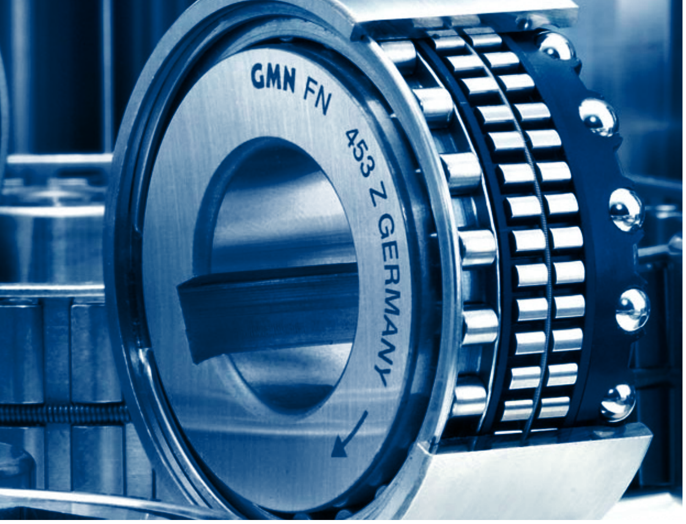

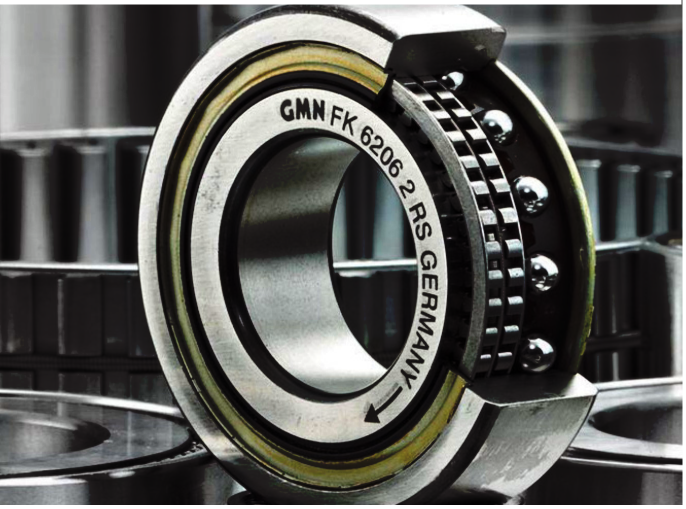

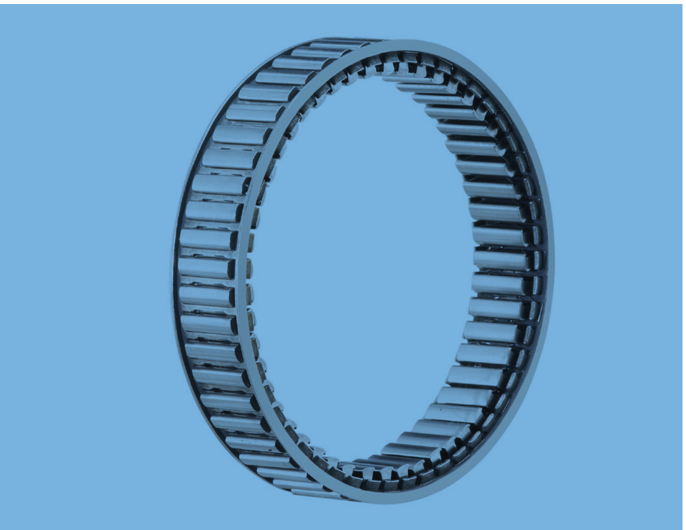

GMN
BEARING USA

Sprag Clutch Guide

Introduction

At GMN Bearing USA, we're here to help you get the information you need fast, no matter where you are in your knowledge journey or your engineering project.

This Sprag Clutch Guide is designed to provide everything you need to know about clutches—what they are, what they do, how they are used. We've dissected each of the nuanced functions, theories and application types for sprag clutches, creating this practical, all-in-one reference tool.

