MAXTON

ULTRA HIGH PERFORMANCE SELF LUBRICATED
POLYMER BEARING MATERIALS

- TECHNICAL GUIDE
- DESIGN MANUAL
- WEAR TEST DATA
- PHYSICAL PROPERTIES

TRI-MACK™
PLASTICS MANUFACTURING CORPORATION

MAXTON

ULTRA HIGH PERFORMANCE SELF LUBRICATED
POLYMER BEARING MATERIALS

Table of Contents

Figures

Tables

1) Introduction to Tri-Mack

Tri-Mack was founded in 1974 by Edward J Mack, a highly respected material scientist and tribologist. From relatively small beginnings as a supplier of a few PTFE parts to a major aircraft engine maker, the company has continuously improved and expanded to become a leading supplier of highly engineered plastic components for critical applications in the aircraft, defense, medical and industrial markets.

The mission of our company is to add value to our customers products, and to make our customers more competitive by providing highly engineered solutions to our customers plastic component needs. This is accomplished through high, and constantly improving standards for mastering the science of the materials, processes, and part design that allows us at Tri-Mack -to deliver the most reliable, highest quality, and most cost effective engineered component available in the marketplace.

2) The New Maxton Material

It is with great excitement that the Tri-Mack company introduces it's breakthrough polymer friction wear material, Maxton. The new material is the result of a research discovery by the Tri-Mack R & D group. This new technology lead to the development of compounds of existing base resins with vastly improved wear characteristics. The compound technology can be applied to most available base resins. We are calling these new compounds, based on available resins, the Maxton materials. Patents are pending on the new materials.

Having been involved with the research and development of plastic friction and wear materials for over 35 years, we at Tri-Mack feel that the Maxton material is one of the most exciting breakthroughs we have seen to date in our field. Why? Because the wear characteristics of the Maxton materials are so much better than any other injection moldable wear compounds that we are aware of. In fact, in our testing, the Maxton materials have showed themselves to be orders of magnitude improvement over existing injection moldable wear compounds. The compounds have wear characteristics that are comparable to, and in some cases better than extremely expensive non injection moldable polyimides and exotic composite bearing materials.

Naturally long life and high performance is important, but what makes Maxton particularly interesting is that the cost of the material is similar to currently available higher end injection moldable wear compounds, and much less than the more exotic non injection moldable polyimides or composites. Naturally Maxton is freely injection moldable and machinable and thus lends itself to parts involving complex geometry and shapes.

While Maxton provides excellent wear characteristics across an incredibly broad range of speeds, loads, temperatures, and other application parameters, Maxton's most impressive properties are in demanding applications. Maxton can operate comfortably at speeds, loads, and temperatures that would cause catastrophic failure of currently available thermoplastic wear materials.

A further unique property of Maxton is that it is mating surface and shaft friendly. Many high performance friction and wear materials are difficult to successfully utilize against soft metal shafting or mating materials. Either the materials themselves do not function well against soft metals, or the materials tend to gall and score the soft metal mating surface. Maxton performs well against soft metals such as aluminum, bronze, and stainless steel, and won't damage soft metal mating surfaces under most conditions.

What does this mean to the end user or a product manufacturer that uses friction wear components in their products? Using Maxton friction wear components can add value to your products, and make your products more competitive by increasing the performance and life of the product and / or reducing costs.

If traditional thermoplastic bearing materials are currently being used in your products, substituting Maxton will very likely allow your product to run faster, or at higher combinations of speeds and loads and / or at higher temperatures, without significantly increasing part costs. Substituting Maxton should also allow a significantly longer life than traditional thermoplastic bearing materials.

Since Maxton offers a superior cost / performance trade off, in some cases substituting Maxton can allow a performance improvement as well as a cost reduction. In most cases where high performance non injection moldable systems are being used, such as non injection moldable polyimides, metal backed bearings, or composite or wound bearings Maxton will offer a significant cost reduction over these existing bearing systems, while offering as good or better performance.

Also, since Maxton has a significantly lower coefficient of friction than other available materials, frictional losses will be lower, and thus energy use can be reduced in a given product.

A particular area that Maxton has shown to have superior performance is in high temperature (up to 500 F) applications that also involve high speed and / or high loads. The wear characteristics of most self lubricated materials are extremely poor under these high heat high PV wear conditions. However, Maxton has proven itself to maintain it's excellent wear characteristics even under severe high heat conditions. Maxton will allow much longer wear component life, and this characteristic of the material also allows a greater margin of safety should unexpected high temperatures be encountered by your product.

Following we will outline some of the performance features of the Maxton materials, and show how these performance features can benefit a product manufacturer by making their product more competitive. We will include data from the Tri-Mack Tribology lab to back up each of the performance claims. But first we would like to present a brief overview of plastic wear theory.

3) Basic Plastic Wear Theory

Wear is a concept that is familiar to all of us, because of it's usually small, but constant presence in every day life anywhere rubbing occurs between two objects. Wear can be defined as the volumetric loss of material when this rubbing together of two surfaces occurs. The dominant component of wear in plastics is a dry sliding type wear that is called adhesive wear. Adhesive wear in plastics is governed by Archard's law, which states that the volumetric loss of material is proportional to the load and rubbing distance:

$K=WH/SF$
Where: K= Wear Factor; W=Wear, Volume; H= Hardness of Softer Material; F=Applied Load
S= Rubbing distance

The most widely used variations of this formula for plastics is as follows:
$K=W/PVT$
The units of K are $in^3min/ft/lb/hr$.
Where:
W= Loss of Material in Inches; K= the Wear Factor; P= Applied Pressure in P.S.I.
V= the Relative Speed of the Two Surfaces in FT/Min; T= Time in Hours
This equation can be rearranged to solve for wear:
$W=KPVT$

While K is called a constant, it actually varies with speed and load. The wear constant is useful for comparing the relative wear of various materials tested under identical conditions, and can be used to make preliminary predictions of the life of a plastic bearing in an end use application.. However, wear is dependant on many different variables, some of which are heavily influenced by the geometry of the test apparatus or end use application. Thus it is very important to test a chosen material in the end use application to confirm or modify material selection.

