CIP Composites™ Engineering Manual

Self-Lubricating Composite Bearing and Wear Material

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Mission

To build and nurture sustainable, honest relationships with our employees, customers, suppliers and distributors, providing exceptional customer service and the highest quality material performance.

Vision

We strive to be the dominant player for the diversified markets in which we design, manufacture, distribute and supply high quality, reliable laminate composite materials; to exceed our customer's expectations by providing superior customer service and honest relationships with a high level of integrity.

Company Introduction

Columbia Industrial Products (CIP) is a manufacturer and global supplier of custom self-lubricating composite bearing materials. In 1998, after 14 years in the plastics industry, founder Stephen Phillips opened the doors to CIP in Eugene, Oregon. For years customers had requested textile reinforced composites to provide high strength, low coefficient of friction, easy machinability, and custom sizes with fast deliveries. Recognizing this market demand for higher quality products and service, Mr. Phillips established a skilled management team, and worked with key suppliers to introduce superior composite products. CIP is proud to offer these solutions, along with personalized customer support to its clients, serving a broad range of industries around the world.

Service & Support

CIP is committed to building sustainable relationships that our customers can rely on when they need it most. Our sales team and engineers work together to provide personalized customer service with:

- Fast order processing, same day order acknowledgment
- Custom tailored design/engineering proposals for your applications
- Engineering support to assure correct material and dimensions
- Technical assistance including machining and installation guidelines
- Finished bearings, wear rings, wear pads and thrust washer supplied ready to install
- 24-hour emergency service

From quick quotes to short lead times, CIP is a custom manufacturing facility in business specifically to serve customers and help solve their bearing and wear problems. A small business building honest personal relationships from the first inquiry through the shipment of the order every time.

Certifications

Columbia Industrial Products Quality Management System is certified to ISO 9001. Our Certificate of Registration is available upon request, and is applicable to the design, manufacture, machining and sale of laminate composite material.

American Bureau of Shipping (ABS) Certificate of Manufacturing Assessment

Material lot certificates and Certificate of Conformance available upon request

CIP is dedicated to providing the highest quality products with a focus on exceeding requirements. We strive for complete customer satisfaction through continuous improvement in service and quality.

Materials

Material Composition

CIP Composites™ are laminated polymer materials made by impregnating textiles with thermoset resins. Solid lubricants are added to the resin to provide evenly dispersed lubrication throughout the material, inherently eliminating the need for external lubrication. CIP offers customers an array of different textile, lubricant and resin combinations. The best combination is determined based on application criteria and environment.

CIP composite materials are represented by
three (3) digits based on the chosen textile, lubricant and resin.

Example CIP151

Textile		Lubricant			Resin	
1	Polyester	0	None	Isolation applications	1	Standard Polyester
2	PTFE/Polyester	1	Graphite	Dry conditions	2	Marine
3	Meta-Aramid	2	Moly (MoS_2)	Wet conditions	3	High Temperature
		3	PTFE	Wet or dry conditions		
		4	Graphite & PTFE	Dry conditions needing lower friction		
		5	Moly & PTFE	Wet or dry conditions		

Fig. 1 - Material Compositions

Proprietary Additives

CIP offers proprietary additives that can be added to the composite material in addition to solid lubricants. Materials with an additive would be represented with a the letter A or B at the end of the name, i.e. **CIP151A.**

Enhancement A offers lower coefficient of friction, and increased physical properties: machinability, strength, durability.

Enhancement B offers the same as Enhancement A with added reduction of noise and stick slip in oscillating or pivoting applications.

Common Materials

CIP Hydro™	Polyester/PTFE Textile Proprietary Lubrication Marine Resin	Proprietary material made specifically for the hydropower generation and inland waterway applications - tested by Powertech Labs
CIP Marine™	Polyester Textile Proprietary Lubrication Marine Resin	Proprietary material made specifically for marine applications - ABS Marine Class Type Approved and RINA Type Approved for Stern Tube and Rudder Bearings
CIP151A	Polyester Textile PTFE & Moly Lubrication Polyester Resin Enhancement A	Wet/dry applications, high loading and slow rotational motion
CIP131	Polyester Textile PTFE Lubrication Polyester Resin	Used commonly with hydraulic fluids
CIP121	Polyester Textile Moly Lubrication Polyester Resin	Wet / dry applications, where high shock or edge loading is anticipated, commonly used in general industrial applications
CIP111	Polyester Textile Graphite Lubrication Polyester Resin	Low friction without grease, used primarily in dry environments
CIP101	Polyester Textile No Lubrication Polyester Resin	No lubricants, made for static applications, commonly used as electrical insulators
CIP251A	Polyester/PTFE Textile PTFE & Moly Lubrication Polyester Resin Enhancement A	High load, slow oscillating movements offering a low coefficient of friction
CIP252A	Polyester/PTFE Textile PTFE & Moly Lubrication Marine Resin Enhancement A	Typically used as propeller shaft and rudder bearings; recommended in sand and silty environments
CIP333A	Meta-Aramid Textile PTFE Lubricant High Temperature/ Chemical Resistant Resin	High temperature applications; excellent chemical resistance

CIP Composites vs. Other Materials

CIP Composites provide designers and equipment manufacturers a simple and reliable option for a high performance bearing material. Providing a self-lubricating composite material option as an alternative to metallic bearing materials, or various grades of reinforced plastics more commonly found in the market place.

Metallic bearings require a consistent film of lubrication for operation, which is generally supplied by the use of grease or oil. Plugged bronze bearings require the use of a thin coating of lubricant initially to prevent wear, then rely on larger rotational movement and thermal expansion of the plug material to create an even lubrication layer. CIP Composites have lubricants evenly dispersed throughout the bearing material allowing for very small angular rotational movements while providing continuous lubrication.

Common **engineering plastics** generally do not have the mechanical strength or stability to handle large bearing pressures, or higher temperature applications, and eventually deform to the point of failure. Often the solution is to use a filler, such as glass fibers, or carbon to increase the strength and stability of these plastics. These abrasive reinforcements can be problematic for bearing applications however, as there are frictional impacts and potential for shaft wear. While some higher performing plastics are available that do not require fillers to provide strength and temperature capability, the cost implications are significant.

Filament wound glass reinforced composites and sintered metallic products rely on a thin sliding layer of lubrication at the bearing surface. When this layer wears away, or becomes damaged due to impacts, the mating surface must ride on the abrasive fiber or metal backing. The outcome is poor performance, and likely extensive damage to the mating counter face. Costly re-machining, or complete shaft replacement is often the only solution, requiring longer and more expensive down time. CIP composites maintain consistent polyester materials with solid lubricants through the entire material thickness and do not come with the risk of such damage to the mating counter face.

Bronze 48 lbs.

CIP Composites 7 lbs.

CIP's composite materials fill the void between the metal and plastic solutions, and help designers avoid many of the design constraints historically associated with them. CIP believes the solution is to use high quality components and processes to ensure even distribution of lubrication additives in the resin system. The results are low coefficients of friction, elimination of stick-slip and noise, and consistent performance over its life cycle.

Industries and Applications

CIP Composites can be utilized in a variety of different industries and applications and are not limited to those listed below. Contact us to discuss your application.

Industrial

CIP Composites offers solutions for rigorous industrial applications by extending wear life while reducing or eliminating external lubricants and undesired maintenance.

- Hydraulic Cylinders
- Pneumatic Actuator
- Pumps
- Food Processing
- Handling Systems
- Crane Systems
- Waste Management
- Earth Drilling & Processing
- Mining Equipment
- Agriculture
- Wood Products
- Wind / Solar Power

Hydro

CIP Composites is the leading manufacturer of environmentally friendly, self-lubricating bearings and wear pads designed to replace greased bronze components inside a variety of turbine designs, gates and valves, and auxiliary equipment. CIP composite products provide the perfect balance of performance, availability, and cost to satisfy the most rigorous demands of your hydro generation project, no matter the schedule or scale.