This guide provides a general understanding of sprag clutches. GMN Bearing USA in-house engineers are happy to answer any of your questions and better learn how we can support your clutch needs. You can reach us at 800-323-5725, **www.gmnbt.com**.

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Sprag Clutch 101

WHAT IS A SPRAG CLUTCH?

A sprag clutch goes by many names: One-way bearing, freewheel clutch, cam clutch, overrunning clutch. Whatever you call it, sprag clutches are a critical mechanical device in many heavy industrial applications—from automatic transmissions to torque converters, industrial winches to helicopter rotors.

HOW IT WORKS

Sprag clutches are designed to transfer torque in one relative direction, referred to as the "engaged direction," and to disengage—or "freewheel"—in the other direction. That means in the engaged direction, there is no relative rotation allowed between the two components connected by the sprag clutch. Both components rotate at the same rate and that rotation is dictated by the driving component. In the disengaged direction, the two components are free to rotate at different rates and directions as long as the driving component doesn't attempt to over rotate the driven component in the engaged direction.

The core component to these clutches are the sprags. The sprags themselves are larger than the gap between surfaces that they operate against. The sprags have curved surfaces on the top and bottom called the engagement surfaces and use a spring to keep them in constant contact with the operating surfaces. When the clutch is in the freewheeling state the sprags slip against the operating surfaces of the two components because the relative rotation is in the direction that causes the sprags to want to lay over.

When that relative rotation changes, the driving component causes the sprags to stand up in the gap and engage on their engagement surfaces. As they engage, they press into the operating surfaces elastically deforming the surfaces. As the torque increases, the level of engagement and elastic deformation increases until an equilibrium is met. At that point, the torque is transferred through the clutch and the driving component causes the driven component to rotate at the same speed as one connected unit. This is maintained until the relative rotation is changed again and the sprags disengage.

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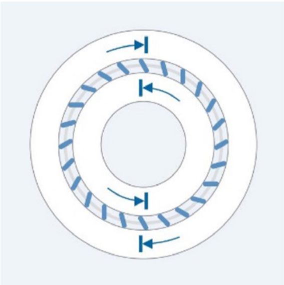
Sprag Clutch Applications

Backstopping Clutch



Sprag Clutch Clamping

A **backstop clutch** is commonly used for safety precautions.

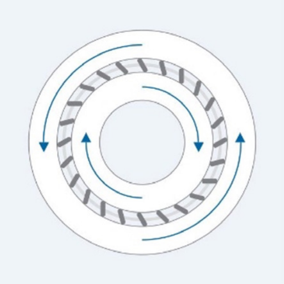
If a machine malfunctions, the backstopping clutch is designed to hold the load it's carrying. A good example is an industrial winch. When it's lifting and moving a heavy object, it needs to hold that object until it's ready to be lowered. A winch clutch is an important component located inside the winch that locks the motor shaft to the brake assembly preventing the spool from unwinding when the motor stops.

GMN FE 8000 Series
Our GMN FE 8000 sprag clutch is a great choice because it has no RPM limits and a high torque capacity. For heavy-duty applications, our RA series hold-back clutch is also a good choice.

Backstopping Clutch Application Examples:

- Conveyors & Winches: Stop Loads
- High Voltage Switching: Safety Device
- Textile Machine: Material Feed Protection
- Industrial Fan: Motor Protection

