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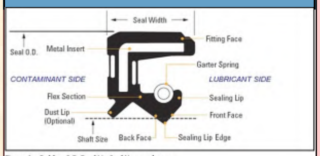

Figure 1 Rubber O.D. Dual Lip Seal Nomenclature.

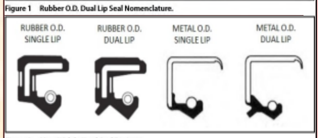

Figure 2 Most Widely Used Seal Designs.

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BEARING SEALS

To ensure that seals will perform adequately and prevent abrasives, corrosive moisture and other harmful contaminates from entering sensitive equipment, the selection of the seal elastomer compound is critical. The application parameters and external environment in which a seal will operate need to be closely considered before choosing a compound. For general industrial environments, the most widely used elastomer is nitrile, due to its excellent abrasion resistance properties. The second most common elastomer is fluoro-elastomer, preferred for its chemical and heat resistance capabilities. Although two of the most important application parameters are temperature and lubricant type, it is also important to determine if any environmental contaminants will have an adverse chemical effect on the seal elastomer compound. Chemical compatibility tables are available from most seal suppliers but provide just a general guideline. For an in-depth analysis of elastomer compatibility, be sure to consult a seal engineer.

Other application parameters that must be taken into account are shaft run-out, shaft-to-bore misalignment, shaft speed and pressure. Bear in mind these parameters may vary greatly from one application to another. While operating a seal at the extreme end of just one parameter may have a small effect on its performance, operating it at multiple extremes in a system will have a much greater impact.

The temperature limitations and general fluid/lubricant compatibility for the most common and premium seal elastomer compounds are shown in Tables 1 and 2.

Basic seal design

The most widespread seal design in use today is shown in Figure 1 which is a typical rubber O.D. dual lip seal. A garte spring is located behind that main seal lip which retains the lubricant. There is a secondary "dust lip" next to it that faces the opposite direction to exclude contaminants. The four most popular seal designs are shown in Figure 2. The main difference is the O.D. of the seal. The metal O.D. seals will provide slightly better retention in the housing bore than would the rubber O.D. seals. However, their carbon steel cases may rust depending upon the environment, while the rubber O.D. seals will not. For many standard applications the seals may be considered interchangeable. Dual-lip seal designs have the optional "dust lip" and should definitely be used in contaminated environments. All of these types of seals are available in both metric and inch sizes.

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Table 1 Most common materials and compounds for sealing elements.

Elastomer Compound	Advantages	Disadvantages/ Limitations	Temperature Range
Nitrile	Low cost. Good low temperature capability and abrasion resistance. Low swell in hydrocarbon fluids.	Does not have excellent heat resistance. Poor resistance to lubricants containing sulphur or EP additives, hydrocarbons/ oxygenate blends (gasoline/methanol). Poor ozone resistance.	-40° F to 225° F -40° C to 107° C
Polyacrylate	Resistance to EP lubricants. Higher heat capabilities than nitrile. Low swell in hydrocarbon fluids.	Limited to low temperature capability. Poor dry running capability. Subject to attack in aqueous media. Higher cost than nitrile.	-20° F to 300° F -29° C to 49° C
Silicone	Good dry heat resistance. Excellent low temperature capability. Good ozone resistance.	Easily damaged during installation. Poor chemical resistance to certain EP additives and oxidized oil. High swell, poor dry running performance. Higher cost than nitrile.	-80° F to 350° F -62° C to 176° C
Fluoro-elastomer	Excellent high temperature capabilities. Compatible with wide range of fluids. Very long life.	Poor resistance to basic (high pH>7) fluids. Attack by high-performance gear lubes. Expensive relative to other materials.	-30° F to 400° F -35° C to 204° C

Table 2 Premium materials and compounds for sealing elements.

