greased Versus Greaseless Journal Bearing Comparisons



Journal Bearing Static Load Comparisons



Journal Bearing Dynamic Load Comparisons



Introduction

Versatile high load, low friction composite bearings.

What "Composites Professionals" Means To You!

The manufacture of MAC-CJ's is the only organization with composite self-lubricating bearings as a primary product focus. Other bearing companies only see this product line as a necessary offering to satisfy the OEM market.

This family of materials is the core competency with the first patents on composite bearing design. We have the experience to better predict the performance of this type of bearing, can better define what factors drive product performance, and have a strong manufacturing infrastructure to support your business needs. Our abilities to specify sizing, assembly, and design parameters are unmatched in the composite bearing industry. Why? Because it is core to what we do. The value to you? MAC-CJ's has the best designed, highest performing bearing material available, at the best cost in the industry.

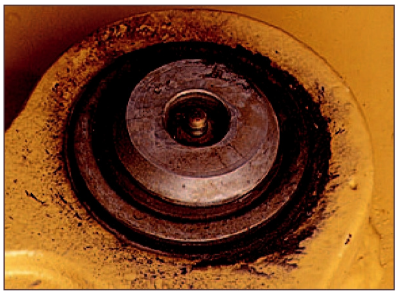
The environmental issues around grease are only now coming to light. With self-lubrication all environmental contaminants are eliminated

MAC-CJ's Lower Total Cost of Operation (TCO)

A design engineer must continually search out materials that increase performance capabilities while reducing total product life costs. How does MAC-CJ's lower total cost of operation?

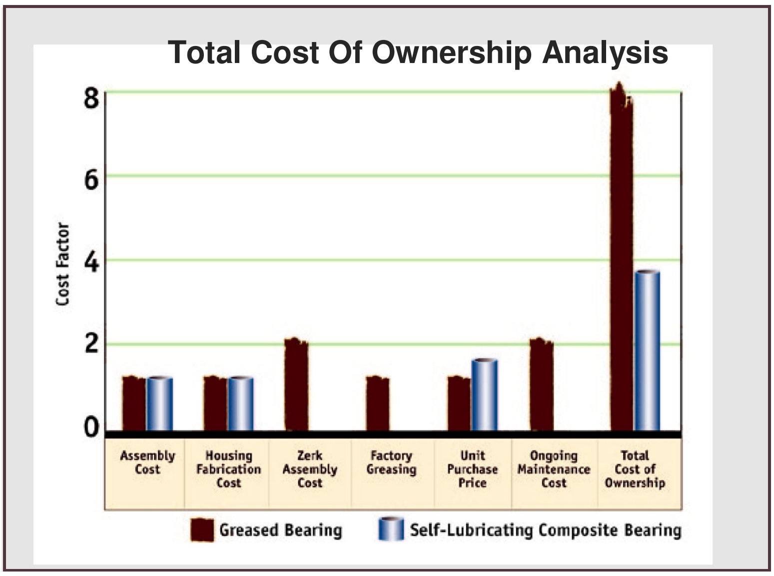
Poor lubricant maintenance is one of the most common failure points for bearings. A properly sealed and lubricated bearing should result in trouble-free field service in theory. Unfortunately, this is rarely the case. Greased joints may not be maintained properly, resulting in boundary/mixed lubrication condition and diminished bearing life. Bearings are often greased only twice in their life, once by the OEM and once before they are sent back for the warranty claim due to bearing failure from lack of lubrication.

- Grease Zirks
- Automatic greasing systems
- Grease costs
- Labor cost for scheduled greasing



Self-lubricating bearings eliminate secondary pin and housing fabrication required for greased bearings.

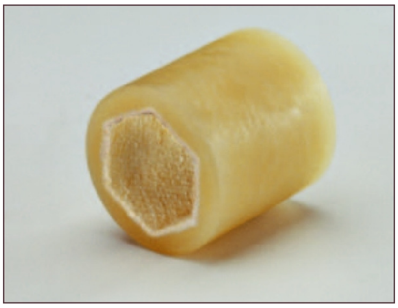
"Many materials claim to offer some level of self-lubrication; however, many lose their self-lubrication properties quickly during operation."



MAC-CJ's Lower Total Cost of Operation (TCO) – continued

The total cost of ownership for a bearing that must be lubricated is greater than the total cost of a self-lubricating composite bearing. Most OEM's clients have found that the cost of purchasing, assembling, and maintaining a greased bearing joint is at a minimum 1.5 times to a maximum of 4 times the cost of a self-lubricating bearing joint. Equipment rental yards are increasingly sensitive to the liability associated with greased bearings.

External lubrication is an uncontrollable design variable for OEM engineers. Once the finished product is shipped to the customer they must properly maintain the bearing assembly. Failure can lead to liability or warranty claims. If proper maintenance is a concern, the best solution is a self-lubricating composite bearing. Self-lubrication is the ideal solution since it fully lubricates the contact surfaces requiring absolutely no field or long term maintenance. Dry lubrication does not attract dust or dirt and results in no environmental grease or oil contamination.



Hex ID and special ID shapes can be incorporated into the bearing as well.

When to use MAC-CJ Bearings

- When dry lubrication is required.
- When bearing neglect could lead to product liability claims or premature failure.
- When conventional lubricants will not function or cannot be used (as in the food processing and pharmaceutical industries).
- When bearing, lubrication system, and maintenance costs need to be reduced.
- When wide temperature ranges, particularly at low temperatures, require bearing performance stability.
- When stick-slip conditions exist.
- When high load capacities are needed.
- When resistance to chemical, galvanic, or fretting related corrosion is a problem.
- When weight reduction is desired.
- When galling and scoring need to be minimized.
- When shock loads present a problem.
- When electrical insulation is required.

Special designs can be economically incorporated for large manufacturing quantities.

"One of the most common failures for bearing design is when lubrication is not properly maintained. MAC-CJ bearings eliminate lubrication maintenance."

Composite Bearings Compared

Today's OEM engineer has many bearing alternatives to choose from. When making a design decision, it can be difficult to weigh material choices for your design. Consult this application-driven discussion comparing composite bearings to common alternatives.

When grease fails these bearings quickly wear through and produce intimate contact between the shaft and bearing.

Greased Bearings

The most obvious difference? These bearings require perpetual greasing, adding both material and labour costs to the product. When the lubricating film fails due to contamination, the bearing will prematurely wear. Performance of this bearing is entirely reliant on the end user properly maintaining and servicing the bearing joint in question.

"Performance of a greased bearing is entirely reliant on the end user properly maintaining and servicing the bearing joint."