Indexing Clutch



Sprag Clutch Idling

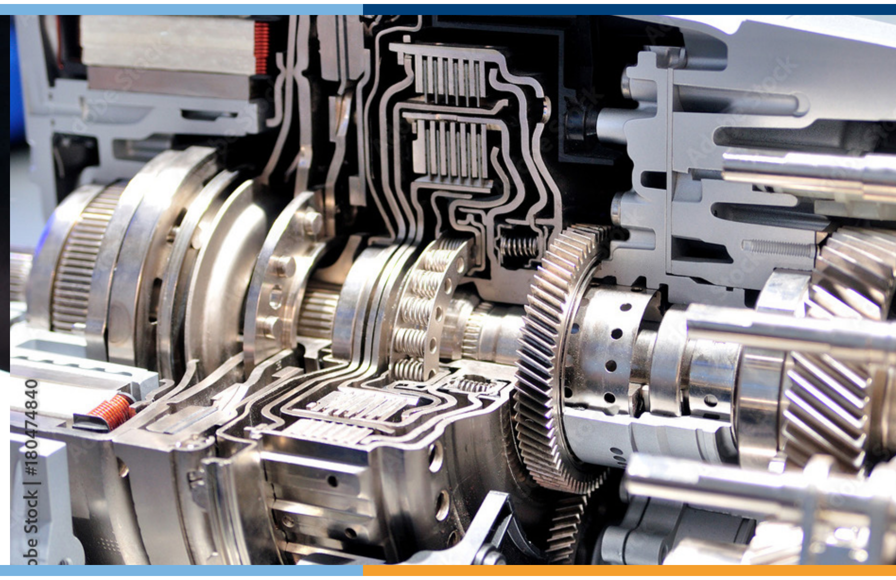
An **indexing clutch** pushes motion in a circular direction and then allows it to idle or stop.

A good example is a production line that moves to one position then stops, waits, and then moves one position over. This motion is controlled, deliberate, and guided by a one-way sprag clutch.

An indexing sprag clutch can also be an added safety precaution in case of a motor or electrical failure.

Indexing Clutch Application Examples:

- Printer: Industrial
- Copiers: Paper Feeding
- Furniture Production: Glue Roller
- Food Production: Bottling Plant
- Sewing Machines: Material Feeder
- Automatic Winch: Controlled Raising/Lowering



Overrunning Clutch

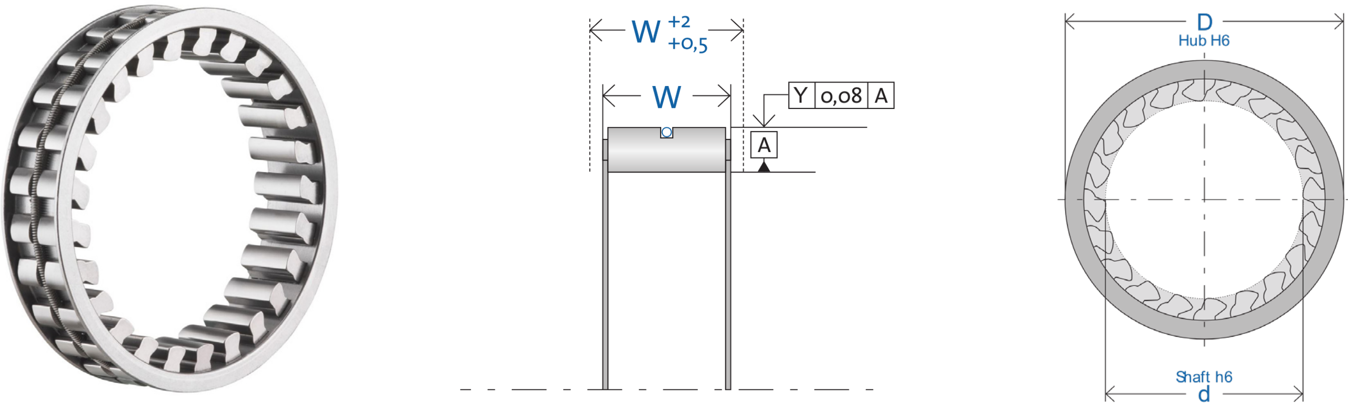
An **overrunning clutch** allows the rotating component to spin faster than the actual driving component that is producing the force. An overrunning clutch allows idle spinning to keep going without the engagement of force. Bicycle pedals are a good example of how an overrunning clutch works.

Typically, an overrunning clutch engages and disengages when the driven RPM exceeds the driving component's RPM.