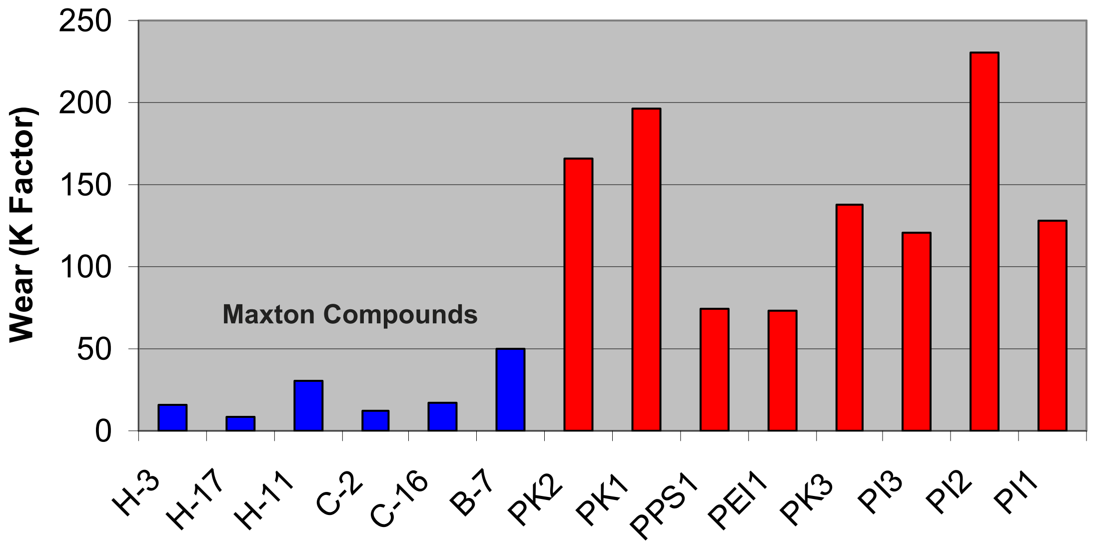
A second major concept in plastics tribology is that the frictional behavior of plastics does not always follow the classic laws of friction. First, the coefficient of friction of plastics can drop considerably as the load on it is increased. Secondly, the coefficient of static friction can actually be lower that the coefficient of dynamic friction. Also, in most cases, the friction in a plastic bearing system is proportional to the speed that the system is subject to. Lastly, for most plastics, friction generally increases as temperature increases, although it's not true for all plastics as will be seen below.

A third aspect that is important to the area of plastics friction and wear is the idea of a limiting PV or LPV. The LPV is the combination of speeds and loads where either one or all of the operating temperature, friction, and wear fail to stabilize, and increase rapidly. This leads to the ultimate failure of the bearing. In general plastic bearings are designed to operate at no more than 50 % of their LPV, for long term use.

4) Maxton Greatly Improves The Wear Life, Operating Temperature and Friction of Plastic Wear Components

To begin to illustrate the level of improvement in wear performance that the Maxton materials have over traditional thermoplastic wear compounds, we will first show the results of 10,000 PV, 100 hour room temperature wear tests conducted under identical conditions on various Maxton compounds, as well as many top commercially available wear compounds. The results are shown on the graphs below (Figures 1 to 3). Table 1 also shows a tabulation of the data from these tests. This 10 KPV wear test is a standard baseline wear test that is a good basic comparison between the relative wear performance of materials under normal operating conditions.

Figure 1: Wear (K Factor) 10K PV Room Temp 100 Hour Wear Test



Description of commercially available wear compounds

PK-1: 10% carbon fiber, 10% graphite, 10% PTFE filled polyetheretherkeytone
PK-2: 30 % carbon fiber filled polyetheretherkeytone
PK-3: 15% carbon fiber, 20 % PTFE filled polyetheretherkeytone
PI-1: 30 % carbon fiber filled injection moldable polyimide
PI-2: carbon fiber and PTFE filled injection moldable polyimide (percentages unknown)
PI-NM: graphite filled non injection moldable polyimide
PI-3: 20% PTFE filled injection moldable polyimide
PEI-1: 15% PTFE filled polyetherimide
PEI-2: 20 % carbon fiber filled polyetherimide
PPS-1: 15% PTFE filled polyphenylenesulphide

These tests clearly show Maxton's significant improvement in wear performance over commercially available compounds. Maxton has much lower wear, and could be expected to have several times the life of the competitor materials under these conditions. Maxton also clearly shows lower friction, and much, much lower operating temperatures than the competitive materials as well.

There are many potential benefits to a product manufacturer of these performance improvements. By substituting Maxton for currently available materials, your product can last longer, run cooler, and be more efficient, due to less wasted energy from frictional forces.

Note: See previous page for detailed descriptions of listed competitive wear compounds

Fig. 2 Shaft Temperature, 10 KPV Wear Test 100 Hours

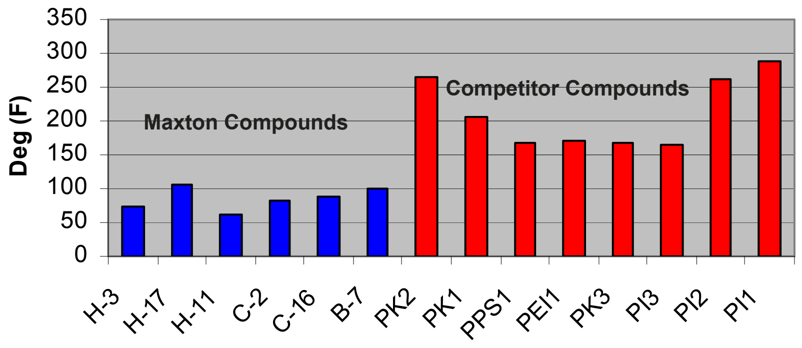


Fig. 3 Coef. of Friction 10 KPV Wear Test 100 Hours

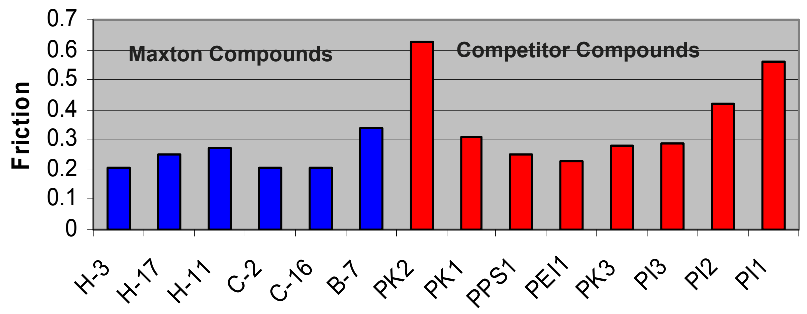


TABLE 1: WEAR, COEF. OF FRICTION, AND SHAFT TEMPERATURE OF MAXTON VS. COMMERCIALLY AVAILABLE WEAR COMPOUNDS.