- Wicket Gate
- Main Guide
- Linkage
- Servo Motor
- Head Cover
- Operation Ring
- Vertical Gate
- Spillway Trunnion
- Lock/Miter Gate
- Fish Screens
- Fish Ladders
- Trash Rakes

Marine

Vessel operators are looking to composite bearing solutions to perform in a wide variety of conditions and applications. From water lubricated bearings as replacements of existing rubber, other plastics, or wood products, to high load steering components in lieu of greased bronze materials operating above and below the water line. Columbia Industrial Products offers a solution to the marine industry with its specially designed material, CIP Marine™, that has low coefficient of friction and excellent wear characteristics paired with fast and superior service to help with unexpected dry docking time.

- Rudder/Pintle
- Stern Tube
- Propeller Shaft
- Fin Stabilizer
- Thrusters
- Fairlead
- Crane Masts/Davits
- Winches/Capstans
- Skidding Pads
- Stern Rollers
- A-Frame/LARS
- Lift/Carry Equipment

Oil & Gas

Bearing materials in the oil & gas industry are presented with the most demanding conditions requiring high load capacity in poor environments and sporadic service schedules. Columbia Industrial Products offer CIP Composites to the oil & gas industry as light weight, self-lubricating composite materials that have a long service life. Although commonly used for bearings, wear pads and thrust washers, CIP's ability to provide large custom size solutions give the oil & gas industry the ability to use our materials in a wide range of applications.

- CALM Buoy
- Launch & Recovery
- Riser Tensioner
- Iron Roughneck
- Boom/Mast
- Pumpjack
- Blowout Preventer
- Pipe Stacker
- Rig Walker
- Mooring Connections
- Chain Jack Systems
- Coiled Tubing Equipment

Physical and Mechanical Properties

The physical properties of CIP Composites make them superior bearing materials. As a general guide, this 100% bearing material is best suited for high load, high impact and slow rotating applications. CIP composite bearings and wear pads are great replacements for your current bronze, babbitt, or thermal plastic applications.

Compressive Strength

CIP materials are made by reinforcing resin with high strength textile giving them a compressive strength of up to 50,000psi (344.7MPa-m/min), and tensile strengths up to 12,000psi (82.7MPa-m/min). In addition to exhibiting high ultimate strengths, CIP materials are resilient and durable in shock and misaligned loading conditions. Their ability to absorb vibrations and load fluctuation while retaining their shape and mechanical strength set them apart from many alternative materials in the marketplace. This mechanical strength also applies to a wide range of temperatures, providing application acceptance in environments found all over the world.

Commonly used to replace bronze components, CIP materials have the mechanical strength required to provide design assurance that they can take the pressure and provide long lasting service.

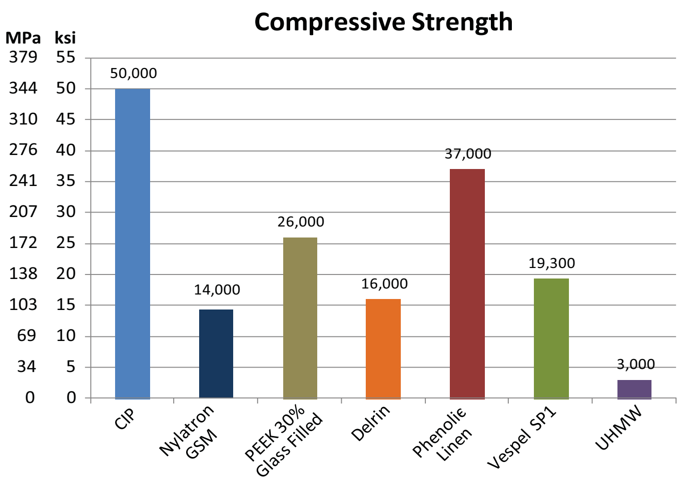


Fig. 2 - Compressive Strength

Elasticity

CIP Composite materials are more elastic and will conform non-permanently at a lower pressure than bronze, allowing it to work well in misaligned conditions. At higher operating pressures CIP materials conform more to the shaft and the housing than bronze. Distributing the pressure across the bearing contact area help to eliminate the effects of galling, a leading cause of bronze bearing failures.

Coefficient of Friction

CIP Composites have lower coefficients of friction (CoF) than bronze in both static and dynamic situations. CoF with CIP Composites range from 0.05 – 0.20 dependent on application, shaft material, surface finish, load, speed, environment and external lubrication. This can eliminate noisy stick-slip problems, extend operating life and reduce wear, making for better operating efficiency. Static coefficient of friction is generally very similar to dynamic, even after prolonged periods of rest, where other materials may develop high break-away torque requirements.

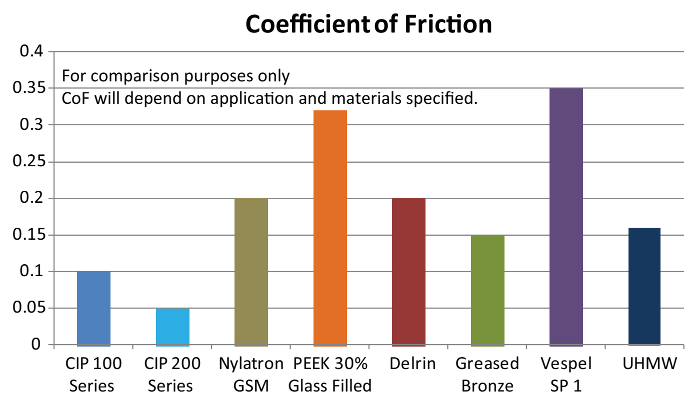


Fig. 3 - Coefficient of Friction

Moisture Absorption

CIP Composites have a negligible absorption of less than 0.1%, eliminating concerns with moisture absorption when moving away from a metallic solution. Some plastics in use today can have a water absorption rate as high as 5-7%, causing the material to swell and expand, potentially leading to bore closure of the bearing, seizing on the shaft, and premature failure.

Electrical Resistance

Certain grades of CIP Composites make excellent insulating materials and may be used in a number of different electrical applications. They do not conduct electrical current like a metallic, and therefore prevent galvanic corrosion between dissimilar metals.

Thermal Properties

CIP Composites are thermal insulators. Under normal circumstances frictional heat is removed via the mating metal surface. The removal of frictional heat may be improved, particularly in dry running applications, by using the housing for additional heat dissipation. The wall thickness of bearings should be kept to a minimum in order to improve heat conduction. However, in cases where shafts or housings are conducting heat into the bearing assembly, a lubricant may be necessary to aid in the removal of heat.

Although thermal expansion of CIP Composites is greater than that of most metal alloy bearings; it is consistent, predictable and less than many plastics. Expansion must be taken into account for applications where there will be a temperature change greater than 60°F (15°C).

Electrical Properties	
Dielectric Strength (ASTM D 149-97a)	200 volts/mil
Volume Resistivity (ASTM D257-07)	4.2 X 10^{15} ohm-cm

Electrical properties listed are general and may change depending on the material build.

Thermal Properties		
CIP 100 & 200 Series		
Operating Temperatures	-40° to 200° F	-40° to 93° C
Coefficient of Thermal Expansion		
Normal to Laminate	$3.5 \times 10^{-5}/\Delta°$ F	$6.3 \times 10^{-5}/\Delta°$ C
Parallel to Laminate	$1.8 \times 10^{-5}/\Delta°$ F	$3.24 \times 10^{-5}/\Delta°$ C
Coefficient of Thermal Conductivity	0.17 Btu/hr-ft-°F	0.3 W/m-°K
CIP 300 Series		
Operating Temperatures	-40° to 400° F	-40° to 204° C
Coefficient of Thermal Expansion		
Normal to Laminate	$4.0 \times 10^{-5}/\Delta°$ F	$7.2 \times 10^{-5}/\Delta°$ C
Parallel to Laminate	$2.0 \times 10^{-5}/\Delta°$ F	$3.6 \times 10^{-5}/\Delta°$ C

Fig. 4 - Electrical and Thermal Properties

Chemical Resistance

CIP Composites do not corrode and are unaffected by many solvents and chemical solutions. This eliminates many of the problems commonly encountered with metal bearings, for example, during chemical wash down procedures the chemicals may attack the metal bearing and strip away lubricating oils.