MATERIAL	MAX. DYNAMIC CAPACITY-MPa (Less than 1.5 mtr/min)	MAXIMUM TEMPERATURE ℃	THERMAL EXPANSION 10^6 mm/mm/℃	SPECIFIC GRAVITY
Cast Bronze	41*	70*	10	8.8
Porous Bronze	27**	70**	10	7.5
Alloyed Bronze	69*	95*	16	8.1
Steel-Backed Bronze	24*	95*	8	8.0
Hardened Steel	276*	95*	7	7.9
Zinc Aluminium	38*	95*	15	5.0
Fabric-Reinforced Phenolic	41*	95*	20	1.6
Reinforced Teflon†	14	260	55	2.0
MAC-CJ MRP	206	162	7	1.87

*with lubrication **oil impregnated †DuPont™

Additional Performance Differences:

- Greased metal-backed bearing materials have very limited operating temperature ranges. They traditionally span from -40 to +100℃ compared to MAC-CJ ranges from -162 to 260℃.
- Particulate contamination leads to mixed-mode lubrication and failure.

Sintered Metallic Bearings

Sintered metallic bearings have innate limitations due to their semi-fused nature. The structure dramatically reduces impact or shock loading capability as well as both the static and dynamic loading capacities.

Additional Performance Differences:

- At best, dynamic capacities of 55 MPa.
- Alloyed bronze bearings have the highest dynamic capacity within this family- and that is 69 MPa or less than 1.5 mtr/min with lubrication.
- Lowered impact or fatigue strength properties.
- Prone to corrosion and shaft fretting.
- Many times burnishing tools are required to get product to final geometric tolerances.

Sintered structure bearings can't handle the load of composite bearings

Filled Thermoplastic Bearing Materials

- Sizing predictability. Injection moulding leads to higher size variation.
- Creep – Thermoplastics will plastically deform over time under load.
- Impact Fatigue. Even glass filled thermoplastic resins can only go so far with resistance to repeated impact.
- Moisture absorption–Swelling can occur with thermoplastic s in submerged or humid environments causing binding between pin and bearing.
- The homogeneous construction of filled thermoplastic bearings means the bearing is being held in the housing with the same material interacting with the pin, allowing a greater frequency of walking or spinning in the bore.

Filled thermoplastics have no chance in highly loaded environments.

Metal Backed Bearings

Metal backed bearing materials have been an obvious choice given their feature/ benefit combination and initial purchase price. However, MAC-CJ bearings are quite often the clear winners when total cost of operation is considered.

Additional Performance Differences:

- Requires regular greasing maintenance by the end user, especially in high contaminate environments.
- This bearing type is very sensitive to misalignment. Load concentration on the edges can cause increased wear on the PTFE overlay, leading to intimate contact between the metal substrate and pin.
- Heavy machinery requires frequent greasing, downtime, and labour costs to perform this maintenance. This adds up to significant costs for the end user over the life of a product.
- Metal backed bearings prematurely fail once the overlay is broken into and the shaft is in intimate contact with the lining.
- Metal ID surfaces cannot embed contaminates, leading to scoring and premature failure.
- Dynamic capacities typically at 138 MPa maximum, compared to 206 MPa with MAC-CJ's.
- Require the added cost of grease zirks, factory greasing, and possibly automatic greasing systems all of which are not needed with MAC-CJ's permanent lubrication.
- As with any metal structure, this type of bearing is subject to severe corrosion— an issue that can occur as quickly as 24 hours into basic immersion testing.
- Thermoplastic bearings are prone to swelling when subjected to moisture.

Once the overlay is worn through, intimate contact and failure can quickly result.

Thermoplastics are highly subject to cold flow under loading—something MAC-CJ bearings do not struggle with.

introduction

Versatile high load, low friction composite bearings.

Rolling Element Bearings

MAC-CJ bearings are able to handle higher load capacities than rolling element bearings, particularly with shock loading.

Additional Performance Differences:

- Reduce the weight and profile of the bearing—in many cases the weight and profile of the bearing can be reduced by over 50%.
- MAC-CJ's exhibit much higher static load capacities—an equivalent sized needle bearing will only have 30% of the static capacity.
- No external lubrication is required with MAC-CJ's—there are no concerns with failed lubrication media resulting in shaft damage.
- By using the PTFE film transfer process instead of macro mechanical moving parts, MAC-CJ's are able to have stable and predictable performance over the life of the application.
- Rolling element bearings can only be used in contaminated environments if the costly option of integrated seals are used.

Typical metal needle bearings fail under high loading.

"No external lubrication is required with MAC-CJ's— there are no concerns with failed lubrication media resulting in shaft damage."

Break-in and Film Transfer

The secret to MAC-CJ high load greaseless operation is the use of uniquely woven PTFE super-filaments in the bearing liner. They exhibit tensile strengths twenty times greater than PTFE resins and are not subject to cold flow under high load. No secondary lubrication is necessary due to the film transfer process, even during start-up.

As the bearing begins service, the liner's PTFE undergoes a phase change and disburses over the mating pin surface, transferring from the inner diameter to the pin's wear surface. and smoothing out any macroscopic surface imperfections. Essentially, a small amount of the liner is worn away and sacrificed to coat the pin in a low friction PTFE film. This wear is often negligible, usually less than 0.025mm.

This allows the bearing to have a very low coefficient of friction with minimal long-term wear, under high loading conditions. Following the break-in period, the wear rate stabilizes, remaining relatively constant for the bearings' life. Testing of the MRP bearing at 10000 kg's, with 50° oscillation angle, resulted in stable wear under 0.12mm at over 1.5 million cycles.

The elapsed time for break-in is PV (Pressure and Velocity) dependent. The equilibrium wear rate varies from operation to operation, due to a number of factors including: loads, speeds, shaft hardness, material, and shaft surface finish. For more specific guidance on the break-in period to anticipate given your specific application, please contact Macplas Ltd.

MAC-CJ MRP bearings are designed to minimize wear; however, the bearing wear is dependent on general operating conditions, such as speed, sliding distance and load. With intermittent rotation or oscillation, radial wear should be negligible over thousands of hours. Hard chrome plating gives excellent wear performance and protects the shaft from corrosion. Coatings such as chrome, electroless nickel, YZD or nitro carbonizing are all common treatments for shaft materials used with MAC-CJ bearings. Some customers have even experienced great results using standard 1018 shaft material.

MRP bearings

Versatile high load, low friction composite bearings.

Standard MRP Bearing.

MRP Bearings

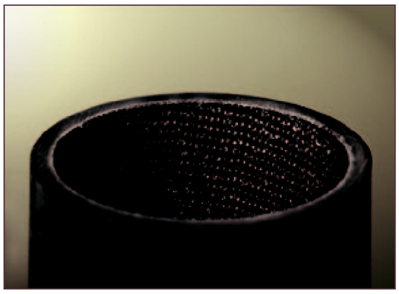
Product History

From a pure load carrying and performance perspective MAC-CJ MRP series bearings are practically identical. Our desire has not to only be the industry leader in performance, but in cost as well. A thorough analysis and value stream mapping of the manufacturing process resulted in the development of the MRP product. Essentially a bearing family of equal performance, but at a lower price point.