Composition	Wear (K Factor)	Friction	Shaft Temp (F)
Maxton H-3	16	0.21	73
Maxton H-17	8	0.25	105
Maxton H-11	30	0.27	62
Maxton C-2	12	0.21	83
Maxton C-16	17	0.21	87
Maxton B-7	50	0.34	100
PK-2	166	0.63	265
PK-1	196	0.31	205
PPS-1	75	0.25	167
PEI-1	73	0.23	170
PK-3	138	0.28	169
PI-3	121	0.29	165
PI-2	231	0.42	262
PI-1	128	0.56	288

5) How Speed (V) Affects the Wear Properties of a Bearing System:

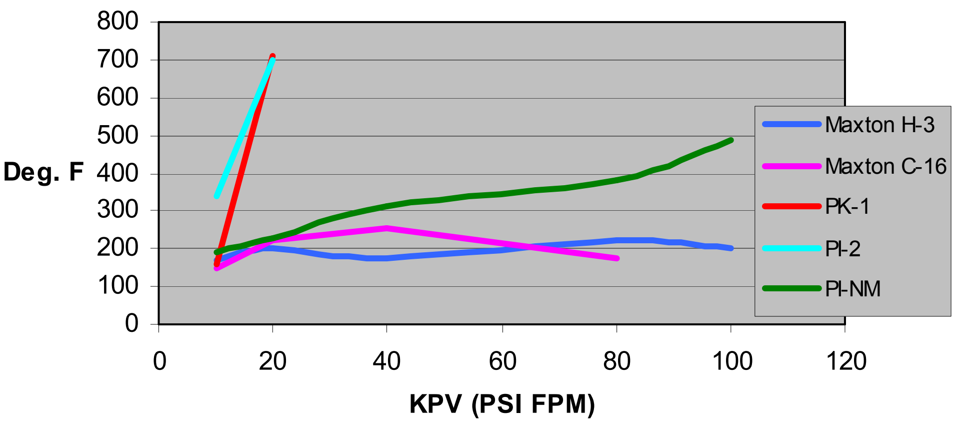
Generally, as speed increases in plastic bearing systems, wear factor (K) also increases significantly. With most plastics, coefficient of friction also generally increases as system speed increases. This generates increased amounts of heat in the bearing. This effect tends to compound, since the coefficient of friction also generally increases as temperature increases. The ability of a plane bearing to operate at high speeds is heavily dependant on it's ability to transmit the generated heat away from the bearing surface. This ability, in turn, is highly dependant on the thermal conductivity of the bearing material, and design considerations, such as the wall thickness of the bearing.

6) Maxton Vastly Increases the High Speed Capability of Injection moldable Bearing Materials:

The speed range of polymer wear materials was significantly increased with the introduction of higher temperature base resins such as PEEK, PPS, and PAI, especially those filled with carbon fiber or aramid fiber combined with other solid lubricants. While improved, the speed range of these materials is still a fraction of the high speed capabilities of more exotic materials, such as non injection moldable polyimides, and other composites. The new Maxton material from Tri-Mack has changed that, and allows performance levels that were previously only available in expensive exotic non injection moldable materials in lower cost injection moldable compounds.

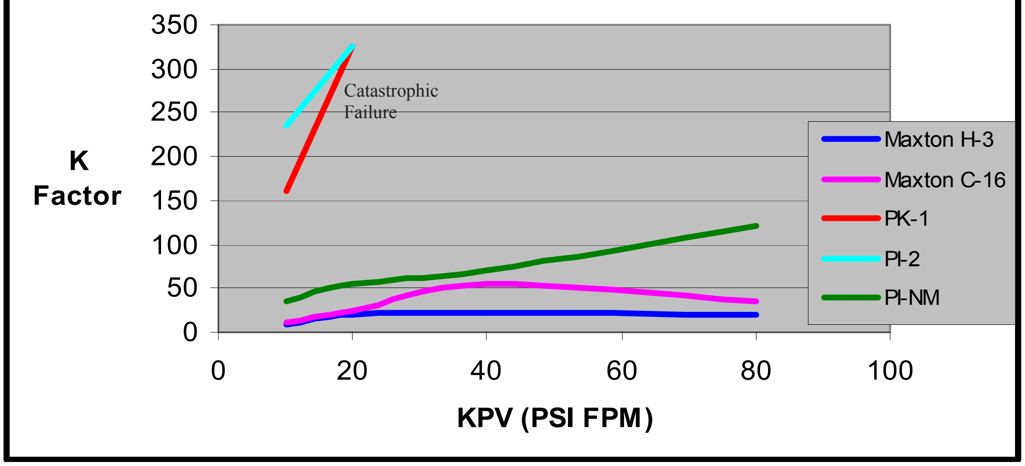
A unique property of the Maxton material is that it maintains very low wear, low operating temperatures and low friction, even if used at speeds that would cause failure due to melting of most injection moldable bearing materials. This characteristic is illustrated in the adjacent graphs, figures 4 through 6. These graphs show the results of individual 100 hour wear tests of the given materials with load held constant at 200 PSI, and speeds ranging from 50 FPM (10,000 PV) to 500 FPM (100,000PV). Two Maxton variants are tested, H-3 and C-16 against three of the best known commercially available plastic wear materials, a peek wear compound, (PK-1), an injection moldable polyimide (PI-2), and a well known high performance non injection moldable polyimide. (**For a detailed description of the competitive materials, see chart on page 4.)** The results for total wear as calculated from weight loss, average shaft temperature during the test, and average friction are shown for each of the tested materials on the adjacent figures (Fig.s 4-6):

Fig. 4 Average Shaft Temp (F) Increasing PV Individual Wear Tests (Constant 200 PSI, Increasing Speed, Room Temp.)