Elastomer Compound	Advantages	Disadvantages/ Limitations	Temperature Range
Ethylene–Acrylic (Vamac®)	Higher heat capabilities than nitrile or polyacrylate. Better low temperature performance than polyacrylate. Good abrasion and dry running capability. Intermediate cost.	High swell in hydrocarbon fluids. Limited capabilities to follow eccentric shafts or perform in high–frequency applications.	–30° F to 325° F –34° C to 163° C
Tetrafluoro–Ethylene Propylene (Aflas®)	Better chemical resistance to all hydrocarbon fluids, acids, bases and oxidizing agents than fluoroelastomers. Capable of performing in the complete range of hydraulic fluids. Continuous heat resistance over 400° F. Fair dry abrasion and radiation resistance.	Poor chemical resistance to hydrocarbon/oxygenate blends (gasoline/methanol). Poor low temperature capabilities. More expense than fluoroelastomers.	–30° F to 400° F –34° C to 204° C

Composite-Steel (Hybrid) Gear

Hybrid gears have been tested consisting of metallic gear teeth and shafting connected by composite web. Both free vibration and dynamic operation tests were completed at the NASA Glenn Spur Gear Fatigue Test Facility, comparing these hybrid gears to their steel counterparts. The free vibration tests indicated that the natural frequency of the hybrid gear was approximately 800Hz lower than the steel test gear. The dynamic vibration tests were conducted at five different rotational speeds and three levels of torque in a four square test configuration. The hybrid gears were tested both as fabricated (machined, composite layup, then composite cure) and after regrinding the gear teeth to the required aerospace tolerance. The dynamic vibration tests indicated that the level of vibration for either type of gearing was sensitive to the level of load and rotational speed.

Materials play an important role in improving the power-to-weight ratio. Currently rotorcraft drive systems utilize lightweight structure materials (aluminum and magnesium) for the housing and minimize gear weight via careful analysis and machining. Generally, rotorcraft gears have only enough mass for load carrying ability. Minimizing the mass of a gear leads to a lack of heat storage capability. This attribute can cause problems during a primary lubrication system failure in which gears would operate under starved or dry conditions. Therefore all operation scenarios need to be carefully considered. Many issues were worked out to attain project success. However, cost and some other technical issues yet to be resolved have been a roadblock to incorporating this technology into production.

In addition to structural components, there have also been recent efforts to incorporate lower-density composites in dynamic components, such as shafts and gears. This report focuses on the potential application of composite material in rotorcraft drive system gears. The web of the test gear was replaced with composite material. The material properties of the composite material used in this study are compared with those of a typical aerospace gear material in Table 1. One property that is of real importance is the density. The density of the composite material used in this study is approximately 25 percent of that of typical gear steel. Also, there was an anticipated benefit expected that the material change should help with mesh-generated vibration and noise that is transmitted from the gears to the shafts and bearings.

The objective of this study is to describe how composite webbed gears (referred to here as "hybrid" gears) were fabricated and the resultant effect on the gear natural frequency, transmitted vibration, and noise.

Hybrid Gear Manufacture

The hybrid gears manufactured in this study followed the process as described (Reference 8); a brief description follows.

The test gear design used for this study has the design shown (Table 2). Figure 2 provides a pictorial explanation of the hybrid gear assembly process. A hexagonal region was machined out of a steel gear leaving two steel gear components: a gear rim with the teeth and a hub region for attachment to the facility shafting. The braided pre-preg composite material (fibrous material pre-impregnated with a particular synthetic resin used in making reinforced plastics) was built up in a fixture around the steel hub and rim as shown (Fig. 2, steps 3–8). A total of 36 layers of composite material were built up and then cured in the fixture (step 9) at a final temperature of 177°C (350°F). The fixture for fabrication and curing used the inner diameter of the hub and the gear measurement over pins in an attempt to keep the gear teeth aligned with the axis of rotation. An example of the cured gear is shown (Fig.3).

Table 1 Composite and aerospace steel material properties.

Property	Composite material	AISI 9310 gear steel
Modulus of elasticity, Pa (psi)	Tension: 44×10^9 (6.4×10^6) Compression: 42×10^9 (6.1×10^6)	200×10^9 (29×10^6)
Poisson's ratio	0.3	0.29
Density, kg/m^3 (lb/ft^3)	1800 (112)	7861 (491)
Thermal conductivity, W/m•°C (Btu/h.ft.°F)	T700 fiber-axial: 9.4 (5.43)	55 (32)
Useful maximum temperature as gear material, °C (°F)	150 (302)	175 (347)
Coefficient of thermal expansion, 10^{-6} m/m-K^{-1} (10^{-6} in/in·°F^{-1})	In plane: 2 (1.1)	13 (7.3)
Failure strain, percent	Tension: 1.9 Compression: 0.94	
Elongation, percent		15

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Table 2 Gear design for this study.

