ADVANCING AIRCRAFT TECHNOLOGY

Materials, Engineering Capabilities, & Services Guide

Marsh Brothers Aviation

Engineer | Design | Manufacture

Contents

Materials, Engineering Capabilities, & Services Guide

Marsh Brothers Aviation

High Performance Specialty Bearings, Seals & Engineered Mechanical Components

With over 30 years of experience in the aviation industry, Marsh Brothers Aviation is revolutionizing the use of non-metallic self-lubricating bearing and polymeric sealing technology. By applying our resources, experiences and creativity, we are continually developing and innovating our bearings and sealing solutions to improve reliability and maintainability.

Marsh Brothers Aviation, a Thomson-Gordon Group company with over 100 years of history, is a family-owned business that develops and manufactures high performance specialty bearings, seals and engineered mechanical components for the aviation industry. Our products offer self-lubricating and grease-free polymer components that improve performance, increase life, significantly decrease weight and reduce maintenance downtime and costs.

Our globally recognized sister company, Thordon Bearings Inc., provides Marsh Brothers with direct access to world class Research & Development, design, engineering and manufacturing capabilities. Thordon Bearings manufactures high performance, oil - and grease-free bearing systems, seals and other shaft line products for the global marine, clean power, pump and industrial markets.

Our in-house team of engineers work closely with customers to provide innovative product solutions and designs that meet and exceed customer technical requirements. With worldwide recognition, Marsh Brothers' quality management system is consistent with the ISO9001 standard and is approved by Transport Canada under our Approved Manufacturer Certificate.

Head Office and Factory: Burlington, Ontario, Canada

Marsh Brothers Solutions for Aviation Markets

Our designs and solutions support a wide range of aviation markets, including commercial aviation, general aviation (pistons & turbo prop), regional and business jets, ground support equipment and tooling, cargo handling equipment, electric aircraft, UAV and space.

Advancing Aviation Technology

Our self-lubricating polymers are used in place of traditional metal bearings, reducing weight, as well as eliminating the need for repetitive lubrication. By reducing the amount of hydrocarbon or synthetic lubricants on your aircraft, chemical stressors entering the environment will also be reduced. As a result of incorporating Marsh Brothers self-lubricating polymers to your aircraft, lower life cycle maintenance costs will be realized.

Maintenance Free

Marsh Brothers self-lubricating bearings and polymeric seals reduce life cycle maintenance costs and improves dispatch reliability.

Longer Life

With its homogeneous construction and built-in lubrication technology, our self-lubricating polymers have demonstrated benefits of lower wear rates and longer life over traditional bearing materials.

Reduces Weight

Marsh Brothers self-lubricating polymers reduce component weight by over 80% compared to traditional metal bushings/bearings.

Zero Environmental Impact

By eliminating the need for repetitive lubrication Marsh Brothers grease-free, self-lubricating materials, provide an environmentally friendly alternative to traditional greased metal bearings.

Customized Engineered Solutions

Working with the specific needs of our customers, Marsh Brothers engineering infrastructure is capable of taking a project from design-to-specification through development and test to certification.

Product Categories

Engineered Designs

Whether it's a new design, or upgrading an existing design, Marsh Brothers' application engineers vigorously work and collaborate with our clients engineering teams ensuring the highest of quality standards are met.

Product Categories:

- Bushings & Bearings
- Seals & Wipers
- Bi-Directional Pistons

Bushings & Bearings

Bushings

Our self-lubricating polymers can be fabricated into any size non-metallic bushing—whether it be sleeve or flanged bushings or sleeve+thrust washer to replace traditional metal bushings.

We have a wide range of proprietary materials, depending on the application including AeroTough® GF, AeroLas™-White, AeroLas™-Black, AeroLas™-Grey & AeroTough®-White. Marsh Brothers grease-free bushings do not require the incorporation of lubrication provisions such as grease grooves and holes or grease fittings in the parent part.

Given the excellent dimensional stability of our self-lubricating polymers, extremely tight geometric and dimensional tolerance requirements can be achieved through conventional machining processes.