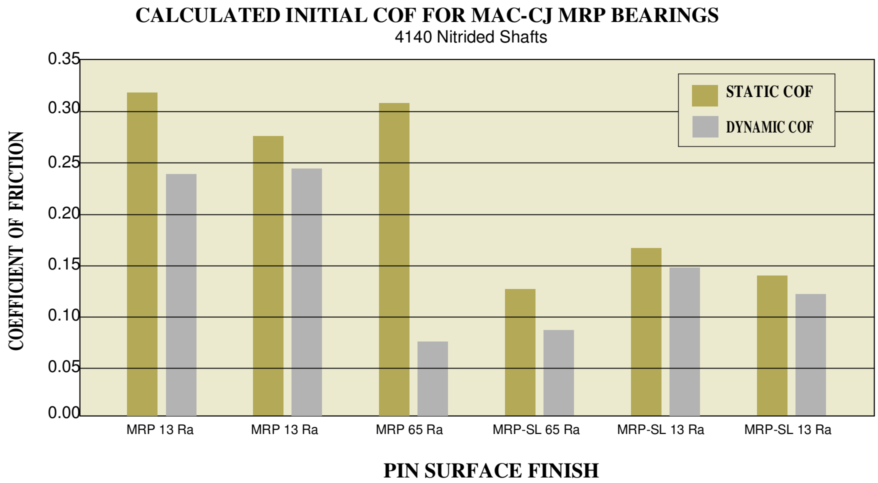
Product Description

The MRP has a unique added lubricant embedded within the surface of the liner material to decrease the initial coefficient of friction. This small change was initiated because in certain lightly loaded joints, upon initial actuation, an intermittent stick-slip or noise could be generated. The MRP addresses this issue by decreasing friction and virtually eliminating the typical break in period.

MAC-CJ MRP bearings are designed to minimize wear; however, the bearing wear is affected by the general operating conditions, such as speed, sliding distance and load. With intermittent rotation or oscillation, radial wear should be negligible over thousands of hours. Hard chrome plating gives excellent wear performance and protects the shaft from corrosion. Softer coatings such as cadmium or zinc may exhibit different wear characteristics but are perfectly suitable for use against the MRP surface.



Close-up showing the unique low friction fiber lining architecture.



"These issues come together to allow Macplas to sell a product better matched to customers' needs."

MRP bearings

Versatile high load, low friction composite bearings.

MRP Bearings

Mechanical and Physical Properties

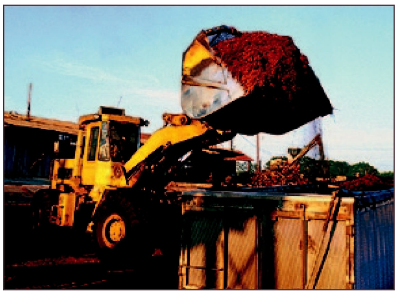
The MAC-CJ MRP bearing can withstand static loads of approximately 480 MPa and 206 MPa under dynamic loading. For dry running applications, the maximum speed is approximately 3 surface metres per minute. The typical average design pressure for high duty cycle applications is 69 MPa.

This bearing's operating temperature range is ±162℃. Maximum continuous operational surface temperature for the standard formulation is 162℃, depending upon load characteristics. The bearing has been heat stabilized at these temperatures, so that little dimensional change will occur in the bearing during operation. In a free state, the coefficient of expansion of the MAC-CJ MRP bearing is approximately 7×10^6 mm/mm/℃, similar to the coefficient of expansion for steel, and actually less than some metals.

Landing Gear Application.

Applications

MAC-CJ MRP bearings are the bearing of choice in highly loaded bearing joints where a life cycle of over 500,000 cycles is desired. Testing has shown this bearing has wear under 0.15mm after 1.6 million cycles. Applications include material handling equipment, high duty cranes, earth-moving equipment, construction equipment, agriculture equipment and food processing systems. MRP bearings have extremely low absorption rates and are well designed for wet and submerged applications.



MRP at work.

Ultimate Compression Strength (MPa)	480
Unit Load Limit (MPa)	206
Temperature Range (Standard Formulation)*	±162℃
Coefficient Of Thermal Expansion (mm/mm/℃)	7×10^6
Thermal Conductivity (W/(m∗K))	0.26-0.33
Water Absorption (2 Hours)	0.12%
Water Absorption (24 Hours)	0.16%
Specific Gravity	1.87
Maximum Velocity (mtr/min)	30

*Note: Special resin formulation available up to 260℃.

Moisture & Corrosion? No Problem.

Glass tape bearings

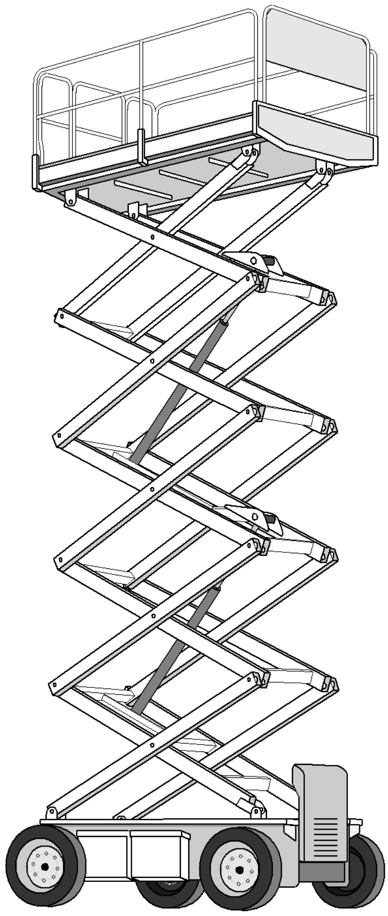
Versatile high load, low friction composite bearings.

Glass Tape bearings

Product Description

The MAC-CJ Glass Tape bearing is a moderate RPM bearing designed for applications with higher surface velocities or when mixed film conditions are desired.

Similar to the Fibre Series bearing, the Glass Tape bearing is manufactured by a filament winding process that results in a continuous fiberglass filament backing composition-ensuring excellent mechanical properties (especially fatigue resistance) are attained. The filament wound fiberglass structure uses a high strength, corrosion resistant epoxy resin as the matrix material. The high strength backing permits the use of a thin wall (2.5mm to 5.0mm) bearing which can often reduce the size and weight of the finished bearing assembly. MAC-CJ Glass Tape bearings will support a dynamic bearing load of 48 MPa, while handling high radial and longitudinal stresses with a static bearing capacity of 276 MPa. This family of materials exhibits exceptional dimensional stability and performance predictability over wide temperature ranges (±162℃).



MAC-CJ is standard in the man-lift industry where reduced warranty claims are made possible by eliminating customer greasing.

Product Schematic

The MAC-CJ Glass Tape lined bearing is similar in backing construction when com-pared to its sister product-the Fibre Series bearing; however, the difference in the construction of the liner material drives the variations in performance. The primary performance variations between the Glass Tape and the Fibre Series bearing are that the Glass Tape bearing has a lower coefficient of friction and will handle higher surface velocities. However, the Glass Tape bearing sacrifices some capabilities with a slightly lower dynamic and static load capacity.