The following chart is based on CIP series 100 materials. CIP offers alternative materials with improved chemical resistance, contact us to discuss the chemicals used in your application.

	68°F/20°C	120°F/49°C
Acetic Acid 15%/100%	S/U	L/U
Acetone 15%/100%	S/U	L/U
Alcohol Ethyl	S	S
Aluminum Sulfate	S	S
Ammonia Liquid	U	U
Ammonia Aqueous	U	U
Ammonium Carbonate	S	L
Ammonium Nitrate	S	S
Benzene	S	L
Bleach Liquors	S	L
Calcium Chloride	S	S
Calcium Hydroxide	U	U
Carbon Tetrachloride	S	S
Chlorine Water	S	L
Creosote	S	S
Citric Acid	S	S
Ethylene Glycol	S	S

	68°F/20°C	120°F/49°C
Fatty Acids	S	S
Hydrochloric Acid	S	S
Hydrofluoric Acid	U	U
Maleic Acid	S	S
Naphtha	S	S
Nitric Acid 15%/100%	S/U	S/U
Oxalic Acid	S	S
Phosphoric Acid	S	S
Phthalic Anhydride	S	S
Potassium Hydroxide	U	U
Sodium Carbonate 25%/100%	S/L	S/U
Sodium Chloride	S	S
Sodium Hydroxide	U	U
Sodium Nitrate	S	S
Sodium Nitrite	S	S
Sulfuric Acid 50/100%	S/U	S/U
Trichloroethylene	U	U

S = Satisfactory L = Satisfactory for limited service U = Unsatisfactory

Satisfactory means that the material retains 50% or more of its original dry strength after immersion of at least six months.

Fig. 5 - Chemical Resistance

Composites may be attacked by ketones, chlorinated solvents, strong alkalis, and hot strong oxidizing agents. Chemical concentrations, solution temperatures, and exposure information will be used to evaluate chemical compatibility.

FDA - Non Contact Only

CIP offers material grades for use in food equipment that are capable of running in higher operating temperatures, have better resistance to harsh cleaning chemicals, and lower coefficient of friction over traditional plastic materials. CIP materials are nontoxic and conform to the FDA requirements when the material is not in direct contact with food.

Manufacturing Capability

Standard Raw Tube & Sheet Sizes

CIP Composites are available in tubes or sheets made to your specification. CIP has the capacity of producing large quantities of tubes and sheets on a daily shift depending on the product mix. CIP has multiple lines of required equipment on site to provide flexibility of running special order parts alongside standard product with no impact to efficiency.

Tubes After trimming to correct length tubes are visually inspected for quality and measurements of inner diameter (ID), outer diameter (OD) and lengths (L) are performed to ensure material is suitable for machine work and secondary operations.

Tube Size Range
  0.5 in. to 65 in.
  13 mm to 1651 mm
Standard Lengths
  16–24–32 in.
  406–610–813 mm

Sheets After sheet stock is trimmed and verified for proper size of both length and width, a visual check is performed for quality before final machining or shipping.

Sheet Thickness Range:
  0.125 in. to 6 in.
  3 mm to 152 mm
Standard Widths
  16–24–32 in.
  406–610–813 mm
Standard Lengths
  24–36–48–60 in.
  610–914–1219–1524 mm

Custom Manufacturing

Columbia Industrial Products prides itself in producing quality components efficiently, with short lead times, and fair pricing. CIP offers full machine shop services, a wide range of quality equipment, and the capability to manufacture custom components. CIP's highly skilled machinists are capable of finishing material to various complex shapes and sizes. They welcome a challenge and enjoy the process of finding solutions. Products are manufactured to customer specifications, requirements and acceptable tolerances, or CIP's sales and engineering staff are available to assist in the development of the design.

Facility Information

CIP's facility is 16,000 square feet and offers a complete machine shop on location, including state-of-the-art CNC machines. The CNC lathes provide live tooling functionality and CNC mill has 4th axis capability. The CNC router with 5 ft. by 10 ft. table allows for quick production of sheet parts. A complete array of manual lathes provide capabilities to turn parts with diameters up to 65 inches.

CIP has put a high priority in reinvestment towards machines, hardware and software to provide cutting edge technology for its workforce. This includes formal training, support services, and equipment maintenance to maximize the transfer of benefits to the finished product. These efforts enable CIP to achieve the high level of efficiency that customers demand.

Testing Services

CIP's facility includes a material testing lab for use in development of our materials. A computer controlled 100kN electromechanical testing machine provides highly repeatable results and allows for customizing testing procedures and formal reporting. Offering the services of this lab to customers allows specific testing to be performed according to the requirements of their project or needs.

Application Considerations

Load and Working Pressure

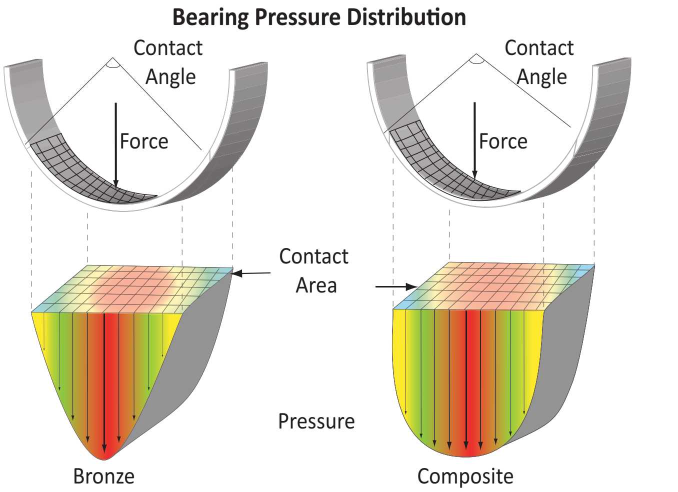


Fig. 6 - Bearing Pressure Distribution

Generally the first thing a designer should determine is what the operational load and associated bearing pressure will be. This will determine material suitability and help define the appropriate bearing size. CIP recommends using the projected area method to determine bearing pressure:

Bearing pressure = Load / (Bearing Length * Shaft Ø)

This simple formula provides the designer with a good understanding of what kind of pressure should be expected.

CIP recommends not exceeding the following design values for bearing pressure for most applications.

Static 10,000psi (70MPa)
Dynamic 5,000psi (35MPa)
For dynamic cases consideration should be taken on the effect of speed and temperature as discussed in the speed section.

In some cases design pressure can be much higher than these values and still provide excellent performance and long term service. Each of these cases are evaluated specifically with CIP's engineering and technical sales group to determine the best product and design recommendation to meet the customer's requirements. CIP will work with you to determine the best solution to maximize effectiveness of your bearing and minimize risk of performance issues.

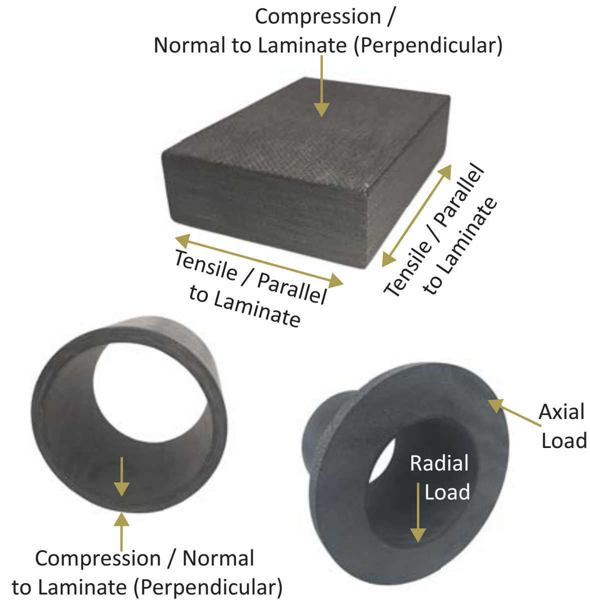


Fig. 7 - Lamination Direction

Load capacity is based not only on the material properties, but also the direction relative to the laminate. The laminates run parallel to the thickness of sheets, and around the circumference of tubes. Loads applied in a direction parallel to the laminate, such as axial loads in a bearing, should be reviewed against the material properties in that direction.