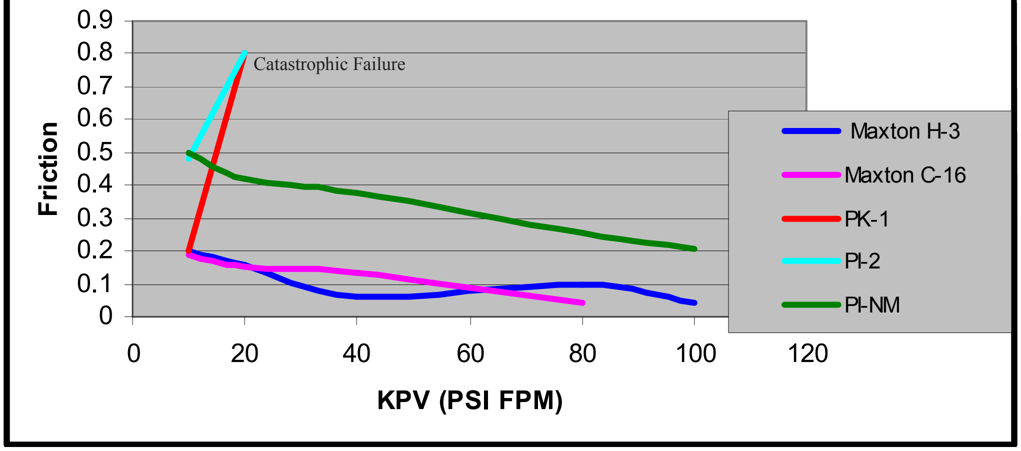
Maxton demonstrates wear characteristics in these tests that are a significant improvement from traditional plastic wear materials. First, the K factor does not increase as speed and PV are increased. Second, the coefficient of

Fig. 5 Wear (K Factor), Increasing PV Individual Wear Tests (Constant 200 PSI, Increasing Speed, Room Temp.)



For a detailed description of the competitive materials, see chart on page 4.

Fig. 6 Average Coef. of Friction, Increasing PV Individual Wear Tests (Constant 200 PSI, Increasing Speed, Room Temp.)



friction likewise does not increase with increasing speed. Also, temperatures stay very low throughout the test. Lastly, the PV capability of the material is extremely high, it is not reached in this test, as the machine is limited to 100 KPV.

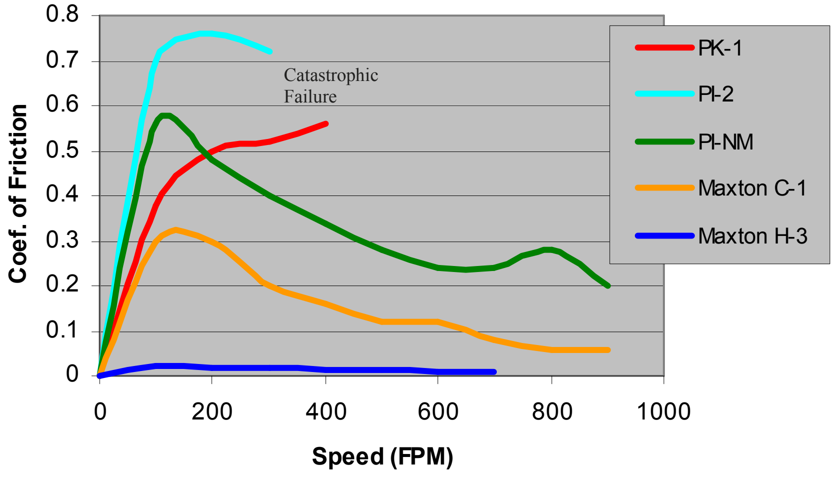
This data is just a small sample of a large amount of test data that which has been compiled by Tri-Mack that shows that Maxton can operate at much higher speeds than any other known injection moldable material. Maxton also manages heat much more efficiently than the competitors, and maintains a low operating temperature up to and beyond 1000 FPM. Frictional forces are also low, and actually decrease as speed increases. Only the expensive and non injection moldable polyimide shown can be considered to be in the same class as the Maxton material when it comes to high surface speed applications.

One very significant quality of the Maxton material, that can be important in many applications is the very low coefficient of friction that the material shows across a broad range of speeds and loads. Other injection moldable materials have a low coefficient of friction at low speeds and loads, but their friction increases greatly as speeds and loads are increased. The non injection moldable polymide has a high coef. of friction at low speeds and loads, which decreases as the speeds and loads increase. Only Maxton has a low coef. Of friction across the broad range of speeds and loads. This will result in lower power requirements and greater efficiency in any product.

7) Maxton Vastly Improves Limiting PV At High Speeds

In addition to high speed wear testing, the effects of sliding speed on wear properties can be observed by utilizing a limiting PV test, with a constant load and increasing velocity. The results of such a test including the Maxton material and several competitors are shown below (fig.s 7 and 8). Load is held at a constant 100 psi, and speed is increased in 100 fpm increments every 30 minutes until the PV limit, which is characterized as the point where wear, friction, and temperature fail to stabilize is reached.

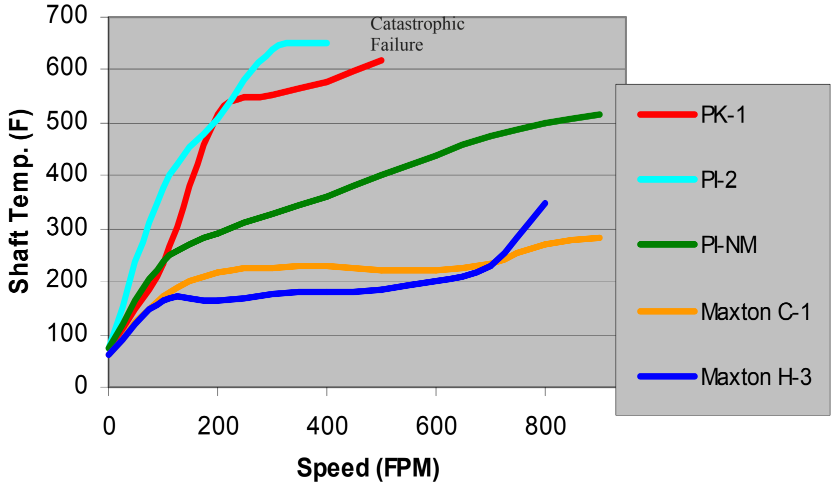
Fig. 7 Coef. of Friction, Limiting PV Test, 100 PSI, Increasing Speed, Room Temperature



For a detailed description of the competitive materials, see chart on page 4.