<u>Overrunning Clutch Application Examples:</u>

- Torque Converters
- Conveyors: Speed Compensation
- Mixers: Motor Protection
- Motorcycles: Gear Box or Automatic Transmissions
- Packaging Machine: Spins Down Freely
- Printing Press: Ink Roller Drive

Sprag Clutches v. Roller Ramp Clutches



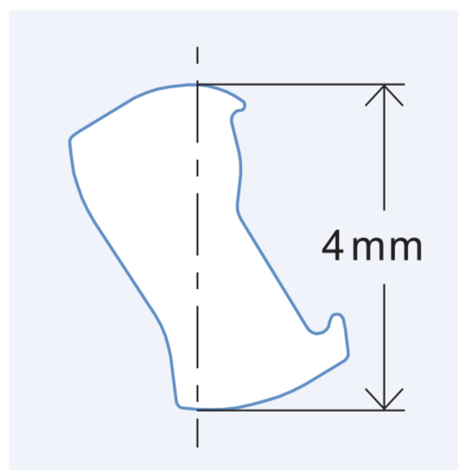
The GMN FE 8000 Sprag Clutch

Sprag clutches are similar in functionality to roller ramp clutches. However, sprag clutches have numerous benefits over roller ramp clutches including:

Simplified mating surfaces:
Sprag clutches operate against smooth cylindrical surfaces. Roller ramp clutches require one of the surfaces to have ramps and holes for the springs to push the rollers up the ramps. This means that roller ramp clutches typically must be provided with inner and outer rings to incorporate the ramps, while sprag clutches can operate directly against the shaft and housing.

More compact design:
Because there are no ramps, sprag clutches don't require nearly as much space. This means that the radial space allotment to the clutches can be much less for sprag clutches.

Higher number of engagement elements:
In roller ramp clutches, the amount of space needed for the ramps limits how many rollers can be used for a given clutch. Since sprags don't need nearly as much space numerous sprags can fit in the space required for a single roller in a roller ramp clutch. More sprags mean there are more elements to transfer torque which corresponds to a higher torque capacity.



Less rotation for engagement:
For roller ramp clutches to engage, the rollers have to move up the ramp and be wedged between the ramp and the outer ring. All the sprags have to do is twist slightly. That means the amount of rotation before the clamping element engages is less for a sprag clutch.

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Material & Wall Thickness Requirements

For optimal sprag clutch performance, GMN offers specific recommendations for mating part material as well as wall thickness.

MATERIAL REQUIREMENTS

GMN Recommendation: Only steel should be used as the mating surfaces for the sprags.

At the very basic level, the sprags ability to engage and stay connected against the mating surfaces is based on the sliding friction of the surfaces. The angle of engagement between the sprag and the mating surfaces is designed so that the tangent of the maximum engagement force is less than the force to overcome static friction of steel. That means if steel is used and everything else is within the design requirements, the sprags will not slip. However, if other materials are used, even if they meet all the other requirements, the change in coefficient of static friction could cause the sprags to slip. For this reason, GMN recommends only steel mating surfaces.

GMN Recommendation: A hardness of HRC 60 to 64 with an effective hardness depth of at least 1.3mm.

In addition to the type of material for the mating surfaces, the hardness and hardness depth are also critical in proper engagement of the sprags. As the sprags engage, they elastically deform the mating surfaces until an equilibrium is reached between the surface pressure applied by the torque and the resistance from the mating surfaces. If the surfaces are soft due to insufficient hardness or hardness depth, there will be less resistance to the sprags which will cause them to engage higher up on the engagement curve. That could result in a substantially decreased overall torque capacity and could cause premature failure.

GMN Recommendation: A surface finish, Rz, of less than 2.5µm.

In overrunning operation, the surface finish of the mating components plays a major role in the life of the sprags. If the surface is too rough, the lubrication will not be enough to prevent degradation of the sprags as they slide over the surfaces.

Note: If the system is unable to incorporate all the material requirements for the mating surfaces GMN offers sprag clutch products that incorporate hardened steel inner and outer rings.