Deformation Under Load

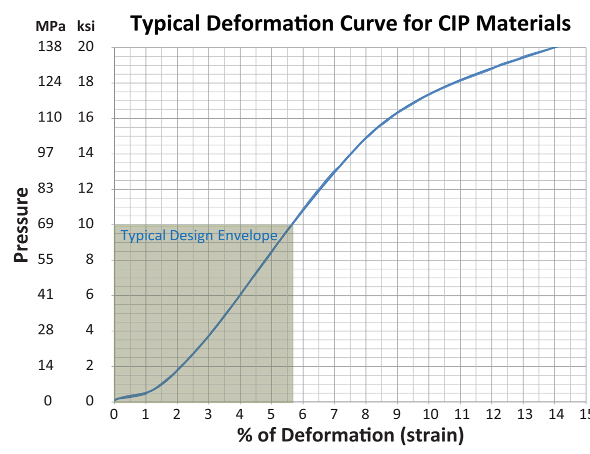


Fig. 8 - Deformation Under Load

Actual deformation will be dependent on several factors including material thickness, installed running clearance, misalignment, and temperature. CIP recommends follow-up testing and installation verification to confirm deformation if this is a critical aspect of the design. Contact us to discuss deformation based on your specific scenario.

Fatigue

For some applications representing relatively low cycles of loading/unloading, CIP's material may be utilized at higher than normal operating pressures. Associated operational speed and duty cycle should be carefully considered if there is a dynamic sliding surface involved with these elevated pressures. The following S-N fatigue chart can be used as a reference to the acceptability of loading and operating CIP materials above standard recommendations.

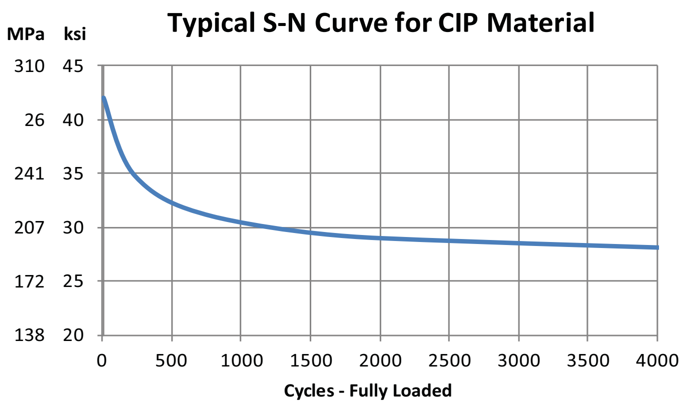


Fig. 9 - Fatigue Chart - stress vs. number of cycles

Edge Load / Shock Load Capabilities

CIP materials offer a unique ability to provide high load capacity with enough compliance to distribute stresses when operating with an edge or shock loading condition. The use of high quality thermoset resins with strong synthetic textile reinforcement results in a material with high impact and energy absorbing properties. This allows CIP composites to handle misaligned shafts, concentricity issues, and impact loads without the longevity and performance sacrifices often associated with such conditions. Testing has shown the ability to operate very well at 0.004 in/in (0.1 mm/mm) misalignment.

If relying on grease to protect against wear, there can be problems maintaining this protective layer when the pressure is uneven, as the grease will migrate to the low pressure zone, leaving the critical high pressure zone lacking adequate lubrication and protection. The result is often galling of the shaft and bushing. This becomes even more critical in applications where the movement is slow, intermittent, or has small oscillations. The solid lubricants used in CIP products are evenly dispersed throughout the resin and bearing, providing consistent wear protection and frictional benefits in both the high and low pressure zones.

Speed

CIP Composites are most effective for applications where speed is limited, or intermittent. The thermal properties of CIP inherently make it an insulator. When frictional heat is generated the bearing must rely on the shaft or its environment to dissipate the majority of this heat energy. The amount of thermal energy created by the bearing contact is dependent on a number of factors including: CIP material selection, shaft material and surface finish, existence of any lubricants (water, oil, grease), operating pressure and speed.

The relationship between operating pressure and speed is generally referred to as the PV (Pressure * Velocity) and expressed in psi-ft/min or equivalent metric units.

It is important to not only consider the design speed, but also take consideration of the duty cycle as well. The underlying constraint is heat generation. If an application represents a high speed, but the duration and frequency of this condition is small, then there is likely sufficient time for the heat to be dissipated. In such cases the PV of an application can be much higher than if the motion is continuous.

As a general guideline or reference, CIP recommends limiting the PV for 100 series materials to 6000psi-ft/min (13.6MPa-m/min) for continuous duty or industrial applications. Similarly CIP 200 series materials have a recommended PV limit of 10,000psi-ft/min (25MPa-m/min). Adding grease will increase the PV limit to 20,000psi-ft/min (42MPa-m/min). The following chart can be used as a guideline.

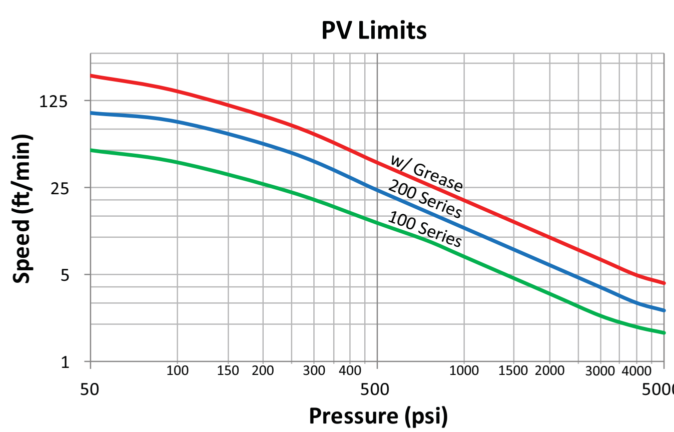


Fig. 10 - PV Limits

Duty Cycle

The duty cycle, or duration an application is in motion relative to the time it is at rest, is important in determining the performance and longevity a wear surface will provide. When accounted for, duty cycle will increase or reduce the allowable PV for a given application. For instance high PV values can be acceptable if the duty cycle is low, allowing thermal energy to dissipate during the rest period. Conversely, applications that represent continuous motion may require reduced PV ratings if there is potential to build heat beyond the bearings rating.

The wear rate will also be impacted as long periods of static condition will not contribute to the wear period that the bearing surface must accommodate, therefore providing longer overall service life. Each application is different, so the dependence on duty cycle is best discussed directly with CIP to determine appropriate PV ratings, and lifespan expectations.

Wear Life / Limit

CIP uses high strength synthetic fibers, advanced resin systems with evenly dispersed solid lubricants and additives to create a family of materials that are highly resistive to wear and abrasion. CIP provides solutions for a variety of operating conditions and environments. Slow speed and oscillatory motion can result in high wear rates with metallic bearings, but are generally ideal for CIP Composites.

CIP can provide assistance in evaluating an application and give some indication of expected wear life or rate based on either testing or experience in similar conditions. Wear rates are heavily dependent on application conditions, the most important factors to consider are the counter surface material and finish, operational pressure/velocity (PV), and CIP material grade. Environmental conditions such as temperature, contaminants, and fluids can also affect the wear rate.

Experience has shown that there is a direct correlation between heat generation and wear rate. However, if the heat can be dissipated and contact surface temperature remains low, the wear rate can be kept to a minimum. For these reasons applications providing large heat sinks via the shaft/housing, or submerged environments can provide better wear rates.

Acceptable wear amounts are almost always dictated by the application itself. CIP Composite materials are self-lubricating throughout the entire thickness; there are no abrasive ingredients used in any portion of the material. This allows CIP's products to provide a high level of frictional and wear performance, without risk of damage to the counter surface, through the entire life of the material. This is an important differentiation between CIP's products and other composite bearing materials utilizing a thin liner surrounded and supported by an abrasive fiberglass shell.