Lined Metal Bushing

Metal-backed bushings are ideal for applications with higher loads. Marsh Brothers solutions include a machinable self-lubricating polymer bonded to metal substrate (bushing shell) design. Using aerospace grade metals, such as AMS 4880 aluminum nickel bronze or high strength stainless steel as the metal substrate material – the bonded liner is then machined back to the optimal thickness, in order to meet the application needs – creating a high-strength metal-backed self-lubricating bushing eliminating the need for repetitive greasing.

Bushings & Bearings *(Continued)*

Rollers

For simple rolling applications a high-performance stainless steel is paired with a self-lubricating bearing element, eliminating the requirement to lubricate the roller. A Marsh Brothers self-lubricating roller solution can include just the roller or the entire system that consists of all the hardware necessary to install the roller mechanism.

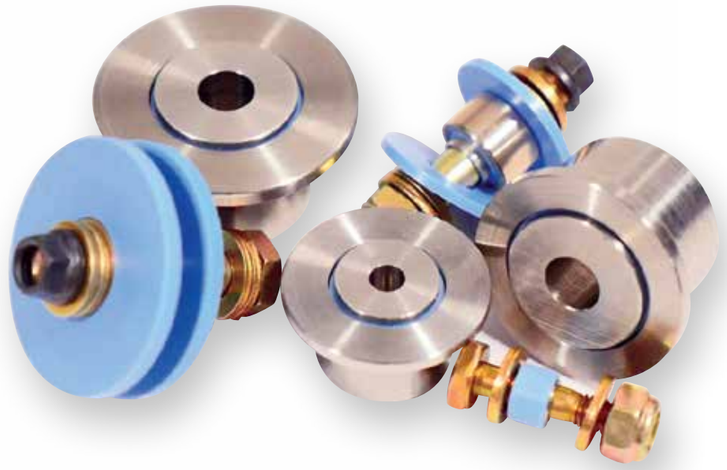
Grease-Free Roller Bearings

For more demanding rolling applications, with higher radial loads, in combination with axial loads, Marsh Brothers offers a line of grease-free roller bearing designs to replace traditional grease packed needle roller bearings. Our grease-free roller bearings can be designed with or without a flange and sized to meet your application needs. In applications where dynamic axial loads necessitate it, an AeroTough® GF thrust washer can be incorporated behind or in front of the flange to provide a self-lubricating non-metallic interface. Once installed, you'll never have to worry about lubricating the bearing again.

Landing Gear Shock Strut Oleo Bearings

The lower bearing and upper bearing of a landing gear shock strut operates under strenuous conditions – landing loads, braking loads, and ground handling loads – while maintaining long life and performance.

AeroTough® GF self-lubricating polymer is a light-weight alternative to the traditional bronze alloy oleo bearings. Due to the dimensional stability and machinability characteristics of AeroTough® GF, it can be machined to meet a wide range of requirements, including MIL-G-5514 static and dynamic seal grooves, threads for insert installation, and snubbing ports for rebound performance.



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Seals & Wipers

Thorseal is a proprietary elastomeric polymer lip seal design tailored to meet each client's unique application requirements. Our custom seal designs are analyzed using FEA (Finite Element Analysis) for the specific application parameters, and validated through testing.

The Marsh Brothers Thorseal is a self-lubricating elastomeric polymer that does not require a fluid film for lubrication. Thorseals dry-run operation makes it the seal of choice for dynamic sealing applications against high density coatings such as HVOF, and other thermal spray coatings.

Single Acting Piston Lip Seal

In a single-acting actuator application, Thorseals provide superior performance compared to typical nitrile rubber O-rings and seals.

The Thorseal design eliminates the possibility of torsional stress cracking, as well as the need for back-up rings to guard against extrusion and nibbling failure modes.