This test shows Maxton's remarkable high speed wear properties, particularly how very low and stable the friction and temperature remain throughout the test. The competitive injection moldable materials show rapidly increasing temperature and friction, and reach their PV limits typically in the 30 KPV to 40 KPV range on this equipment. The expensive non injection moldable polyimide material performs well in this test, however, it shows consistently higher operating temperature and friction than the Maxton materials. The Maxton materials however, show low and stable friction and temperature as speeds are increased. The Maxton materials generate much lower temperatures than the competitor materials, and is well within it's operating range at 1000 FPM. The PV limit of the Maxton material is well beyond the maximum speed (1000 FPM, 100,000 PV) of this equipment.

Fig. 8 Shaft Temperature, Limiting PV Test, 100 PSI, Increasing Speed, Room Temperature



An interesting characteristic of the Maxton and non injection moldable polyimide materials is that they exhibit decreasing coefficient of friction as speed is increased. This is not true of the lower performance injection moldable competitors.

8) Maxton Proves To Have Superb High Load Wear Performance

Good high load performance in a plastic bearing material depends on the wear material having high compressive strength, high compressive modulus, and low creep. Fortunately, Maxton excels at all of these properties and also has superb high load frictional characteristics and other beneficial properties that allow it to excel under high load conditions.

The high load wear capabilities of Maxton are illustrated in the following chart of high load wear tests Table 2). This is a 50,000 PV room temperature wear test; the pressure is 2000 psi, the speed is 25 fpm. The test duration is 24 hours. No other competitive material can survive at these high load conditions. Maxton easily operates at these 50,000 PV high load conditions, and shows low temperature, very low wear and low friction. Maxton also strongly exhibit's a desirable property of some plastics, that the coefficient of friction drops dramatically as the load on the system is increased.

TABLE 2: HIGH LOAD, LOW SPEED WEAR TESTS, MAXTON VS. COMMERCIAL COMPOUNDS LOAD = 2000 PSI, SPEED = 25 FPM, 24 HOURS, ROOM TEMPERATURE.

COMPOSITION	WEAR (k)	SHAFT TEMP (F)	COEF OF FRICTION
MAXTON H-3 (trial 1)	20	180	0.09
MAXTON H-3 (trial 2)	20	250	0.1
MAXTON H-3 (trial 3)	11	180	0.16
PEI-2	FAILED	FAILED	FAILED
PK-1	FAILED	FAILED	FAILED
PK-2	FAILED	FAILED	FAILED
PPS-2	FAILED	FAILED	FAILED

Description of commercially available wear compounds

PK-1: 10% carbon fiber, 10% graphite, 10% PTFE filled Polyetheretherkeytone
PK-2: 30 % carbon fiber filled Polyetheretherkeytone
PK-3: 15% carbon fiber, 20 % PTFE filled Polyetheretherkeytone
PI-1: 30 % carbon fiber filled injection moldable Polyimide
PI-2: carbon fiber and PTFE filled injection moldable Polyimide (percentages unknown)
PI-3: 20% PTFE filled injection moldable Polyimide
PI-NM: graphite filled non injection moldable polyimide
PEI-1: 15% PTFE filled Polyetherimide
PEI-2: 20 % carbon fiber filled Polyetherimide
PPS-2: 30% PTFE filled Polyphenelynesulphide

9) Maxton Excels at High Temperatures

The designer of plastic bearings and wear components should be aware of the temperatures that the bearing system will be exposed to. This is due to the fact that like the physical properties of plastic materials, the wear properties of many plastic materials tend to deteriorate seriously with temperature. Even well below their heat deflection temperature and highest continuous use temperature range, the wear life of many plastics can be ½ to ¼ their life at room temperature, or even worse. When high temperatures are combined with high loads, the wear performance can be further worsened, due to plastics tendency to creep, a phenomenon that also is temperature dependant. Fortunately, Maxton provides a solution to this long term issue affecting the use of plastic friction and wear materials. Maxton has shown to have high temperature wear properties that are far superior to any other injection moldable material.

The tables 3 and 4 below show some of Maxton's excellent high temperature wear properties. The first (Table 3) shows wear tests of Maxton vs. some commercially available materials at relatively high load (400 psi) and low speed (50 ft/min) (20,000 PV) at 500 F. Table 4 shows the same materials wear tested at the same speed and load, but with the temperature increased to 550 F. No other injection moldable material was able to survive this test, which Maxton is able to handle with minimal wear. Maxton shows wear that is lower than that of non injection moldable polyimide, which showed other signs of distress during the test, such as squealing, and becoming loose in the holder during the test, indicating shrinkage due to excess heat

TABLE 3: BEARING WEAR OF MAXTON COMPOUNDS AFTER 4 HRS. AT 550° F AND PV OF 20,000 (P=400 PSI; V=50 ft/min).

COMPOSITION	WEAR (.001")	CONDITION OF BEARING
H-12	1	NO SHRINKAGE
H-3	2.5	EXCELLENT COND.
H-2	2	V.GOOD EXCEPT TIGHT IN SHAFT
PI-NM	6	AFTER 1 HR EXTREMELY NOISY VERY LOOSE IN HOLDER EXCESS WEAR .006"