These differences are driven from fact that the Glass Tape bearing uses a proprietary filled PTFE resin structure as opposed to the continuous PTFE filaments used in the MRP product. Two liner thicknesses are available with the 0.25mm thick liner being standard and a 0.5mm thick liner being available for unique applications. The 0.5mm thick liner is designed for applications where boring the inner diameter might be required in order to achieve tighter tolerances in an effort to address sizing and minor misalignment conditions.

Mechanical and Physical Properties

The MAC-CJ Glass Tape bearing can withstand static loads of approximately 276 MPa and 69 MPa under dynamic loading. At these loading levels, minimum distortion will occur. For dry running applications, the maximum speed is approximately 91mtr per minute.

This bearing's operating temperature range is ±162℃. Maximum continuous operational surface temperature for the standard formulation is 162℃, depending upon load characteristics. The bearing has been heat stabilized at these temperatures, so that little dimensional change will occur in the bearing during operation. In a free state, the coefficient of expansion of the MAC-CJ Glass Tape bearing is approximately 7 x 10^6 mm/mm/℃, similar to the coefficient of expansion for steel, and actually less than some metals.

Glass tape bearings

Versatile high load, low friction composite bearings.

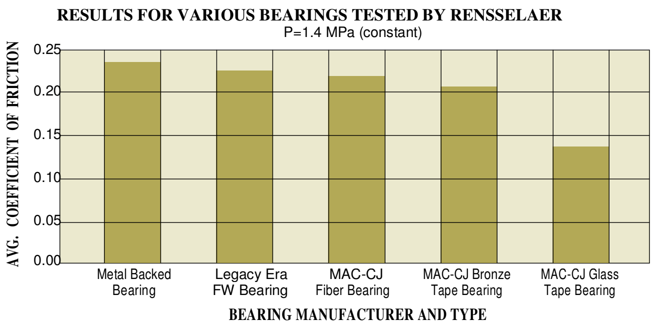
Glass Tape Bearings

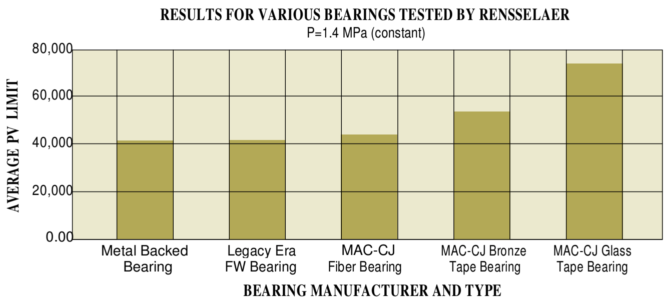
Mechanical and Physical Properties

Ultimate Compression Strength (MPa)	276
Unit Load Limit (MPa)	69
Temperature Range (Standard Formulation)	±162℃
Coefficient Of thermal Expansion (mm/mm/℃)	7 x 10^6
Thermal Conductivity (W/(m∗K))	0.26-0.33
Water Absorption (2 Hours)	0.12%
Water Absorption (24 Hours)	0.16%
Specific Gravity	1.95
Maximum Velocity (M/min)	91

Comparative pv and coefficient of friction test results

Testing performed independently at Rensslaer Department of Mechanical Engineering





Applications

Applications for MAC-CJ Glass Tape Bearings range from guide rod bearings to linear motion components to hydraulic pumps. Swashblock mounted bearings are ideal applications for the Glass Tape bearing material as long as application considerations are consistent with a mixed film condition.

The MAC-CJ bearing offers a more elastic, damage tolerant structure when compared to traditional metallic bearing materials. In addition, the Glass Tape bearing exhibits good cavitation resistance when subjected to high pressure fluids during cyclic conditions.

bearing design principles

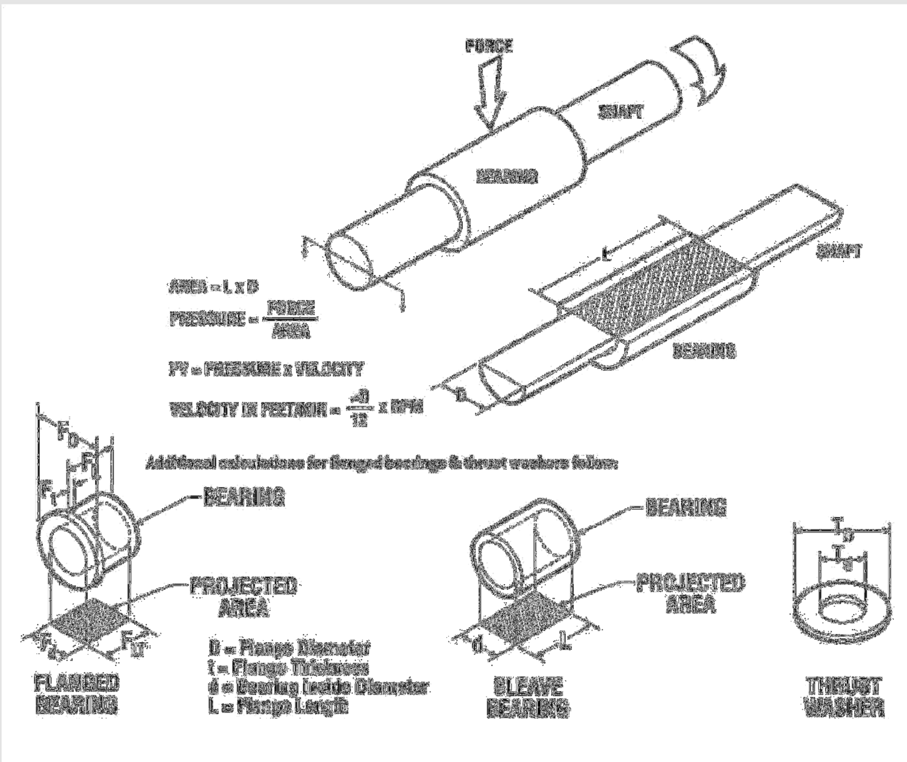
Versatile high load, low friction composite bearings.

PV Calculations

PV (Pressure & Velocity) is the most common empirical tool to use when comparing and contrasting bearing performance. “P” is related to pressure on the projected bearing area, while “V” is velocity of the wear surface. Knowing the PV limit of a bearing, the designer can determine the loads and surface running speeds under which a bearing can safely operate. Since heat generated by friction is one of the major causes of degradation in liners, evaluation of the operating conditions of a fiberglass-reinforced, composite journal bearing requires that you know the approximate temperature generated on or near the actual wear surface. The temperature rise is also dependent on the running speed and is not a linear function of the PV product.

As a guideline, we specify a 25,000 PV average limit for the MAC-CJ bearings. Test results conducted at 15,000 PV gave only 0.05mm wear after 10 million cycles, ±25° oscillation run at 60 cpm and 343 pounds radial load. For special applications, 50,000 PV is possible.