WALL THICKNESS REQUIREMENTS

GMN Recommendation: The sprags should engage against a solid shaft and the housing should have a ratio of the housing outer diameter to the housing inner diameter be 1.4 or greater.

Similar issues to the insufficient hardness and hardness depth can occur if the wall thickness of the mating surfaces is too thin. As the sprags start to push into the surfaces, if the walls are too thin, they won't be able to resist the elastic deformation as much, decreasing the torque capacity.

In some applications these recommendations may not possible, and that doesn't mean that the sprags will fail. However, a decreased torque capacity should be expected depending on how far the actual application conditions deviate from GMN's recommendations.

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Lubrication Requirements


Lubricating a Sprag Clutch: Best Practice Guide

Proper lubrication is critical for sprag clutches. When the sprags are in the freewheeling state, there is sliding contact between the sprags and the shaft and housing surfaces. So, there must be a film of oil to protect against metal-to-metal contact. If the oil film isn't present or is not adequate, then excessive wear and premature failure would occur. However, too much lubrication can also cause the sprags to not engage properly or it can generate too much drag.

GMN Recommendations:
For oil bath systems, GMN recommends 1/3rd of the sprag clutch height is submerged.
For greased clutches, GMN recommends 30-60% of the available volume to be greased.

Some oils or greases, especially in engine or gear box applications, can have anti-friction (or EP) additives in the lubrication. While these additives are great for gears and other components, they hinder the performance of the sprags and can prevent them from engaging. These additives are designed to make sure a film of oil remains in place between the metal components no matter how much pressure is applied. However, the sprags must be able to push through the oil layer and act directly against the metal shaft and housing when engaging or they will slip. For this reason, lubrication without these additives is required for GMN clutches.

GMN STANDARD CLUTCH LUBRICATION

All GMN's sealed clutches come lubricated for life with grease in the Ball Bearing units and oil in the Complete units. GMN can supply open clutches pre-greased, and standard manufacturing lead times will apply.

RECOMMENDED OILS:

Operating Temperature	-65 to 100° C	-35 to 160° C	15 to 90° C
Manufacturer	**Klüber** Isoflex PDP 38 **LUBCON** Turmofluid SF 48	**Klübersynth** GH 6 oils **LUBCON** Turmopoloil HT	**Shell** Tellus S2 MA 32
Oil type	Diester oil based	Polygl.oil based	Mineral oil
Characteristics	Synthetic long-term oils	Synthetic transmission and high-temp. oils	High performance hydraulic oils

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RECOMMENDED GREASES:

Operating Temperature	-50 to 120° C	-40 to 180° C	-40 to 200° C	-40 to 260° C
Manufacturer	**Klüber Isoflex** LDS 18 Special A **LUBCON Turmogrease** Highspeed L 252	**Klüber Asonic** GHY / HQ 72-102 **LUBCON Turmogrease** PU 703	**Klübersynth** BHP 72-102 **LUBCON Turmogrease** NBI 300 P	**Klüber Asonic** GHY / HQ 72-102 **LUBCON Turmogrease** PU 703
Base Oil	Mineral oil Diester oil	Diester oil	Perfluropolyether oil Diester oil	Diester oil
Thickener	Lithium soap	Polyurea	Polyurea, PTFE	Polyurea
Characteristics	Dynamically light long-term lub. grease	Synthetic long-term lub. grease	High temperature long-term lub. grease	High temperature long-term lub. grease