Double Acting Piston Lip Seal

In a double-acting application, two Thorseals are configured back-to-back, which can be housed in a single, wider groove or separated in two adjacent grooves. Thorseals provide superior performance when compared to typical nitrile rubber O-rings and seals. This is primarily due to the lip design that eliminates the possibility of typical torsional stress cracking, as well as the need for back-up rings to prevent extrusion and nibbling failure modes.

Seals & Wipers *(Continued)*

Piston Rod Lip Seal

Housed in the gland bearing, Marsh Brothers' rod lip seal is custom designed for this specific application. While the rod lip seal can be housed in traditional metal gland bearings, for optimal results, the best value is provided in a fully upgraded Marsh Brothers Gland System consisting of an AeroTough® GF Gland Bearing, an AeroLas™-Flex Lip Seal and a ThorWiper. The combination of a Marsh Brothers lip seal with a non-metallic bearing, eliminates the possibility of any metal-to-metal contact which can cause further damage.

Piston Rod Wiper *(Environmental Seal)*

To prevent environmental contaminants from entering the gland area, a ThorWiper must be installed. Manufactured from one of our proprietary self-lubricating elastomeric polymers and designed for this specific application, Marsh Brothers ThorWiper prevents foreign object debris (FOD) from entering the gland bearing and seal area.

Bi-Directional Pistons

In hydraulic accumulators, oleo strut floating pistons and similar applications, where two fluid/gas combinations are separated by a piston, AeroTough® GF offers a light-weight, non-metallic alternative to traditional metal pistons. Marsh Brothers' customized solutions, provide the ability to integrate a Thorseal arrangement or MIL-G-5514 standard seal groove geometry based on the client's needs.

Material Portfolio

The Highest Standards in Quality

Key Benefits:

- Low Maintenance
- Reduced Life Cycle Maintenance Costs
- Long Wear Life
- Improves Aesthetic Appearance
- Corrosion Reduction
- Eliminates Risk of Metal-to-Metal Damage

Material Portfolio:

- AeroTough® GF
- AeroTough®-White
- AeroLas™-Black
- AeroLas™-White
- AeroLas™-Grey
- AeroLas™-Flex

AeroTough® GF

AeroTough® GF is a proprietary engineered thermoplastic, designed exclusively for aviation applications to replace existing metal bushings, providing a smooth grease-free operation. AeroTough® GF does not require lubrication as it has built-in self-lubricating properties and can also run with typical aviation lubricants. AeroTough® GF offers good dimensional stability in oil and operates through a wide range of temperatures so it can be installed with tighter clearances in applications such as control surfaces and landing gear oleo struts.

AeroTough® GF is a homogeneous self-lubricating polymer, capable of withstanding operating pressures up to 65MPa (9427 psi) installed in a full form, interference-fit bearing configuration. AeroTough® GF was originally formulated for use in landing gear applications, but can be used in a wide range of aviation applications including any rotating and oscillatory joints throughout the aviation industry.

Features

- Excellent wear / abrasion resistance
- Excellent dry-run performance
- Low friction, self-lubricating, high pressure – velocity (PV) limit
- High strength and low creep
- Excellent chemical resistance to aviation fluids and compounds
- Good strength retention with increasing service temperature up to 70°C (158°F)
- Maximum continuous service temperature in oil: 80°C (176°F)
- Maximum continuous service temperature in air: 110°C (230°F)

AeroTough®-White

AeroTough®-White is a proprietary self-lubricating thermoplastic developed for use as a high-pressure bearing material for food equipment and drinking water applications where extended wear life and lubrication-free operation is desirable. With similar properties to AeroTough® GF it can also be used in cabin equipment applications where a white colour is preferred.

Features

- Maximum dynamic working pressures up to 55 MPa (7977 psi)
- Low coefficient of friction (typically 0.10-0.17)
- Very low wear in non-abrasive environments

Reasonable abrasion resistance – less than other MBA elastomer grades, but better than bronze, epoxy phenolics and many other non-metallic bearing materials.

AeroLas™-Black

AeroLas™-Black is a general-purpose self-lubricating polymer offering good performance as an interference fit bushing in applications requiring low friction, wear resistant performance in applications requiring up to 12 MPa (1740 psi) compressive strength.