For a practical illustration of applied and defined PV calculations, reference this illustration:



Calculating Sleeve Bearing PV Limit

Example: .750” Shaft @200 rpm
85.0 lb. total load, bearing length .750”

V = 0.262* x rpm x diameter
= 0.262 x 200 x .750 = 39.3 ft/min

P = total load / projected area (A)**

A = .750 (shaft) x .750 (bearing length)
= .562 in.2

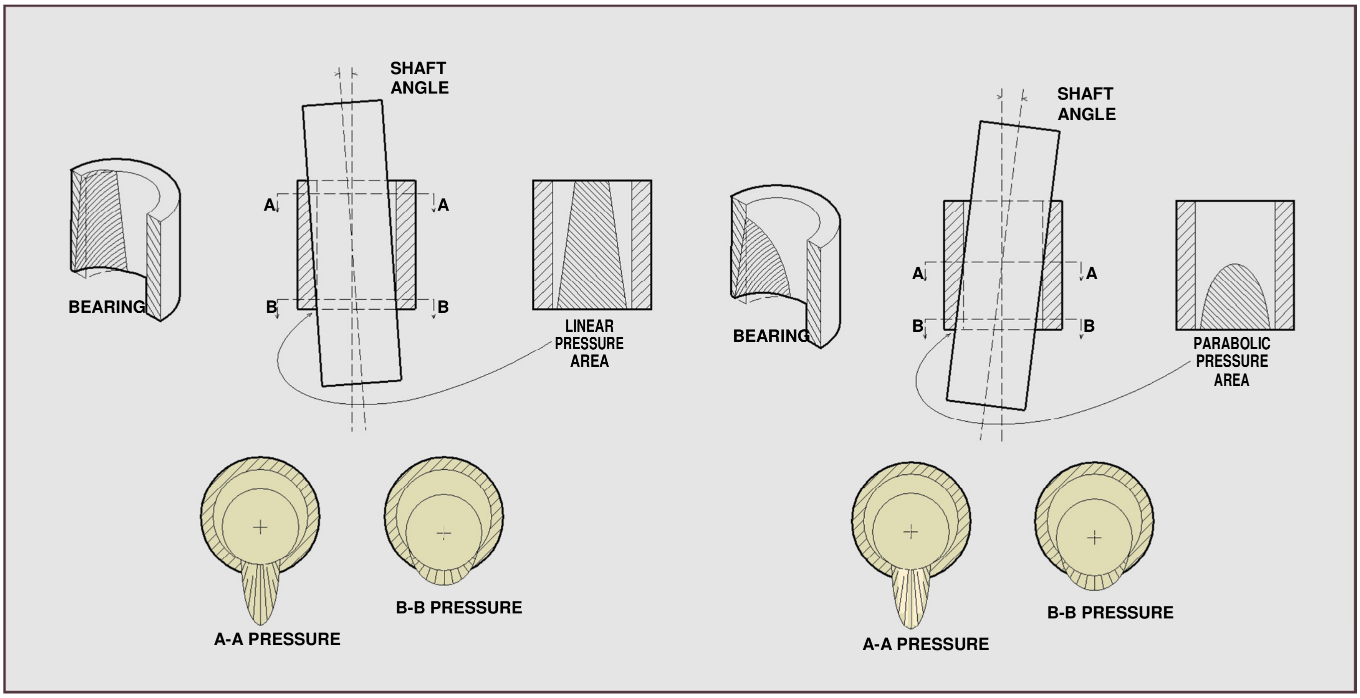
P = 85.0 lbs. / .562 in.2
= 151.2 psi

PV = 151.2 psi x 39.3 ft/min
= 5,942 psi* ft/min

Misalignment Conditions

Many applications undergo regular stressing of the bearing corners due to a misalignment condition. Should that condition be irregular, the existing MAC-CJ series bearings are acceptable. It is important; however, to understand how misalignment impacts bearing performance and what conditions are identified and analysed by the manufacturers application engineers. Misalignment conditions create a non-linear pressure area and significantly increase the edge stresses on the bearing. As a result, premature fatigue cracking can occur. The schematic below illustrates both conditions. For MAC-CJ bearings, concerns with edge stress and fatigue cracking become acute as the effective misalignment increases to 0.015 in/in or 0.86 degrees. Beyond that level, a different -backing construction can be used to increase the bearing's resistance to impact and resulting fatigue.

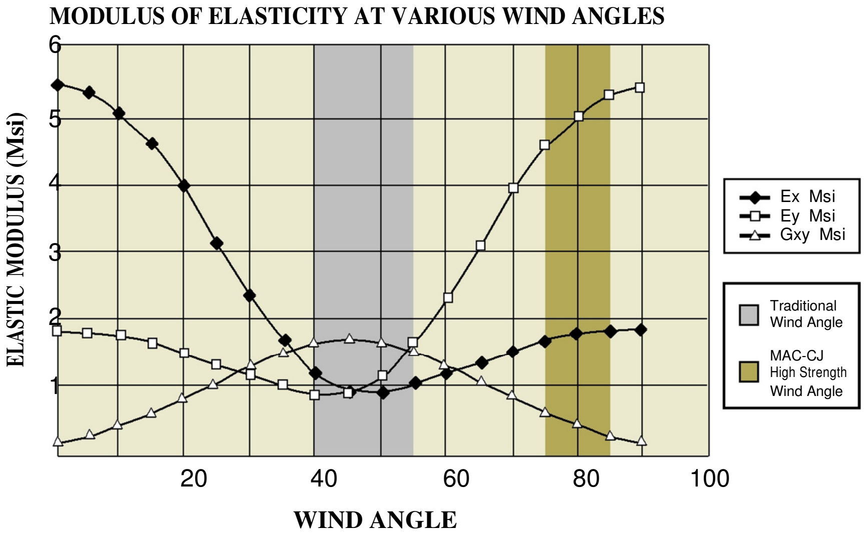
Angle	Effective Misalignment
0°- 13' - 45"	0.004 in./in.
0°- 20' - 38"	0.006 in./in.
0°- 34' - 23"	0.010 in./in.
0°- 51' - 34"	0.015 in./in.



Designing For Edge Loading

As with liner construction, in order to optimize a composite bearing's impact resistance, the bearing must also take advantage of the performance drivers that are related to the wind angle of the fiberglass backing. The fiberglass backing's orientation off of the neutral axis is a significant driver in the finished performance of the bearing itself. Most composite bearing companies utilize winding equipment that produces bearings between a 40 and 55 degree wind angle. For most applications this is acceptable; however, for applications where repeated high stress/strain is of concern, the backing can be further optimized by positioning the wind angle closer to a theoretical 90 degree wind angle. This type of performance optimization is what the MAC-CJ manufacturer does that other companies do not. Our manufacturing equipment is all precisely computer controlled.

The result of an ability to optimize performance is that conditions of high edge loading can be better controlled and designed around by utilizing specialised design skill. This allows for a direct translation between theoretical laminate theory, the manufacturing process itself, and the performance of your product.