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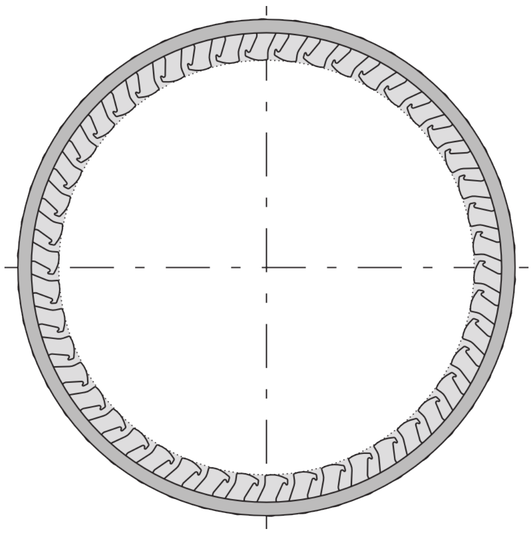
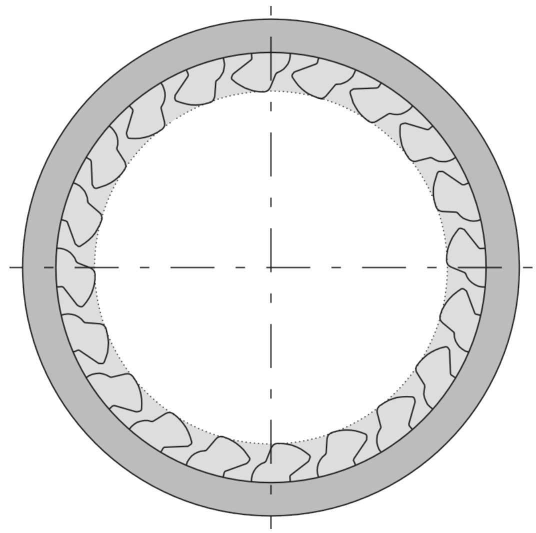
Torque and Hertzian Pressure



GMN FE 400 - front



GMN FE 8000 - front

The entire purpose of a sprag clutch is to be able to transfer torque when the sprags are engaged. This makes **torque capacity** one of the most important factors considered when selecting a clutch.

When freewheeling, the sprags are in sliding contact with the shaft and housing. When the relative rotation changes, the sprags lock against the shaft and housing surfaces. As the torque starts to increase, the sprags elastically deform the mating surfaces which provides the resistance to the continued twisting of the sprags until an equilibrium is achieved between the torque transmitting and the resistance from the mating surfaces.

Because the sprags are creating that elastic deformation, the torque capacity of the clutches comes down to what happens between the sprags and the mating surfaces. The contact area of the sprags creates a pressure against the mating surfaces that is causing the elastic deformation. That mating pressure is called **Hertzian pressure**, which is a term used for contact stresses or pressures between two curved components. If that pressure gets too high, the sprags and the mating surfaces will go from elastic to plastic deformation which will cause system failure. GMN uses a value of 4,200 MPa for the nominal pressure, and 4,600 MPa for the maximum pressure.

The torque capacity is then determined working backwards from the nominal and maximum Hertzian pressures factoring in the surface area and then the number of sprags. For this reason, simple things like going from a Z-Spring to an M-Spring sprag can increase the torque capacity because the sprags with the M-Spring don't feature the spring notch on the outside surface of the sprag which results in higher surface area. Similarly, using a wider sprag will also increase the torque capacity because of the increased surface area per sprag. Also, going with a larger diameter clutch will allow for room for more sprags which divides up the torque, allowing for more per sprag for higher torque.

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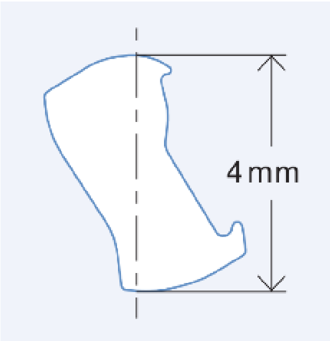
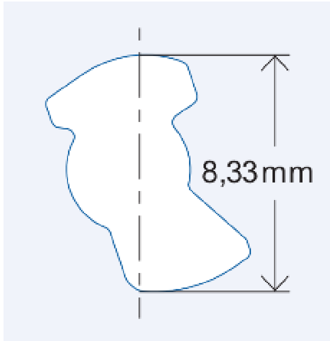
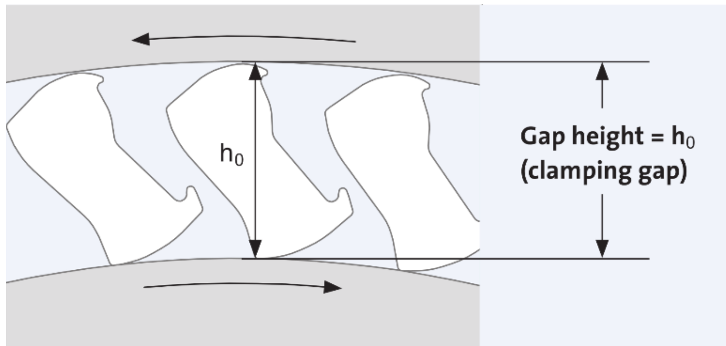
Gap Height