When bonded to a metal substrate and machined to its optimal thickness, AeroLas™-Black offers superior compressive strength in self-lubricating metal-backed bushing applications.

Features

- Long life with low dry coefficient of friction
- Good abrasion resistance
- Low coefficient of friction (typically 0.20-0.25)
- High resistance to abrasion in dry applications
- High resistance to shock loading and vibration

Material Portfolio

The Highest Standards in Quality

Key Benefits:

- Low Maintenance
- Reduced Life Cycle Maintenance Costs
- Long Wear Life
- Improves Aesthetic Appearance
- Corrosion Reduction
- Eliminates Risk of Metal-to-Metal Damage

Material Portfolio:

- AeroTough® GF
- AeroTough®-White
- AeroLas™-Black
- AeroLas™-White
- AeroLas™-Grey
- AeroLas™-Flex

AeroLas™-White

AeroLas™-White is an elastomer, designed for moderate bearing pressure applications as a metal-backed bushing in applications requiring up to 20 MPa (2900 psi). AeroLas™-White also has applications as rub strips and anti-chafing protection in sheet form. AeroLas™-White can be produced in sheets of any thickness down to 0.020 inch (0.508mm). AeroLas™-White sheets can then be cut to suit any application via CNC routing, knife, shears, punch cut, etc.

Features

- Lower coefficient of friction (typically 0.10-0.20) compared to AeroLas™-Black
- High abrasion resistance
- High resistance to shock loading and vibration
- Very good dry-run performance

AeroLas™-Grey

AeroLas™-Grey is designed for high pressure applications either as an interference fit bushing in applications requiring up to 30 MPa (4351 psi) compressive strength, or as a metal-backed bushing, which is able to withstand high bearing pressures.

Features

- Self-lubricating
- Very good dry-run performance
- Moderately abrasion resistant
  (lower abrasion resistance than AeroLas™-Black or AeroLas™-White)
- High resistance to shock loading and vibration

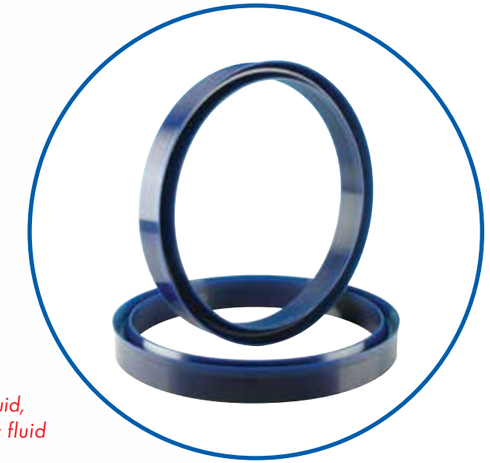
AeroLas™-Flex

AeroLas™-Flex is based on a material that was originally developed by Marsh Brothers' sister company and used for more than 20 years in various marine, industrial and hydro power applications. AeroLas™-Flex has been adapted for use in the aviation industry. Due to its inherent toughness, chemical resistance, low temperature performance and vibration energy absorption, AeroLas™-Flex is the standard for aircraft red oil systems in primary seal and piston wiper applications. AeroLas™-Flex has also been used to replace rubber in bumper applications.

Features

- Abrasion resistance
- Tough, tear and cut resistance
- Lightweight replacement for metals
- Oil & solvent resistance
- Ozone & oxidation resistance, reduced noise & improved vibration/shock absorption, low compression set
- Hardness ranges from shore 30(a) to 75(D)
- Wide array of colours
- Can be bonded to metal and other elastomers
- Temperature ranges from -60°C to 105°C (-80°F to 225°F)

Caution: *AeroLas™-Flex is not compatible with phosphate ester hydraulic fluid, commercially known as Skydrol. Exposure to phosphate ester hydraulic fluid contamination will damage seals and wipers.*



Applications

Believe in a Better Way

There are a wide variety of applications on aircraft where the benefits of Marsh Brothers self-lubricating polymers have been and can be realized; from hydro-mechanical subsystems, to cabin equipment, to ground support equipment—there is a self-lubricating polymer solution to meet your needs.