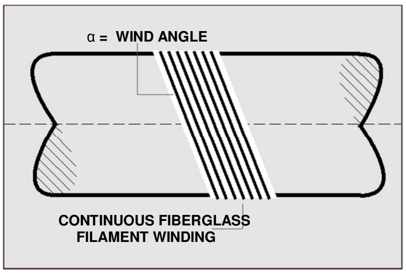
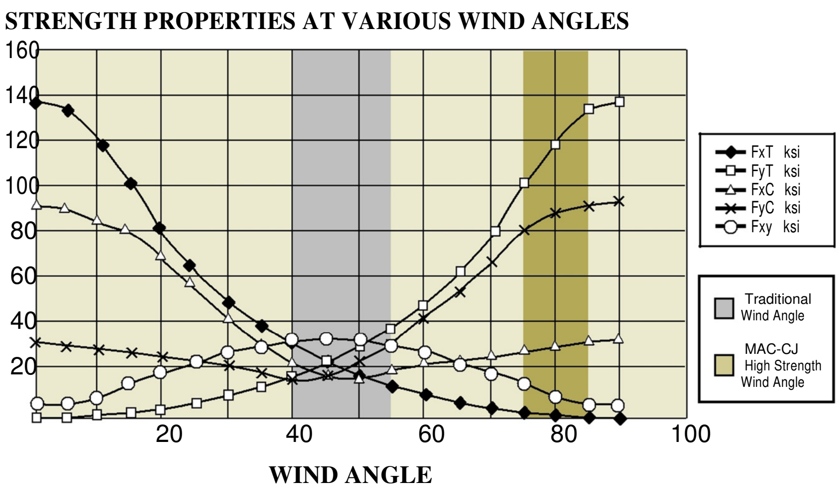


Illustration of wind angle.



Bearing design principles

Versatile high load, low friction composite bearings.

Load Capacity

The proprietary process of fiberglass filament winding results in exceptionally strong structures that can support the bearing surface more than adequately. Loading in excess of 206 MPa can be tolerated in many situations, provided the design and the conditions of service are fully outlined and analysed by a bearing specialist. Fatigue is not a limiting factor in the use of MAC-CJ bearings. Frequent laboratory tests have shown that the bearing is often more fatigue-resistant than the shaft. The typical average design pressure for high duty cycle applications is 69 MPa.

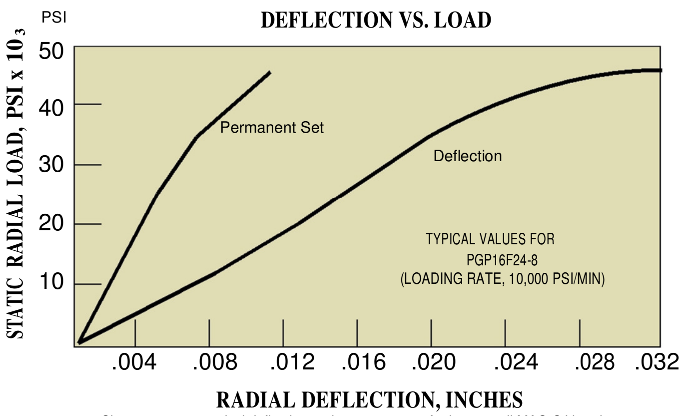
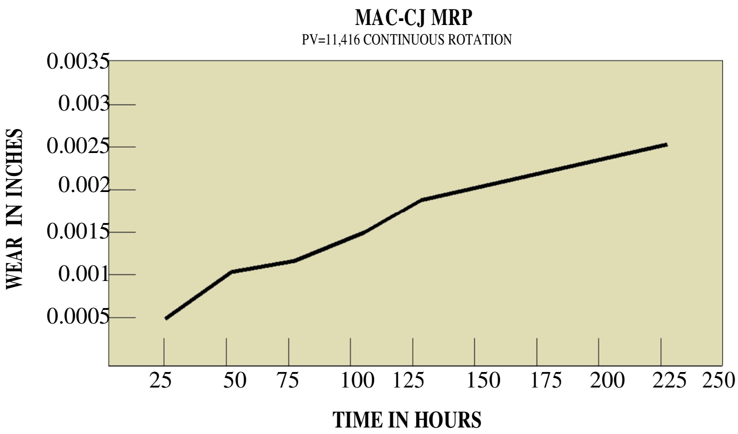


Chart represents typical deflection and permanent set for heavy wall MAC-CJ bearings

Mechanical and physical properties

The MAC-CJ MRP bearing can withstand static loads of approximately 480 MPa and dynamic loads as high as 206 MPa. A general design approach for application with oscillating pins and angular force vector changes less than 45 degrees should be designed to an average working pressure of 55 MPa. MAC-CJ MRP bearings will allow pressure spikes as high as 82 MPa during approximately 5% of the operational life. Elastic deformation will occur at the rate of 0.025mm per 13 MPa of pressure. Dry running applications can be operated at speeds as high as 10 surface feet per minute. Please consult an Application Engineer with any questions regarding loading conditions and bearing performance.

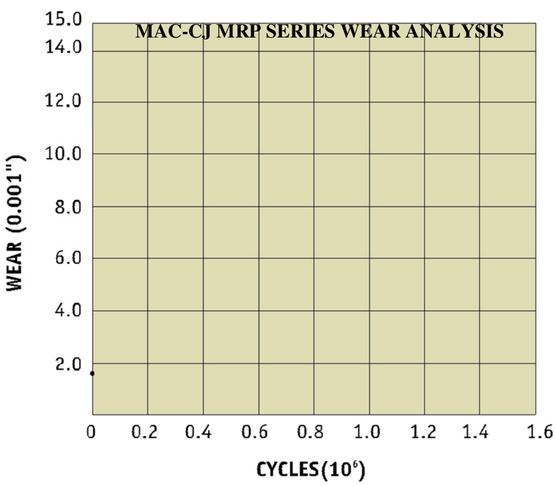


Bearing Wear

During the initial break-in period of a MAC-CJ bearing, a transfer film is created on the mating surface. In some operations, as much as 0.025mm of wear may occur during this period, while in other operations, break-in wear may be negligible. For more detail on the break-in period and the mechanism by which each bearing achieves sufficient film transfer, refer to the respective product inserts.

TEST CONDITIONS:

Bearing: 1.5" dia Bore x 0.75" Wide
Wear Surface: 4140 Steel
5-8 Microinch Ra, 50-55 Rc
Test Conditions: 22,500 lbs
Radial Load (20,000 PSI)
50 Degree Oscillation Angle
50 Cycles Per Minute



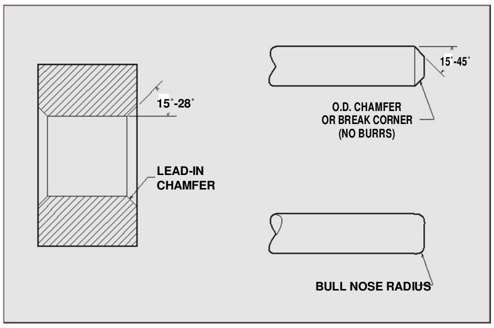
Bearing design principles

Versatile high load, low friction composite bearings.