Number of teeth	42
Module, mm (Diametral pitch 1/in)	2.12 (12)
Circular pitch, mm (in.)	6.650 (0.2618)
Whole depth, mm (in.)	4.98 (0.196)
Addendum, mm (in.)	2.11 (0.083)
Chordal tooth thickness, mm (in.)	3.249 (0.1279)
Pressure angle, deg	25
Pitch diameter, mm (in.)	88.9 (3.5)
Outside diameter, mm (in.)	93.14 (3.667)
Measurement over pins, mm (in.)	93.87 (3.6956)
Pin diameter, mm (in.)	3.66 (0.144)
Backlash ref., mm (in.)	0.15 (0.006)
Tip relief, mm (in.)	0.013-0.018 (0.0005-0.0007)
All-steel gear weight, kg (lbf)	0.3799 (0.8375)
Hybrid gear weight, kg (lbf)	0.3242 (0.7147)

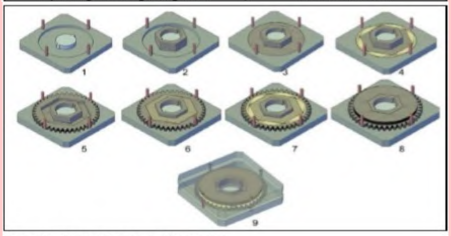

Figure 2 Hybrid gear assembly process.

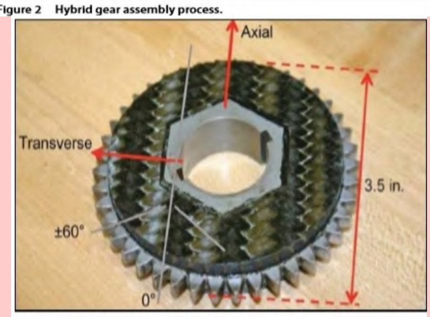

Figure 3 Assembled and cured hybrid gear.

Identifying Bearing Failure

Guy Gendron, certified bearing specialist and technical sales representative at Timken Canada L.P. explains how he used his bearing expertise to increase a customer's productivity.“Working for a bearings manufacturer, we are often asked by our distributors to visit end users who experience bearing problems, to examine them and find potential solutions. I visited a lime quarry, which had several unplanned bearing replacements, causing production interruptions. My goal was first to identify the cause of the bearings failures and identify the customer expectations, such as improving time in operation, better maintenance practice, guidance on bearing installation, etc. A lime quarry is a very harsh environment for bearings; limestone is very abrasive. I found out that the type of bearings causing production interruption were mostly spherical self-aligning double row bearings installed in split cap housing (plummer block). Several conditions were found, contamination of the lubricant due to seals wearing out from the abrasive stone, mounting procedure of the taper adapter on the spherical bearings had to be reviewed and several bearings were mounted with a RIC too tight. Several pillow blocks were installed in hard-to-reach areas, which made the bearing adjustments hard to do on site.

The end user was looking for an easy-to-install pillow block, having the load capacity for the application, with a better protection against the harsh conditions. Not requiring any structural modification on his part, in other words, being dimensionally similar to the existing Plummer block.

I was able to offer them a Spherical Roller Bearing Solid Block pillow block with the same principal dimensions as the plummer block, using the same sized spherical double-row self-aligning bearing, having features such as an extended inner race on which the seals are sitting, having the seal in contact with the inner race of the bearing versus having the seal in contact with the equipment shaft as the plummer block design improved seal life and does not damage the shaft, the Timken unit uses a triple leap self-purging urethane seal which has a ten times better resistance to abrasion versus the standard nitrile seal material, for ease of installation we use the double V-lock locking system, thus avoiding using a filler gauge to adjust the RIC and you cannot over tighten the bearing. For extra protection, we installed auxiliary covers fill with grease to create a barrier against contaminants. The installation of this type of pillow block also reduces the downtime.

In conclusion, by finding out the customer priorities, inspecting the damaged bearing to find out the reason of the failure, we were able to replace the SNL22520×37⁄16 TG with a Timken QVVPN20V307SO with cover CV20T307S. We more than tripled the life of the bearing.”

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Certified Bearing Specialist

BSA's Certified Bearing Specialist (CBS) program is the only bearing industry-specific program that identifies and quantifies the specific skill sets to certify an industry professional as a bearing specialist. The CBS program is all about developing the expertise to help customers and end users make the best bearing decisions. Take advantage of this complimentary access to a Certified Bearing Specialist. Please email your question to *info@bsahome.org*. An expert CBS will respond to your inquiry and it may appear in this article.