Landing Gear Systems

- Oleo Strut, Gland Bearing, Upper Bearing, Dynamic Seals & Wipers, Floating Pistons
- Bushings & Thrust Washers, Torque Links, Side Brace, Drag Brace, Other Linkages
- NWS Actuator; Pivot Bushings, Rod Ends, Glands, Dynamic Seals & Wipers

Flight Control Systems

- Structures; Bushings, Thrust Washers, Rollers, Roller Bearings
- Hydro-Mechanical Actuators; Glands, Dynamic Seals & Wipers, Rod Ends
- Electro-Mechanical Actuators; Glands, Piston Rod Wipers, Rod Ends

Actuation Systems

- LG RET/EXT Linkages; Bushings, Thrust Washers, Rollers, Bearings, Rod Ends
- Actuators; Glands, Dynamic Seals, Piston Rod Wipers, Rod Ends
- Door Hinge Linkages; Rollers, Bushings, Thrust Washers

Cabin Equipment

- High Load Hinges
- Rollers
- High Performance Rub Strips, Anti-Chafing Pads & Bumpers

Ground Support Equipment & Tooling

- High Performance Rub Strips, Anti-Chafing Pads & Bumpers
- Actuator; Glands, Dynamic Seals, Piston Rod Wipers
- Rollers, Bearings, Bushings, Thrust Washers

Cargo Handling Equipment

- High Performance Rub Strips, Anti-Chafing Pads & Bumpers
- Actuator; Glands, Dynamic Seals, Piston Rod Wipers
- Spherical Rollers, Bearings, Bushings, Thrust Washers

Other Equipment Applications

- Fuel Cap Washers
- Spinner Washers
- Seat Rollers

Engineering Capabilities & Services

Whether you're looking for an initial concept design, certified products or something in between, you can always rely on Marsh Brothers' engineering and manufacturing capabilities to meet your requirements and challenges. From design-to-specification to building-to-print—we offer extensive industry expertise in the areas of engineering design and development, prototyping, testing and certification, integrated with advanced proprietary self-lubricating polymers to provide unique and innovative solutions. When the need arises our engineering teams are capable of working collaboratively with a clients design team in the early stages of a project to assure optimized integration of our materials with the component, sub-system and vehicle systems depending on the application.

Conceptual Design and Prototyping

Marsh Brothers has the infrastructure and skilled engineering, manufacturing and aircraft maintenance technicians to progress a project from conceptual design through proof of concept following an iterative prototyping and product evolution process.

- Engineering design of aircraft components (SolidWorks®)
- Design review and evolution
- Structural analysis (FEA)
- Prototype manufacturing
- Test and validation
- Test equipment design/build

Build to Print

Marsh Brothers has the infrastructure and manufacturing capabilities to support customer needs in the area of contract manufacturing. With ePDM, ERP and integrated CAD/CAM business systems, we have the capabilities to efficiently meet your needs.

- CNC and manual turning
- CNC and manual milling
- CNC multi-axis

Are you looking to outsource manufacturing of approved product design? Contact us today.

Business Systems

With the demand for accelerated cycle times through the design, development and certification phases of projects, digital data management tools coupled with robust business processes, assures the requirements of customers are met. Marsh Brothers has the infrastructure to effectively manage data, provide traceability and assure safety throughout the entire product life cycle.