Assembly

When a MAC-CJ bearing is press fit into a housing, it creates a highly loaded interference condition. This is possible because of the elastic properties of the bearing's backing material. Press fits on wall thicknesses up to 2.5mm have demonstrated that the close-in ratio is one-to-one (0.01mm press yields a 0.01mm close in). The amount of interference between the bearing and housing is directly proportional to the amount of force needed to install the bearing. Minimising interference fits will offer a larger array of installation options for OEMs. This is especially important for applications requiring the installation of new pins and bearings in the field.

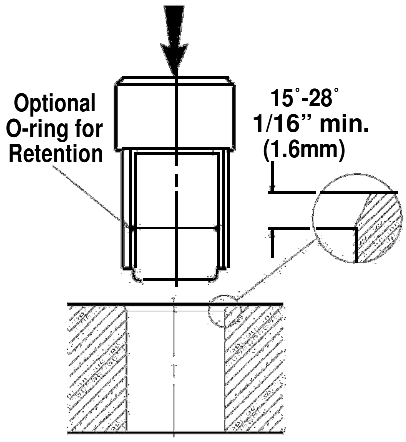
Due to thermal lag, the bearing wear surface may be hotter than the adjacent housing, when heat is generated from running friction. As a result, the installed bearing may expand inward, reducing the shaft clearance.



need caption

For optimum performance shaft clearances should be increased for dry running applications with high velocities. Fluid cooling and lubricants will reduce the operating temperatures, permitting tighter shaft clearances. Heat transfer through the bearing wall is inversely proportional to the wall thickness. The thinner the wall, the greater the transfer of heat. Thermal conductivity, for example, is 1.8 to 2.3 Btu • in/(hr • ft^2 • °F).

MAC-CJ Bearings are typically installed prior to painting processes to increase installation efficiency, decreasing costs due to overspray in the bore. E-coat and powder coat processes with temperatures as high as 200°C may be employed with the bearings already installed. It is recommended to use a plug in the bearing ID during abrasion and paint processes to maintain the integrity and frictional response of the bearing.



STANDARD BEARING INSTALLATION

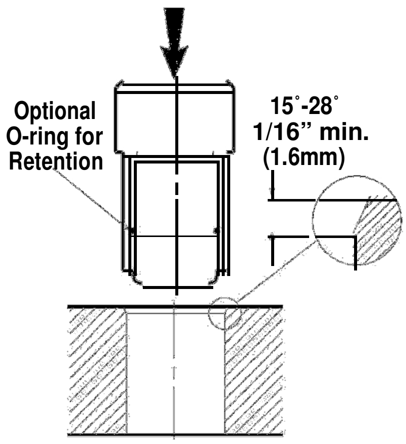
Pin Selection

MAC-CJ bearing wear is a function of the interaction between the wear materials in the liner and the pin. The majority of pins used in conjunction with MAC-CJ bearings are carbon steel. The grades range from 1018 to 4140. Pin selection is most important for designers to ensure the shear and tensile strengths are suitable for the specific application. The major properties of concern are the surface finish, hardness, and corrosion resistance. Each of these pin characteristics contribute to the bearing wear.

System Lubrication Information

Since lubrication is inherent in the bearing surface of MAC-CJ, engineers do not have to worry about these bearings drying out, causing shaft seizure and costly repairs. Because lubricants are not required, shaft corrosion should be a consideration during selection.

Lubricants may actually reduce wear rates by up to eight times. Liquid lubricants can carry away heat and reduce the coefficient of friction. Greases can be used to help prevent corrosion and keep contamination out of the housing when maintained properly. Additional lubrication can increase the performance characteristics of composite bearings. The major drawback for using lubricants is forcing the end user to maintain the joint. Lubricants can often trap contamination, which act as a grinding compound to increase wear, adversely affecting the joint ultimately.



STANDARD BEARING INSTALLATION

Bearing design principles

Versatile high load, low friction composite bearings.

Surface Finish

The optimum pin surface finish is a roughness average of 32 microinches. The mechanism allowing the bearing to operate in a dry condition is the transfer of the PTFE from the bearing to the pin. The peaks and valleys of the surface finish determine how much PTFE is transferred and if it will remain imbedded into the pin. During the break-in period, the bearing liner is shearing some of the peaks and filling the valleys with PTFE. The typical amount of bearing break-in wear running with 32 µin Ra pin is approximately 0.025mm. Following the PTFE transfer, the wear rate will stabilize to an approximate rate of 0.025mm/35,000 cycles. The rate of wear given is intended to be a guide and will be affected based on load, speed, hardness, surface finish, contamination, and oscillation angles.

The manufacturer has many applications currently using pins rougher than the recommended surface finish. Pins with surface finishes higher than recommended will experience both a higher initial coefficient of friction and a longer break-in period due to the additional PTFE needed to fill the deeper valleys. After the break-in period has been completed, the rate of wear and the coefficient of friction will behave similarly to the steady state experienced using the optimum pin finish. The trade-off to the cost savings for using a rougher pin is additional clearance after the break-in period. Some of the more extreme examples of higher surface finish pins are cold drawn 1018. The surface finish of these pins range from 50 – 120 microinches R.A.

Pins with too smooth a surface finish will adversely affect the bearing. The problem with using pins smoother than 16 µin Ra, is the inability for the surface finish to hold the transferred PTFE. The result is a continuous break-in period leading to a faster rate of bearing wear compared to joints using pins with the recommended surface finishes. It is better for the MAC-CJ bearings to have pins with a surface finish greater than 32 microinches R.A. than a surface finish lower than 16 microinches R.A.

Hardness

Pin hardness requirements are dependent upon the operating conditions of the equipment. Softer pin materials, such as stainless steel, may be used when contamination is expected to be very low or the bearing is suitably protected with a seal or due to location. Empirical and laboratory data confirm the compatibility of the various MAC-CJ liners with softer steel grades such as, 304, 316 and 1018, based on absence of pin wear.

Applications operating in moderate to highly contaminated environments will require pins with greater surface hardness. We recommend a pin surface hardness of 50 Rockwell C. A hard surface will be less likely to score when contamination is rolled in the contact area between the pin and bearing. Pin wear is caused by aggressive contamination rather than materials contained in the MAC-CJ bearing liners.

Corrosion Resistance

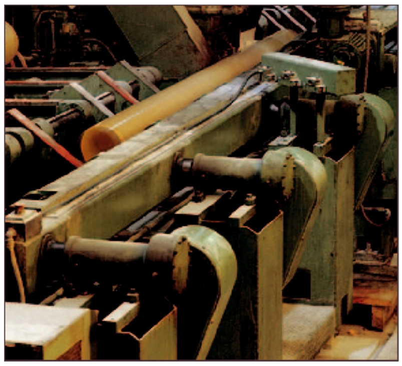
Pin corrosion will affect the surface finish of the pin as well as the running clearance. As a pin corrodes, there are a number of consequences to the operation of the joint. The three main problems introduced into the joint are increased pin OD, rougher surface finish, and oxide material contamination. The increased pin diameter could result in an interference fit and increased torque needed to turn the pin. The increased roughness of the pin surface will serve to additionally increase the torque required to operate the joint as well as increase the rate of wear. The addition of contaminates, in the form of the metal oxide, will further degrade the pin and bearing. Protecting the pin and bearing from contamination will lead to long term predictable wear regardless of the frequency of operation of the equipment.