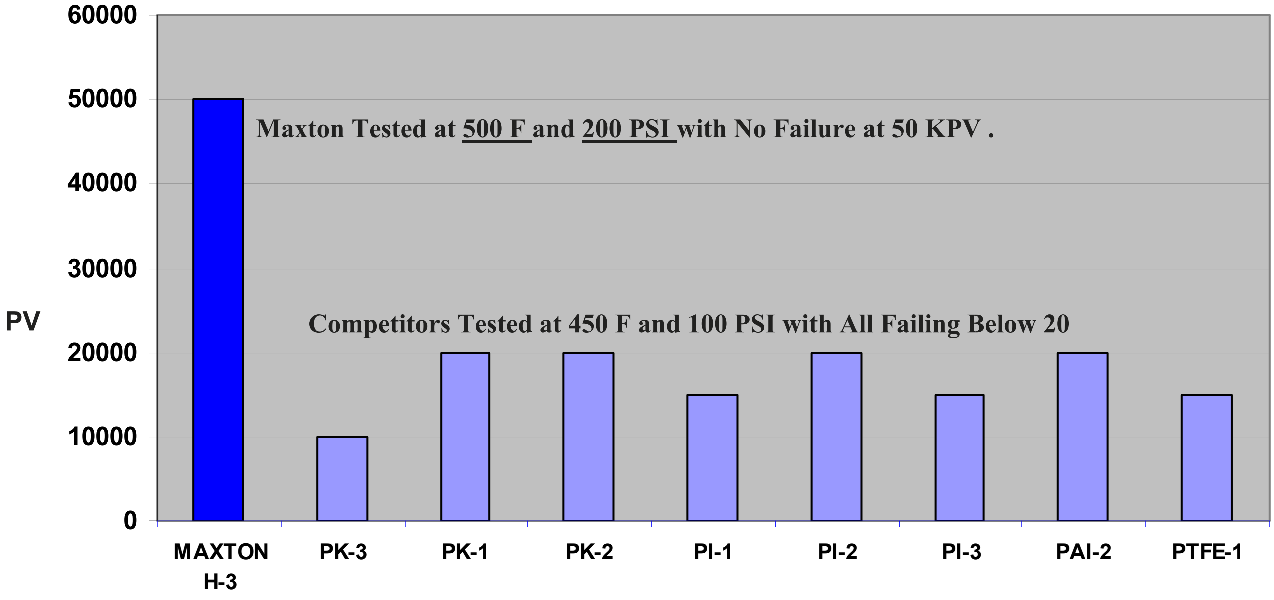
TABLE 4: BEARING WEAR OF MAXTON COMPOUNDS AFTER 4 HRS. AT 550° F AND PV OF 20,000.(P=400 PSI; V=50 ft/min).

COMPOSITION	WEAR (.001")	CONDITION OF BEARING
H-12	1.5	NO SHRINKAGE
H-2	1	EXCELLENT COND.
H-3	2	EXCELLENT COND.
H-3	2.6	EXCELLENT COND.

10) Maxton Improves Limiting PV at High Temperature:

Like the wear factor, limiting PV values for many plastic wear materials can deteriorate dramatically when high temperatures are encountered. Maxton, however retains much of it's PV capability, even at high temperatures, and at high loads. The following Tables 5 through 7 and graph (fig.9) show a series of three high temperature limiting PV tests. The first is Temp= 450 F, P=100 psi, and increasing velocity, summarized in table 5. The second test conditions are P=200 psi, Temp = 450 F and increasing speed, shown in table 6. Lastly, Temp = 500 F, P=200 psi, and increasing speed, shown in table 7. The bar graph, figure 9, summarizes the results of the three tests. At 450 F and P=100 psi, the Maxton material, and also the non injection moldable polyimide material maxed out the machine without failing (25 KPV). All of the injection moldable competitors failed at between 10 KPV and 20 KPV in this severe test. The Maxton material was tested again at 500 F, and 50 KPV and again maxed out the machine without reaching it's PV limit.

Fig. 9: PV Limits of Maxton Vs. Commercial Compounds at High Temperatures (450 F @ 100 PSI and Increasing Velocity)



Description of commercially available wear compounds

PK-1: 10% carbon fiber, 10% graphite, 10% PTFE filled Polyetheretherkeytone
PK-2: 30 % carbon fiber filled Polyetheretherkeytone
PK-3: 15% carbon fiber, 20 % PTFE filled Polyetheretherkeytone
PI-1: 30 % carbon fiber filled injection moldable Polyimide
PI-2: carbon fiber and PTFE filled injection moldable Polyimide (percentages unknown)
PI-3: 20% PTFE filled injection moldable Polyimide
PI-NM: graphite filled non injection moldable polyimide
PEI-1: 15% PTFE filled Polyetherimide
PEI-2: 20 % carbon fiber filled Polyetherimide
PPS-2: 30% PTFE filled Polyphenelynesulphide
PAI 2: 20 % graphite and 3 % PTFE filled PTFE
PTFE-1" PTFE/BR/MOS2 55/30/15

TABLE 5: LIMITING PV’S OF MAXTON VS. COMMERCIAL COMPOUNDS (450 F @ 100 PSI WITH VELOCITY INCREASED EVERY 30 MINUTES)

COMPOUNDS	LIMITING PV	CONDITION OF BEARING	COMMENTS
MAXTON H-3	25000+ (1)	EXCELLENT	
PK-3	10000	MELTED	
PK-1	20000	MELTED	
PK-2	20000	MELTED	
MAXTON J-3	25000+ (1)	EXCELLENT	SHRINKAGE
PI-1	15000	MELTED	
PI-2	20000	MELTED	BAD VIBRATIONS
PI-3	15000	MELTED	BAD VIBRATIONS
PAI-1	20000	MELTED	BAD VIBRATIONS
PAI-2	15000	MELTED	BAD VIBRATIONS
PTFE-1	15000	DEFORMED	BAD VIBRATIONS
PI-NM	25000+ (1)	EXCELLENT	

TABLE 6: LIMITING PV’S OF MAXTON VS. COMMERCIAL COMPOUNDS (450 F @ 200 PSI WITH VELOCITY INCREASED EVERY 30 MINUTES)

Compound	Limiting PV	Velocity (FPM)	Condition of Bearing	Total Wear (001”)	Comments
Maxton H-1	25,000+	125	Some Creep	1	
Maxton H-3	25,000+	125	Some Creep	1	
PI-NM	25,000+	125	Excellent	2	Shrinkage in OD

+ indicates that the LPV was not reached, at the highest PV capability of the test machine

TABLE 7: LIMITING PV’S OF MAXTON VS. COMMERCIAL COMPOUNDS (500 F @ 200 PSI WITH VELOCITY INCREASED EVERY 30 MINUTES)

Compound	Limiting	Velocity	Condition	Total Wear	Comments
	PV	(FPM)	of Bearing	(.001”)	
Maxton H-3	50,000	250	Some Creep		Bearing tight on shaft.
Maxton H-12	50,000+	250	Excellent	1.2	No Change

11) Maxton Vastly Improves The Wear of Plastics Against Soft Metals:

Traditionally, somewhat of a difficulty is encountered when using plastic bearing materials against soft metal bearing surfaces or shafting such as those made of stainless steel, aluminum, or bronze. In general, plastic bearing materials prefer a harder mating surface and, broadly speaking, the harder the mating surface, the lower will be the wear of the plastic wear component. Thus soft metal mating surfaces generally result in high plastic bearing wear. A further difficulty regarding soft metal facing materials is that they themselves can tend to wear quite badly, and become galled and scored during use with plastic bearings.