Sprag clutches transmit torque when the sprags engage against the shaft and housing. This engagement occurs because the sprags are just slightly larger than the gap between the shaft and housing. At the top and bottom of the sprag are special surfaces that are designed to produce an optimal clamping angle against the shaft and housing. These surfaces are called the engagement curve.

If the sprag tries to engage outside this engagement curve, it could slip or roll over. It is critical that the sprags make contact on the engagement curve. But just being on the engagement curve isn't enough because, as torque increases, the contact point on the engagement curve moves up. The higher the sprag starts on the engagement curve, the less capacity there is remaining for added torque.

This all demonstrates just how important the gap is between the shaft and the housing, because the starting gap value dictates where the sprags contact along that engagement curve or if they are even able to hit the engagement curve.

To keep the starting gap height controlled as much as possible but also allow room for manufacturing, GMN recommends the following shaft and housing tolerances and runouts:

GMN Series	Shaft	Housing	Runout
FE 400	h5	H6	30µm
FE 8000	h6	H6	80µm

These tolerances and runouts ensure that the sprags will engage in a correct spot on the curve with sufficient room left on the curve for torque transfer no matter where the resultant starting gap is due to the tolerance and runout stack up.

As the sprags engage and roll up the engagement curve, they press outwardly radially against the shaft and housing causing the gap to expand. GMN has set nominal and max torque values and gap heights based on resultant Hertzian pressure values and locations on the engagement curve. Below is a table of the gap heights for the GMN FE 400 and FE 8000 sprag clutches.

GMN Series	Starting Gap	Nominal Torque Gap	Maximum Torque Gap
FE 400	4.00 mm	4.06 mm	4.07 mm
FE 8000	8.33 mm	8.46 mm	8.60 mm

If the gap height exceeds the maximum value due to over torquing or from tolerance stack up outside the GMN recommended range, the contact angle of the sprags to the shaft and housing will start increasing and can either cause the sprags to slip or roll over. So, it is important to limit the design parameters with the tolerances and application torque to prevent the sprags from exceeding the maximum gap height and operational zone on the engagement curve.

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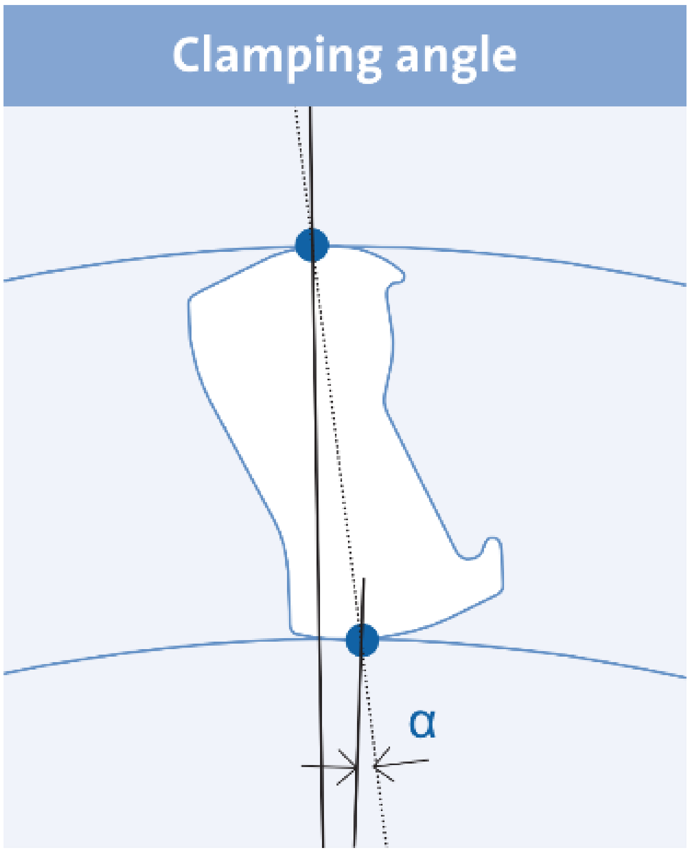
Clamping Angle