External Lubrication

CIP Composites can be used with external lubricants if desired. Bearings and wear pads can be custom designed with lubrication grooves for water, grease or oil. Although most lubricants will not harm CIP Composites, it is recommend to use synthetics.

Thermal Expansion Rate & Operating Temperature

Designers must consider thermal expansion and its effect on running clearance. Typically designs are intended to be machined and inspected at "room temperature" (73°F/21°C), if the bearing is then put into service at a different temperature there will be some amount of thermal expansion. This occurs both through the thickness of the bearing or pad (normal/ perpendicular to the laminate), and through the length/circumference of the bearing (parallel to the laminate).

Due to the construction of CIP's composite materials the Coefficient of Thermal Expansion (C.T.E.) in the perpendicular direction is greater than in the parallel direction. The difference in service temperature to room temperature is considered the change in temperature (ΔT). C.T.E. values can be found on page 7.

When CIP provides a bearing calculation report the thermal expansion is taken into account and recommended designs will account for changes in running clearance. Designers can perform simple approximate calculation as follows:

(Bearing OD – Bearing ID) * ΔT * C.T.E. = Change to running clearance

For example if OD is 12.000" and the ID is 11.000"

1.000" * 27°F * $3.5\text{x}10^{-5}$ = 0.001" of bore closure

For additional support and more detailed calculations contact CIP directly.

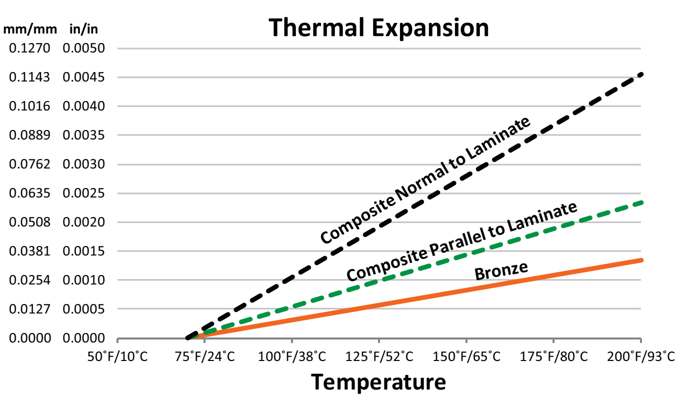


Fig. 11 - Coefficient of Linear Thermal Expansion

Environment

When designing the bearing, CIP recommends considering the application's environment. The environment a bearing or component operates in can impact wear, PV limitations and frictional performance.

Applications in dusty environments or where abrasive particles are present will represent a different set of criteria than in protected, relatively clean conditions. CIP Composites are self-lubricating and can eliminate the need for greasing systems that can attract dirt. Additionally, CIP offers materials, such as our 200 series, that handle foreign contaminates better.

CIP often considers incorporating sealing elements into the bearing design. The use of seals to prevent ingress of foreign particles or other contaminants can be highly effective in protecting the bearing surface, resulting in extended operational life.

Applications that are submerged in water can provide improved performance, often allowing for higher PV values due to the improved ability for the bearing to dissipate heat.

Design Support

CIP's dedicated team provides technical assistance, application engineering services and design guidance directly and in a timely manner. Utilizing multiple CAD software packages CIP is able to provide valuable design information efficiently, and in a variety of formats: product prints, 3D models, visual renderings. Internally there is a direct line of communication between the engineering, sales, and manufacturing staff to ensure the product and design will meet specification.

Wall Thickness

Wall thickness of a bearing is often dictated by the current space available or existing shaft and housing dimensions. For scenarios where there is some freedom in designing to an optimum wall thickness with CIP Composites, the following is recommended:

Wall = 0.05*ShaftØ+ 0.05 (inch)

Wall = 0.05*ShaftØ + 1.3 (mm)

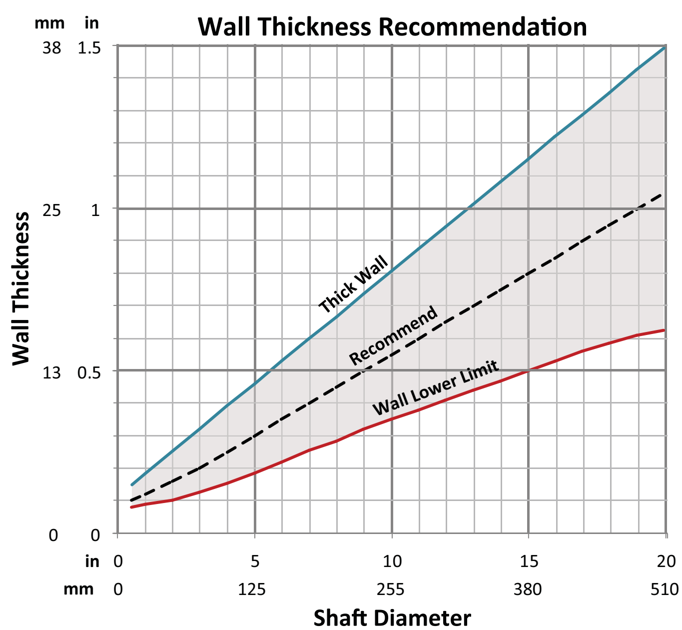


Fig. 12 - Wall Thickness Recommendation

When designing bearing wall thickness, some application conditions should be considered:

- Applications that represent a potential for heat generation, such as **high speeds** and **dry running condition**, or where the **environmental temperatures** are high. In these cases it is often best to design for the minimal allowable wall thickness to provide better heat dissipation into the housing, and reduce the amount of thermal expansion.
- Applications with very **high contact pressures** should avoid overly thick walls to minimize displacement of the shaft and maintain adequate bearing clearances.
- Applications that are **not installed with an interference fit**, such as adhesive bonded installations or bands installed into grooves can be designed with less than typical wall thickness as they do not rely on wall pressure to be retained in the housing.

Interference Fit

Appropriate interference fit is based on the size of the bearing, application and temperature range.

Interference = 0.002*ShaftØ (inch)

Interference = 0.05*ShaftØ (mm)

When designing for an interference fit, the goal is to provide enough wall pressure on the bearing to retain it and prevent any movement of the bearing relative to its housing. This wall pressure is not only dependent on the amount of interference, but also the wall thickness of the bushing, temperature range of the application, housing material and size.

For bushings with relatively thick walls, less than normal interference is often required to generate sufficient pressure. If the bearing is to be exposed to low temperatures, the amount of interference may need to be increased to assure sufficient wall pressure at these low operating temperatures.

If the bearing is going to operate in elevated temperatures, designers should use caution not to apply too much interference, as excessive undesirable wall pressure may result.

CIP is available to provide bearing size calculations based on your specific application conditions.

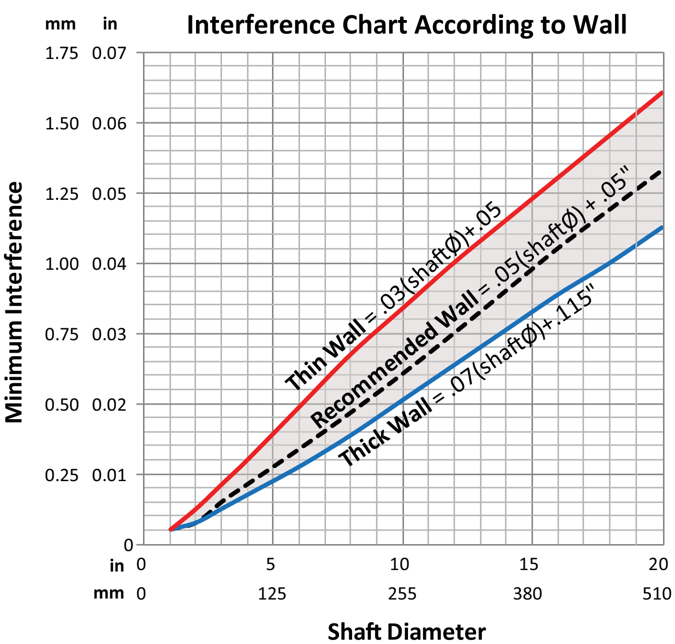


Fig. 13 - Interference Chart According to Wall

Bore Closure

When designing with an adhesive bond, mechanically fastened, or clearance fit installation, bore closure should be ignored.