We recommend a corrosion resistant surface treatment for pins used in dry running applications. Many years of success have been experienced with customers using Hard Chrome, Electroless Nickel, and Nitrocarborization. Pins with these surface treatments will have hardness in excess of our recommendations for moderate to highly contaminated environments. Thickness or depth of the treatment should be determined based on the chosen materials. Typical values are 0.013mm for both thickness and white layer depths. These values are not intended as recommendations, only as examples to allow designers a value to begin a conversation with pin suppliers.

Softer surface treatments are also in use with MAC-CJ bearings. Yellow Zinc Dichromate (YZD) is a cost effective alternative to the previous treatments given. YZD can be thought of as metal paint. The coating will be removed in the contact area by the bearing very quickly. The break-in period between the bearing and the base material will begin after the YZD has been worn away. There will be some added wear resulting from worn away YZD acting as contamination. Equipment seasonal in nature will also have a possibility of pin corrosion at the contact area. The transferred PTFE will act as a corrosion inhibitor if a sufficient amount has been transferred during the first season operation. The main purpose most designers state when using YZD is corrosion protection for the surface not in contact with the bearing. The result is a decrease in the migration of metal oxide particles into the joint compared to an untreated pin.

Electrical Properties

The MAC-CJ manufacturer also produces epoxy fiberglass tubes to the UL-FW-G-10 specification. MAC-CJ bearings exhibit similar electrical properties. The bearing wall provides dielectric strengths in excess of 400 volts/mil.



Stock tube during processing.

Fabrication Guidelines

The most common type of fabrication customers have questions about is how to cut composite bearing materials. Depending on how critical the squareness (perpendicularity) of the cut needs to be, on smaller bearings a standard chop saw can be used. The typical tolerance for perpendicularity is 0.005" off the chop saw. We recommend a diamond plated blade tipped with 120 grit diamonds. A rougher grit (80) can be used but that will often result in a poorer surface finish. We also recommend having the blade turning at between 1500-3000 rpm with a water-soluble coolant flooding the tube as it is being cut. This coolant will allow the tube to be cut without burning the end, will extend the life of the diamond blade, and will reduce the dust particulates generated during the cutting process.

On larger tubes, or when perpendicularity is critical, we recommend cutting the tubes on a standard lathe. In production, this type of cut is done by mounting a tool post grinder on the cross slide and dividing the tube using a 120 grit diamond blade. A three jaw chuck is used to turn the tube indicating the tube so that it turns true to the tool post grinder. The tool post grinder is typically used at between 1500-3000 rpm and the tube is turned at 15-20 rpm when divided. Once again, the same type of coolant system is recommended. In addition, it is advisable to cut from the inside out whenever possible to eliminate the fraying of the liner on the inside of the bearing.

Many times after the bearing has been cut, a de-burring operation needs to take place. A very simple de-burring operation consisting of nothing more than spinning the part and holding a piece of sand paper against the outside edge of the bearing will work quite well. The reverse is also possible by mounting a piece of sand paper in a drill press spindle and running the part onto the paper to remove any loose fibres caused by the cutting operation.

When turning the tubes on a lathe, we recommend using a diamond tipped cutting insert. On our standard CNC lathe, the tube is turned at 2000-3000 rpm with a 0.003" per revolution feed rate. The depth of the cut is usually dependent on the length of the diamond tip on the cutting insert (typically between 0.060"-0.100"). It is important when cutting fiberglass using a diamond insert to again use a water soluble coolant to dissipate the heat generated while cutting. Excessive heat will cause the bond between the diamond and the carbide insert to fail, causing the tip to come off.

Metric bearings

Housing bore and shaft diameter tolerances: H7/H8 and h7/h8 respectively.

Smaller tolerance in length available on request. All measurements in millimeters.

BEARING PART NUMBER	NOMINAI ID	id		od		recommended Housing bore		press fit		recommended shaft size		running clearance		length tolerance	
MCJ015020	15	15.120	15.200	20.050	20.100	20.000	20.025	0.025	0.100	14.975	15.000	0.020	0.200	+/-	0.250
MCJ020025	20	20.120	20.200	25.050	25.100	25.000	25.025	0.025	0.100	19.975	20.000	0.020	0.200	+/-	0.250
MCJ025030	25	25.120	25.200	30.050	30.100	30.000	30.025	0.025	0.100	24.975	25.000	0.020	0.200	+/-	0.250
MCJ025035	25	25.120	25.200	35.050	35.100	35.000	35.025	0.025	0.100	24.975	25.000	0.020	0.200	+/-	0.250
MCJ030035	30	30.120	30.200	35.050	35.100	35.000	35.025	0.025	0.100	29.975	30.000	0.020	0.200	+/-	0.250
MCJ030040	30	30.120	30.200	40.050	40.100	40.000	40.025	0.025	0.100	29.975	30.000	0.020	0.200	+/-	0.250
MCJ035045	35	35.120	35.200	45.050	45.100	45.000	45.025	0.025	0.100	34.975	35.000	0.020	0.200	+/-	0.250
MCJ040045	40	40.120	40.200	45.050	45.100	45.000	45.025	0.025	0.100	39.975	40.000	0.020	0.200	+/-	0.250
MCJ040050	40	40.120	40.200	50.050	50.100	50.000	50.025	0.025	0.100	39.975	40.000	0.020	0.200	+/-	0.250
MCJ045055	45	45.130	45.230	55.055	55.105	55.000	55.030	0.025	0.100	44.975	45.000	0.020	0.200	+/-	0.250
MCJ050055	50	50.130	50.230	55.055	55.105	55.000	55.030	0.025	0.105	49.975	50.000	0.020	0.200	+/-	0.250
MCJ050060	50	50.130	50.230	60.055	60.105	60.000	60.030	0.025	0.105	49.975	50.000	0.020	0.200	+/-	0.250
MCJ055065	55	55.145	55.245	65.070	65.120	65.000	65.030	0.025	0.105	54.970	55.000	0.020	0.200	+/-	0.250
MCJ060070	60	60.145	60.245	70.070	70.120	70.000	70.030	0.025	0.105	59.970	60.000	0.025	0.235	+/-	0.250
MCJ065075	65	65.145	65.245	75.070	75.120	75.000	75.030	0.025	0.105	64.970	65.000	0.025	0.235	+/-	0.250
MCJ070080	70	70.145	70.245	80.070	80.120	80.000	80.030	0.025	0105	69.970	70.000	0.025	0.235	+/-	0.250
MCJ075085	75	75.175	75.275	85.075	85.125	85.000	85.035	0.025	0.110	74.970	75.000	0.050	0.265	+/-	0.250