These problems with soft metal facing surfaces are made worse in the realm of high performance friction and wear, where high temperature, high speeds and high loads are common. Some high performance materials do not work well at all with soft mating materials, and heavy wear of the bearing and the mating material can be expected.. Many, such as carbon fiber or glass fiber filled thermoplastic compounds can exhibit low wear themselves, but are very tough on the soft metal mating surface, due to the abrasiveness of the fibers, and thus are not generally a good solution. Aramid fiber and PTFE filled compounds have been reported to have low wear against soft metals, but these compounds have limited PV capability, due to their inability to conduct heat well, these materials can also be difficult to machine to tight tolerances. Also carbon bearings are popular for high heat and underwater applications, however, they cannot be used with soft metal mating surfaces at all, and generally require a hardened steel counter face surface.

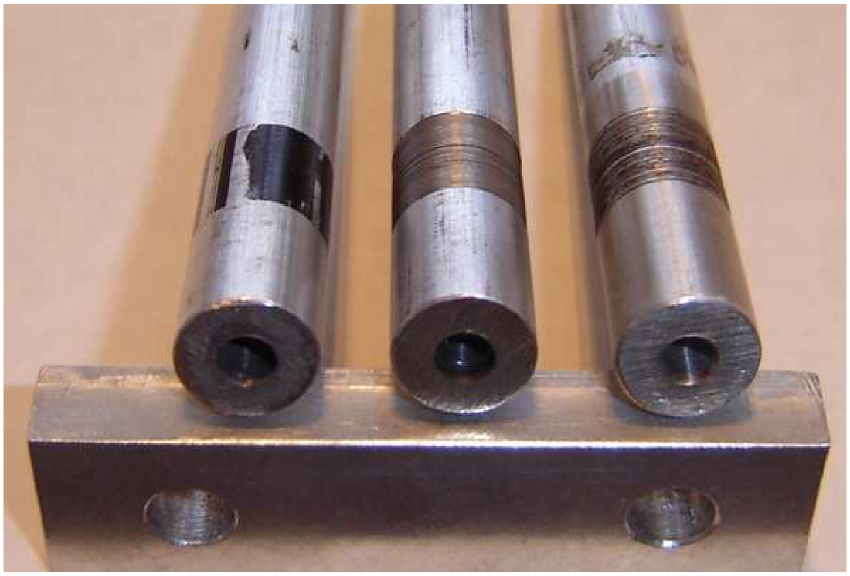
Thus Maxton is unique in it's ability to deliver low wear and high PV capability when run against soft metals, and to be extremely friendly to the soft metal mating surfaces themselves. The reason for this is that the reinforcing system and lubricants that make up the Maxton system are non abrasive, and lend themselves extremely well to developing a transfer film on the soft metal mating surface. This film development is a well know phenomenon in plastic friction and wear, however, many bearing compounds will not transfer a film to soft metals.

TABLE 8: BEARING WEAR TEST OF MAXTON VS. COMMERCIAL COMPOUNDS AGAINST BEARING BRONZE (ALLOY 932) 316 STAINLESS STEEL, 6061 ALUMINUM, RUN AT 10,000 PV (100 PSI X 100 FPM).

	Stainless Steel Shaft			Bronze Shaft		
	Hrs.	Wear	Cond. Of	Hrs.	Wear	Cond. Of
Materials	tested	(K-Factor)	Shaft	tested	(K-Factor)	Shaft
Maxton H-3	100	22	OK	100	12	OK
Maxton B-3	100	43	OK	100	16	OK
Maxton H-1	112	78	OK	124	15	OK
PPS-3	101	54	SCORED	0.5	10	BADLY SCORED
PI-NM	100	213	SLIGHTLYSCORED	101	166	SLIGHTLY SCORED
PK-4	-	-	-	-	-	-

In addition to not damaging it's mating surface, Maxton also retains it's excellent wear capabilities when run against soft metals, exhibiting extremely low wear and high PV capabilities. Test results showing the wear properties of Maxton vs. other available compounds, tested against Aluminum, Stainless Steel, and Bronze Shafts are detailed in table 8.

The adjacent photograph shows the advantages that Maxton has over commercially available materials when used against soft metal facing surfaces. This photograph shows three Aluminum test shafts tested according to the 10 KPV conditions in table 8. The shaft on the left was tested with a Maxton bearing, the center and right shafts were tested with bearings made from competitive plastic self lubricated materials. Maxton has developed a significant transfer layer, and has not damaged the soft aluminum shaft. The competitor materials have badly scored their shafts, and have not left a transfer layer.



	Aluminum Shaft		
	Hrs.	**Wear**	**Cond. Of**
	tested	**(K-Factor)**	**Shaft**
	100	22	OK
	-	-	-
	-	-	-
	3	-	BADLY SCORED
	104	162	BADLY SCORED
	75	-	BADLY SCORED

TABLE 9: TYPICAL MAXTON PHYSICAL PROPERTIES.

Properties	Maxton H-3	Maxton C-1	Maxton C-16
Specific Gravity $^{(1)}$ (grams/cc)	1.61	1.54	1.69
Tensile Strength at Break (PSI)$^{(2)}$	17,800	11,700	18,200
Elongation $^{(2)}$	<1%	<1%	<1%
Flexural Strength $^{(3)}$ (PSI)	26,400	16,400	27,800
Flexural Modulus $^{(3)}$ (PSI x 10^6)	3.9	2.16	5.35
Thermal Conductivity (W/ MK)$^{(4)}$	2.9	2.1	3.1
Notched Izod (ft lbs./in) $^{(5)}$	0.56	0.67	0.41
Unnotched Izod (Ftlbs/in) $^{(5)}$	2.79	1.9	1.57

1) ASTM Test Method D792
2)ASTM Test Method D638-98
5) ASTM Test Method D256-00
3) ASTM Test Method D790-98
4) Mathis

12) Physical Properties

Table 9, above, contains the physical properties of three typical Maxton compounds. In General, the Maxton compounds are characterized by high strength, high tensile and flexural modulus, and high thermal conductivity. These physical characteristics are ideal for optimal friction and wear performance in a plastic compound.