Bore closure, or reduction of the bearing ID, upon installation is something that must be considered when designing with an interference fit. This is a result of the wall pressure and hoop stress on the bearing from the interference fit causing the ID of the bearing to be reduced. This amount of closure is dependent on the relative wall thickness for a given bearing diameter. For thin walled bearings this bore closure can be 100% of the interference. For thicker walled bearings it may only be 70% of the interference.

Bore Closure = Interference*% Closure (see figure 14)

This bore closure must be accommodated by the design, and added to the recommended amount of clearance, to provide a proper fit of the bearing to the shaft once it has been installed.

The following chart can be used to determine what percentage bore closure your design will represent.

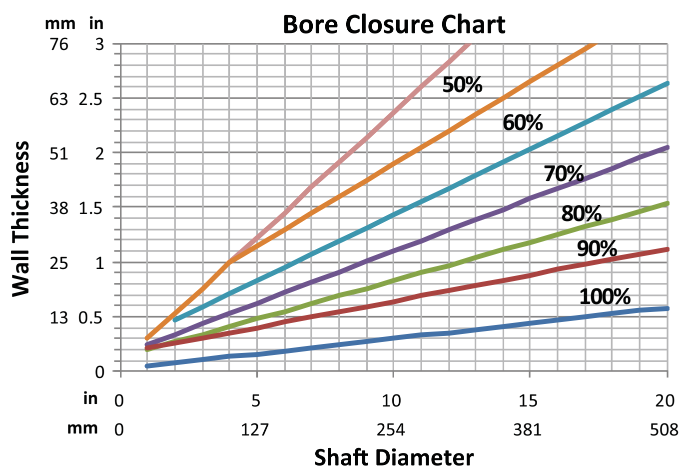


Fig. 14 - Bore Closure

Running Clearance

All clearances are referring to diametrical clearances.

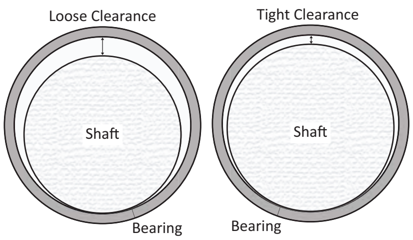


Fig. 15 - Running Clearance

Using proper design considerations to result in adequate running clearance is one of the more critical aspects of working with self-lubricating composites. CIP Composites are very tolerant of large clearances, and can accommodate a wide range of applications. When rotational speeds are consistently elevated, or frictional performance is critical, designers should ensure adequate operational clearance. Although performance problems are rare, they are usually the result of insufficient running clearance.

Running Clearance = 0.002*ShaftØ

When applications have demands for tighter running clearances, CIP can help evaluate the conditions and provide recommendations on materials for your application.

Some specific conditions which result in other guidelines for clearance are:

- **High speed water lubricated** bearing applications where hydrodynamic operation is desirable require larger running clearances for proper development of the hydrodynamic boundary layer.
- The **use of external lubrication** such as grease, oil or water will often allow for designing with tighter running clearances.
- Applications that have **misalignment conditions** usually benefit from larger running clearances.

The actual installed running clearance of a bearing will be dependent on the combined tolerances of the bearing, housing bore, and shaft. The use of an interference fit will require the consideration of all of these tolerances.

Some design techniques that may provide better control over the running clearance are:

- Designing the bushing with tolerance control on the **OD and wall specification** rather than OD/ID.
- Bearings installed with **adhesive and associated clearance** fit to the housing bore will eliminate the impact of the bushing OD and housing bore tolerances.
- **Minimizing the tolerance** on the housing bore and shaft.

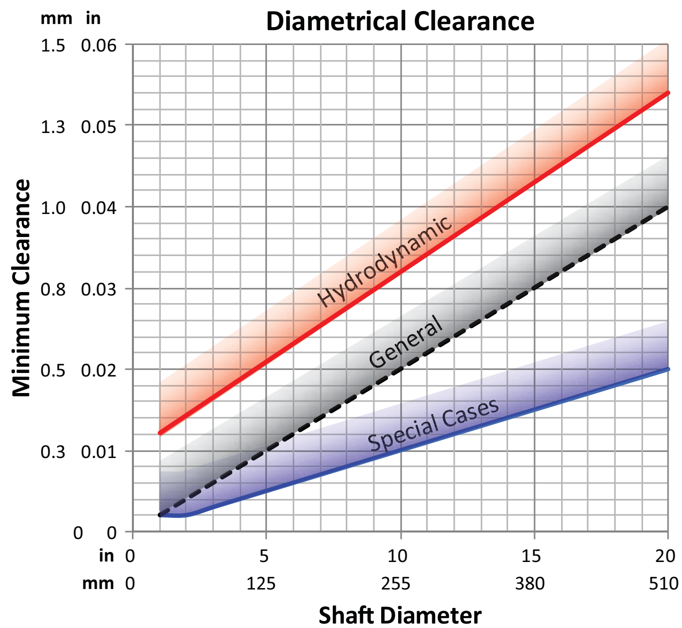


Fig. 16 - Diametrical Clearance

Counter Surface

The counter surface finish of the mating operating component has a major effect on the performance of the composite.

Surface finish should ideally be:

- 16 – 32 RMS or 0.4 – 0.7 µm Ra
- Rockwell B Hardness (HRB) of 80
- Free from cutting edges and lubrication grooves or holes

Preferred mating materials are hardened steel, stainless steel and Inconel.

Machining

CIP Composites are readily machinable by conventional machining techniques. As a general guide they may be treated as bronze, but machined **dry** without coolant. CIP materials are nontoxic, however, it is advisable to use adequate dust extraction when machining.

Turning

For turning, solid carbide tools should be used to obtain a fine finish. High speed steel tools can be used for machining where accuracy is not critical and for small quantity production.

Cutting Angle

Top Rake	0° to 6°
Front Rake	4° to 5°

Negative or positive rake tools will work depending on the setup of your particular machine.

Speeds for Cutting

Normal surface feed finish is 800-1200 SFPM (3600-25500 SMPM). RPM speeds will be dictated by your particular machine, and on manual lathes often by the chuck size. For larger diameter parts over 3ft (1m), speeds below 9000 SFPM (2700 SMPM) are common.

Feed Rates

First pass or roughing can be 0.015 to 0.035 IPR (0.4-0.9 MMPR).

Finish passes are recommended at 0.004 to 0.015 IPR (0.1-0.4 MMPR).

Milling

CIP recommends two flute cutting tools to be used, suitable for aluminum. Typical cutting rates at 9000-36000 SFPM (2700-9000 SMPM). Depending on your tooling and chuck speed, feed rates of 150 to 275 in/m (4-7 mm/m) are achievable.

CIP Internal Tolerance Guidelines

Tolerance tables are for turning only. For milling/routing parts it is generally recommend ±0.005” (0.13mm).

		Length (inches)			
		.5 - 8	8 - 12	12 - 18	18 +
OD	.5 - 7	+/- .002	+/- .003	+/- .004	+/- .005
OD	7 - 12	+/- .002	+/- .004	+/- .004	+/- .005
OD	12 - 17	+/- .003	+/- .004	+/- .005	+/- .005
OD	17 - 32	+/- .005	+/- .006	+/- .006	+/- .007

		Length (metric)			
		13-200	200-300	300-450	450 +
OD	13-175	+/- .05	+/- .08	+/- .1	+/- .13
OD	175-300	+/- .05	+/- .1	+/- .1	+/- .13
OD	300-425	+/- .08	+/- .1	+/- .13	+/- .13
OD	425-800	+/- .13	+/- .15	+/- .15	+/- .18

Fig. 17 - CIP Internal Machining Tolerance

Installation

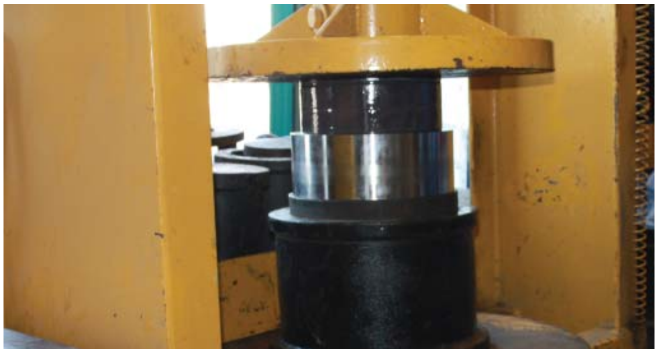
CIP Composite bearings can be designed for a variety of installation processes.