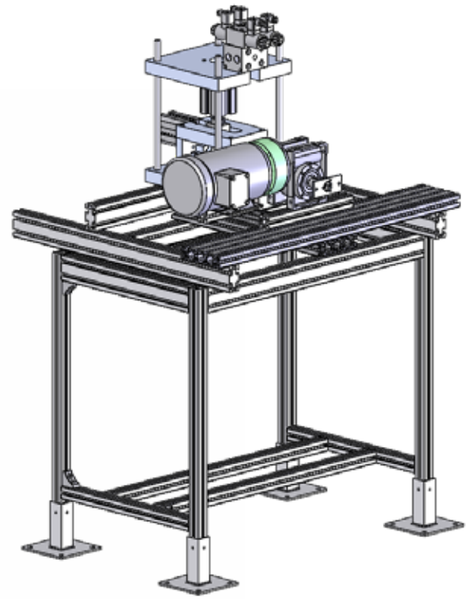
- **Enterprise Product Data Management (ePDM)**
  Assures the management of source data, engineering data and manufacturing engineering data
- **Enterprise Resource Planning (ERP)**
  Assures manufacturing configuration management, inventory management and traceability

Test Engineering

Marsh Brothers Aviation has the capability to design, build and commission test equipment in support of its development and certification activities. From initial proof of concept (developmental) functional testing, to qualification testing involving test unit and test set-up conformity witnessed by regulatory agencies, Marsh Brothers' Test Engineering Group has extensive experience and capabilities.

From simple hydro-mechanical testing involving air-spring curve characterization—load-stroke and pressure-stroke surveys over the full range of actuator cycling, and sudden extension testing to validate out stop snubbing are some of the landing gear shock strut test and evaluation capabilities within Marsh Brothers.

Marsh Brothers is also capable of designing, building and commissioning fully automated complex functional test rigs to perform endurance testing which simulate duty cycle load profiles — with closed loop PLC control modules controlling multi-axis variable load actuators and VFD drive motors.



Company Timeline

1911

Thomson-Gordon Group was established.

1991

Thomson-Gordon Group acquires Marsh Brothers Aviation.

1993

Marsh Brothers Aviation acquires Lectron Avionics.

1995

Marsh Brothers Aviation acquires Cheyenne engine upgrade STC from Jim Christy to produce the "Super Cheyenne".

1996

Marsh Brothers Aviation starts designing and manufacturing components to support the warbird collection at the Canadian Warplane Heritage Museum; including seals and bearings for landing gear and propeller regulator repair and overhaul.

1999

Operations are relocated to Burlington, Ontario in Canada.

2010

A V-35 Beech Bonanza was acquired to lead the launch of Marsh Brothers Aviation first STC project consisting of landing gear system grease-free bearings.

2014

Transport Canada approval was achieved as Marsh Brothers Aviation became an Approved Manufacturer of aeronautical products.

Transport Canada and FAA approvals were also realized for the first STC to provide grease-free bearings for the Beech, Bonanza and Baron landing gear door hinges.

2016

Achieved Transport Canada approval as an Approved Maintenance Organization.

2017

Achieved Transport Canada and FAA STC approval for the complete Aerostar aircraft landing gear (grease-free bushings, seals & hydromechanical components).

2018

Achieved Transport Canada and FAA STC approval for the non-metallic piston and lip seal design for the Aerostar aircraft hydraulic accumulator.

The 1st Full Landing Gear Upgrade kit was sold overseas to an international customer.

2020

Achieved first King Air certified product.

1990 | 2000 | 2010 | 2020

Quality

Marsh Brothers Aviation quality assurance program is consistent with the ISO9001 standard and recognized by Transport Canada under our certifications as an Approved Manufacturer and as an AMO (Approved Maintenance Organization). The US Federal Aviation Administration recognizes a Canadian AMO as equivalent to Part 145 Repair Station status. We are dedicated to the continuous improvement of our Quality Assurance Program to ensure that we continue to meet the requirements of our customers to the fullest.

Applications Engineering

Marsh Brothers Aviation engineers work closely with customers to provide innovative product solutions and designs. We maintain in-house design, CAD/CAM and proprietary design tools to correctly size custom seals. Our decades of experience enable us to offer the right technical support over the entire product lifecycle.

Research & Development

Marsh Brothers Aviation maintains extensive in-house new product development laboratory capabilities as well as established relationships with academic institutions, offering Marsh Brothers Aviation a diverse and powerful R&D resource pool.

MB Marsh Brothers Aviation

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