13) Available Maxton Compounds

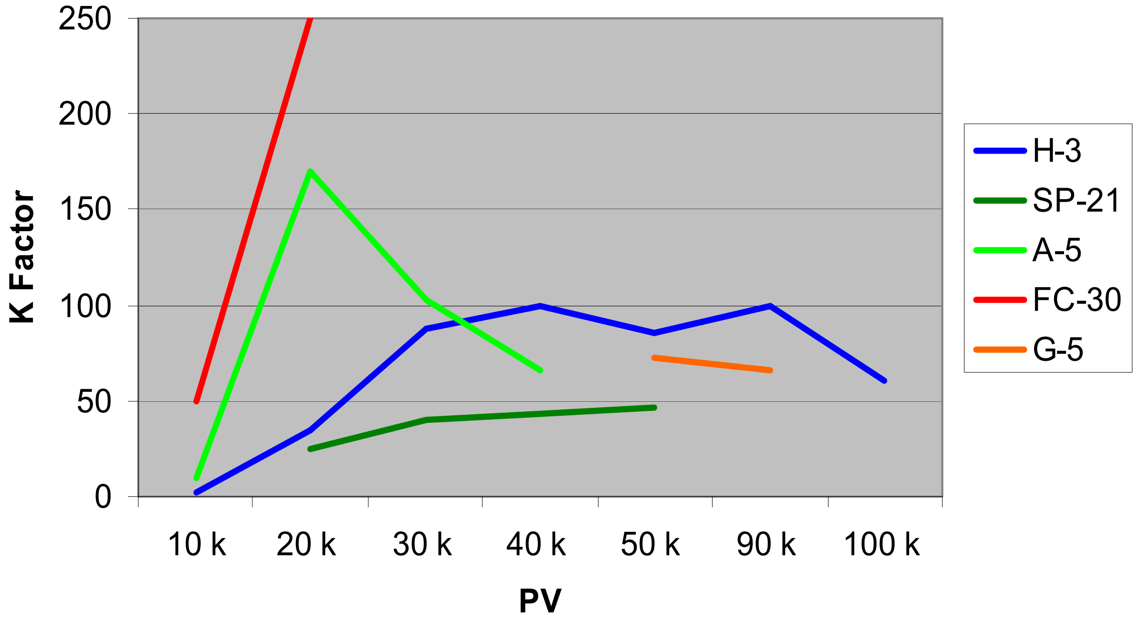
During the development of the Maxton material, many different variants and compounds of Maxton were formulated and tested. Data from many of these formulations are presented here for illustrative purposes only. Because the differences between many of these compounds are subtle, and many of the properties overlap, not all of the compounds presented here will be commercially available. Initially, one compound that offer the best overall combination of properties versus costs will be offered, H-3. Additional compounds will be added as market need develop. Following is a brief description of this compound:

Maxton H-3: Excels in all areas of friction and wear. Very low friction, operating temperatures and wear in all conditions. Superb high speed, high load, and high temperature performance. High strength, and excellent chemical and steam resistance. Easily injection moldable and machinable. The best performing injection moldable wear material known to Tri-Mack today.

14) Thrust Washer Tests:

All of the test results presented elsewhere in this brochure were generated from various types of journal bearing testers. The Maxton material also excels when tested with other types of test equipment, such as the ASTM 3702 thrust washer tester. Below is a graph (Fig. 10) showing the results of thrust washer wear tests at increasing PV of several Maxton formulations, a popular commercial injection moldable compound, and a non injection moldable polyimide. The commercial PEEK compound shows poor wear in this test. The Maxton materials show low wear, and performance that is comparable to the non injection moldable polyimide material

FIG. 10: WEAR RESULTS (K FACTOR) INDIVIDUAL ASTM 3702 THRUST WASHER TESTS AT INCREASING PV (ROOM TEMP.).



Disclaimer:
To the best of our knowledge, all the information in this brochure is accurate. However, Tri-Mack assumes no responsibility or liability for the accuracy or use of the information. In all cases, we strongly recommend that prototype testing be done.

15) Commercial Applications of Maxton

Because the wear properties of the Maxton material are such a large improvement over the current state of the art, the potential commercial applications of the material are many. Because of Maxton's superb high speed and high PV capability, Maxton will can be used in many PV intense applications, such as electric motor bearings, blower bearings, pump components, air tool vanes and air tool components, and vacuum pump and gas compressor vanes. For example, Maxton is the only plastic bearing material that we are aware of that can replace carbon graphite in high speed rotary vacuum pump vanes. Since Maxton can be used lubricated or non lubricated, Maxton will excel in high PV applications where lubrication is limited or impossible.

An area of particular interest is high speed non lubricated journal bearings, such as for air tools, motors, or anywhere a shaft is turning at high speeds.

Maxton also excels in high temperature, high load applications, such as chain bushings, conveyor oven components, and tentor components. Maxton also excels in high load room temperature applications, such as off road equipment bushings, air frame and engine bushings, pivot bushings in machinery, etc.

Since Maxton excels against soft metals, it will work well in high PV applications where soft metals must be used. Such applications as stainless steel medical and dental equipment, such as air motors, dental drills, etc fall in this category.

Naturally, since Maxton is readily injection moldable, it can replace non injection moldable materials, in areas that require high PV capability and complex geometry such as seals, piston rings, pump components, etc. The cost advantages of injection molding, coupled with the design flexibility to allow molded in features, such as snaps, combined with the lower material cost of Maxton, will allow significant cost savings over non injection moldable materials, with the same or better life and performance.

At this time Tri-Mack Plans to supply finished custom components in the Maxton material, or in some cases blanks for finish machining. There are no plans in place at this time to sell the material in pellet form.

For additional information regarding Maxton, or for assistance evaluating a possible application of the material, please contact Tri-Mack:

Tri-Mack Plastics Manufacturing Corp.
66 Tupelo St.
Bristol RI 02809
401 253 2140 (Phone)
401 253 4654 (Fax)
www.trimackplastics.com