Freeze-Fit

CIP bearings do not become brittle during the freezing process. Liquid nitrogen is the most efficient method; in some cases dry ice or refrigeration may be used. Extreme caution is suggested, please consult your supplier for safety procedures and appropriate personal protective equipment. Liquid nitrogen will use up oxygen when it is gassing, be sure to ventilate the work area.

- Assemble a container large enough for the bearing with a few inches above the bearing when the bearing is on end. This container should be insulated due to the extreme coldness of the liquid nitrogen (-320° F).
- Fully submerge bearing in the liquid nitrogen and cover for 15-30 minutes. The liquid nitrogen will be boiling. Once boiling stops, let bearing stand for an additional 25-30 minutes. Remove the cover and check the bearing OD to see that it has sufficient clearance.
- Once the bearing is ready, remove it from the container and proceed with the installation. Block or hold the bearing in the housing, especially if the installation is vertical. As the bearing returns to ambient temperature and increases in size, the proper interference with the housing will be obtained.

Press-Fit



CIP bearings can be installed using a hydraulic press or porta power. Bearings should be fully supported over their loaded area, with uniform interference fit. A suitable lead-in chamfer should be provided in the housing and on the bearing diameter to assure proper start.

The end of the bearing may be machined with a lead in area, or step, to assure that the bearing starts into the housing in a correct manner.

Upon request, CIP can provide an evaluation of the required force to fully press in bearings based on your specific application.

Mechanically Fasten

When bolting, CIP recommends a minimum of .10” (2.5mm) under the bolt head. Bearings should be retained on either side. Shoulders, bolt on rings, other rings or keepers can be used to prevent the bearing from moving over time.

Most flat components such as wear pads can be retained by countersunk screws or metal inserts and located by keeper plates where high lateral or shearing loads are anticipated.

Bonding

CIP Composites bond well with adhesives. Bearings can be designed for glue-in installation with a clearance fit between bearing and housing.

As a general guideline the bonding surfaces should be clean, dry and properly prepared and the bonded parts should be held in place until the adhesive is set. Adhesive manufacturers guidelines should be followed.

Adhesive Recommendation:

Experience has shown that two-part epoxies work exceptionally well. Important considerations that should be reviewed when choosing an adhesive:

- Is the adhesive compatible with polyester composite material and the mating material (steel, aluminum, galvanized surface, etc.)?
- Is the adhesive suitable for the environmental conditions that it will be used in (temperature, ocean/fresh water exposure, UV, etc.)?
- Is the adhesive suitable for the design conditions (strength, stiffness, impact toughness, lifespan, etc.)?
- Does the adhesive come in appropriate sizes/methods? Consider if you need a large quantity or have a small job, is a gun applicator required or recommented, etc.

Products that have been used successfully with CIP material:

- Hysol - E9309.3 or EA9359.3
  (toughened 2 part epoxy with glass beads for bond-line thickness control)
- Hysol - 9460
  (general purpose epoxy)
- Hysol - E-20HP
  (general purpose amine epoxy)
- Hysol - E-12oHP
  (general purpose polyamide epoxy)
- Loctite - F246
  (one component toughened acrylic adhesive)
- Hunstman - Araldite 2004
  (heat resistant 2 part epoxy)

Shipping and Storing

CIP ensures all products are properly packaged to arrive safely and free of damage. Located just 2 hours from the Port of Portland and a quick drive from the airport, Columbia Industrial Products' central location makes shipping easy. While our preferred carrier for small packages is UPS, our knowledgeable coordinators make use of numerous logistics companies to make international orders both simple and efficient. For larger or LTL shipments CIP is happy to arrange delivery with your preferred freight line or transport service.

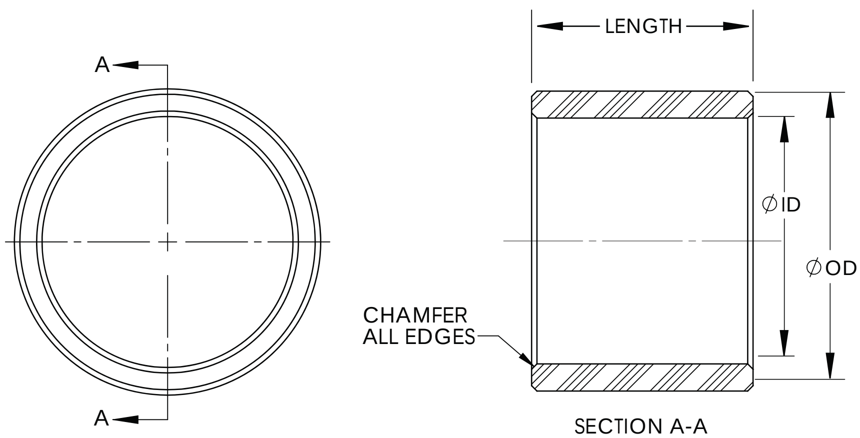
When storing CIP composites it is recommended that the product be left in the container in which it shipped to prevent contamination from debris or foreign substances. For long term storage, composites should be kept in warehouse conditions or a dry location.

CIP Composites™
Columbia Industrial Products

Please send completed forms via
email to **sales@cipcomposites.com**
or fax to (541) 607-3657

Straight Sleeve Bearing Design Worksheet

PROVIDE DETAILS IN BOX TO THE RIGHT



BEARING DIMENSIONS
Provide hardware dimensions below.
Bearing ID Min ________ /Max ________
Bearing OD Min ________ /Max ________

BEARING LENGTH
Length (required):________________

CONTACT INFORMATION

Company________________________ Name________________________
Phone________________ Fax________________ E-Mail________________________

HOUSING AND MATERIAL INFORMATION

Sizes are required if bearing dimensions were not provided above.
Housing Size: Min __________ Max __________ Housing Material (required):________________
Shaft Size: Min __________ Max __________ Shaft Material (required):________________
Current Bearing Material:________________________________

ENVIRONMENT

Wet (water): ❑ Dry: ❑ Caustic: ❑ Dusty: ❑ Greased: ❑ Other: ❑ Temperature at Bearing: __________

OPERATION

RPM ______ Load Weight ______ Hours of Operation/day ______

Rotation

360° ❑ Osculating ❑ Intermittent: Yes ❑ No ❑ Frequency/Cycles ________________

MANUFACTURING OPTIONS

❑ Raw Material (raw tube is supplied with additional material allowance for machining)
❑ Semi-Finished (CIP to rough turn ID/OD and machine water grooves)
❑ Finished Machined (CIP to machine complete to design)

ORDER DETAILS

CIP Material:________________ Quantity Needed:__________

CIP Only:
Raw Tube:________________
Mandrel Size:________________

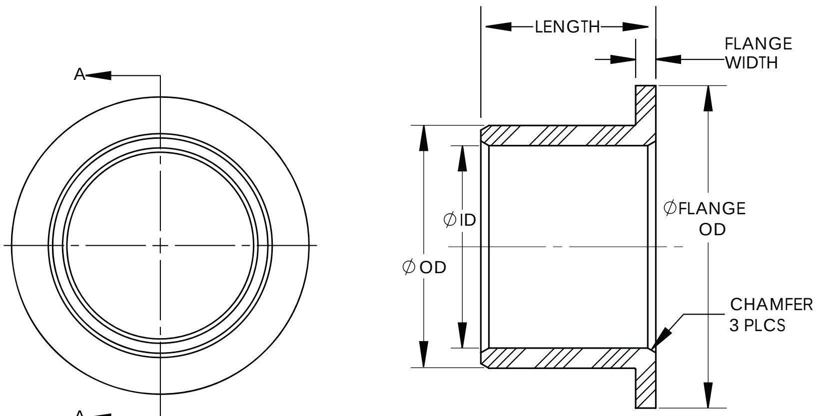
APPLICATION:

CIP Composites™
Columbia Industrial Products

Please send completed forms via email to **sales@cipcomposites.com** or fax to (541) 607-3657

Flange Bearing Design Worksheet

PROVIDE DETAILS IN BOX TO THE RIGHT



SECTION A-A

BEARING DIMENSIONS
Provide hardware dimensions below.
Bearing ID Min ________ /Max ________
Bearing OD Min ________ /Max ________
Flange OD Min ________ /Max ________

BEARING LENGTH
Length (required): ________

FLANGE BEARING WIDTH
Width: ________

CONTACT INFORMATION

Company ________ Name ________
Phone ________ Fax ________ E-Mail ________

HOUSING AND MATERIAL INFORMATION

Sizes are required if bearing dimensions were not provided above.
Housing Size: Min ________ Max ________ Housing Material (required): ________
Shaft Size: Min ________ Max ________ Shaft Material (required): ________
Current Bearing Material: ________

ENVIRONMENT

Wet (water): ❑ Dry: ❑ Caustic: ❑ Dusty: ❑ Greased: ❑ Other: ❑ Temperature at Bearing: ________

OPERATION

RPM ________ Load Weight ________ Hours of Operation/day ________

Rotation

360° ❑ Osculating ❑ Intermittent: Yes ❑ No ❑ Frequency/Cycles ________

MANUFACTURING OPTIONS

❑ Raw Material (raw tube is supplied with additional material allowance for machining)
❑ Semi-Finished (CIP to rough turn ID/OD and machine water grooves)
❑ Finished Machined (CIP to machine complete to design)

ORDER DETAILS

CIP Material: ________ Quantity Needed: ________

CIP Only:
Raw Tube: ________
Mandrel Size: ________

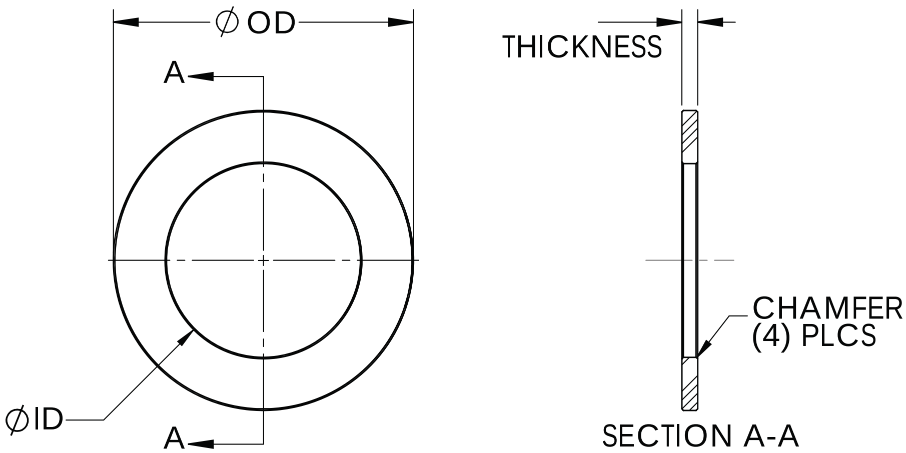
APPLICATION:

CIP Composites™
Columbia Industrial Products

Please send completed forms via
email to **sales@cipcomposites.com**
or fax to (541) 607-3657

Thrust Washer Design Worksheet

PROVIDE DETAILS IN BOX TO THE RIGHT



DIMENSIONS
Provide hardware dimensions below.
ID Min ________ /Max ________
OD Min ________ /Max ________
Thickness ____________________
Additional Notes

CONTACT INFORMATION

Company ____________________ Name ____________________
Phone ____________ Fax ____________ E-Mail ____________________

HOUSING AND MATERIAL INFORMATION

Sizes are required if dimensions were not provided above.
Housing Size: Min __________ Max __________ Housing Material (required): ____________________
Shaft Size: Min __________ Max __________ Shaft Material (required): ____________________
Current Material: ____

ENVIRONMENT

Wet (water): ❑ Dry: ❑ Caustic: ❑ Dusty: ❑ Greased: ❑ Other: ❑ Normal Operating Temperature: ______

OPERATION

RPM ______ Load Weight ______ Hours of Operation/day ______

Rotation

360° ❑ Osculating ❑ Intermittent: Yes ❑ No ❑ Frequency/Cycles ____________________

MANUFACTURING OPTIONS

❑ Raw Material (raw sheet is supplied with additional material allowance for machining)
❑ Semi-Finished (CIP to rough ID/OD)
❑ Finished Machined (CIP to machine complete to design)

ORDER DETAILS

CIP Material: ____________________ Quantity Needed: __________

CIP Only:
Raw Sheet: ____________________
Cloth Size: ____________________

APPLICATION:

23205 Rev. 00

Please send completed forms via email to **sales@cipcomposites.com** or fax to (541) 607-3657

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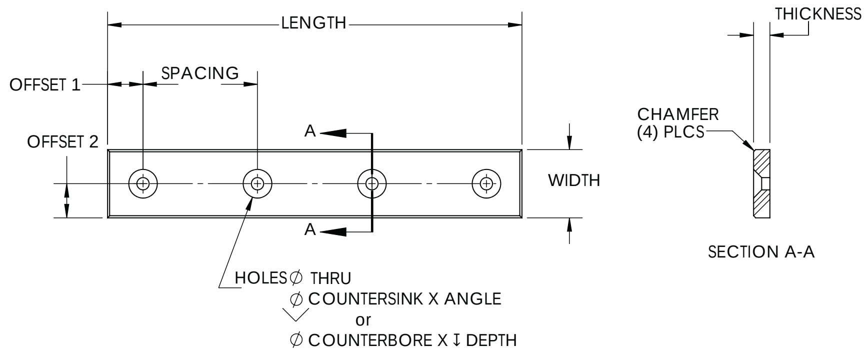
Columbia Industrial Products

Wear Pad Design Worksheet

PROVIDE DETAILS IN BOX TO THE RIGHT



DIMENSIONS
Provide hardware dimensions below.
Length Min ________ /Max ________
Width Min ________ /Max ________
Thickness Min ________ /Max ________

COUNTERSUNK HOLES
Spacing ________
Offset 1 ________ Offset 2 ________
Holes ________ X Ø ________ Thru
❑ Ø ________ Countersink X ❑ 82° ❑ 90°
❑ Ø ________ Counterbore X ↧Depth ________

CONTACT INFORMATION
Company ________ Name ________
Phone ________ Fax ________ E-Mail ________

HARDWARE INFORMATION
Mating Surface Material (required): ________
Finish: ________

ENVIRONMENT
Temperature Min. ________ Max. ________ Normal Operation ________
Pressure/Load ________ psi/lbs

LUBRICATION
Water: ❑ Grease: ❑ Oil: ❑ None: ❑

SPEED / MOTION
Linear ________ Feet/min.

MANUFACTURING OPTIONS
❑ Raw Material (raw sheet is supplied with additional material allowance for machining)
❑ Semi-Finished (CIP to rough turn machine)
❑ Finished Machined (CIP to machine complete to design)

ORDER DETAILS
CIP Material: ________ Quantity Needed: ________

CIP Only:
Raw Tube: ________
Mandrel Size: ________

APPLICATION:

One Group, One Location,
Reaching Globally

Columbia Industrial Products, Inc.
29538 Airport Rd., Unit A
Eugene, Oregon 97402
Phone: 541-607-3655
Toll Free: 888-999-1835
Fax: 541-607-3657
E-mail: sales@cipcomposites.com
www.cipcomposites.com