The clamping angle is the angle of engagement of the sprag against the shaft and housing relative to the line going from the engagement point to the centerline of the shaft. It is represented with an α in the below picture.



This angle is important because of its relation to the coefficient of static friction. For an object to engage and not slip, the friction force (F_S) must be larger than the force trying to make the object slip (F_R). The friction force is dependent on the normal force (F_N) and the coefficient of static friction (μ_0) such that:

$$F_S=\mu_0 F_N$$

That means that the object doesn't move if:

$$\mu_0 F_N > F_R$$

Now here's where the clamping angle comes into play. For an object on an incline plane (similar to how the engagement between a sprag and the shaft and housing can be modeled), both the normal force and the force trying to make the object slip can be calculated from the force of the sprag pushing against the shaft and housing (F_E) because that force acts along that line going from the engagement point to the centerline of the shaft. The force equations then become:

$$F_N=F_E \cos \alpha$$

$$F_R= F_E \sin \alpha$$

Then, by adding these equations in to the one above, for the sprags to stay in contact with the shaft and housing:

$$\mu_0 F_E \cos \alpha > F_E \sin \alpha$$

From this equation, we can see that the sprag force (F_E) doesn't matter in keeping the sprag from slipping since it's on both sides of the equation. Also, since the clamping angle is on both sides, the equation can be rearranged to:

$$\mu_0 > \sin \alpha / \cos \alpha \rightarrow \boldsymbol{\mu_0 > \tan \alpha}$$

What this shows then is that keeping the sprags engaged and not slipping is a factor of only the coefficient of static friction and the clamping angle. GMN clutches require the sprags to operate against hardened and ground steel. So, the coefficient of static friction value of 0.11 can be used. That means that:

$$0.11 > \tan \alpha \rightarrow \boldsymbol{\alpha < 5.8°}$$

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As long as the clamping angle is less than 5.8°, the sprag should stay engaged and not slip. However, this is not as easy as it seems because that **clamping angle** is the result of:

- The torque applied
- The radius of curvature of the engagement curve, and
- The shaft and housing diameter.

As a result, for many sprag clutch manufacturers, the clamping angle is never constant.

This is where GMN sprag clutches are unmatched. GMN has developed a unique, complex sprag curvature radius that ensures that the clamping angle remains below 5.8° throughout the engagement zone, regardless of shaft and housing diameters. If the torque is within the limits and the sprag engagement remains within the operating zone, the clamping angle will stay below 5.8°.

NO CATASTROPHIC FAILURES

GMN sprag clutches have an additional unique feature that relates to the clamping curve. Typically, when a sprag experiences excessive torque the engagement point will move past the operating zone of the sprag and it will roll over. This will result in catastrophic failure of the clutch and will likely damage other components.

However, GMN designed the sprag curvature radius so that when the engagement point begins to move past the operating zone, the clamping angle starts to exceed the 5.8° value. **That means when the torque gets too high, the GMN sprags will tend to slip instead of roll over protecting the clutch from catastrophic damage*.**

**Even though this is a feature of GMN sprags, this performance cannot be relied upon, and care must be taken to ensure the maximum torque for the application isn't exceeded.*

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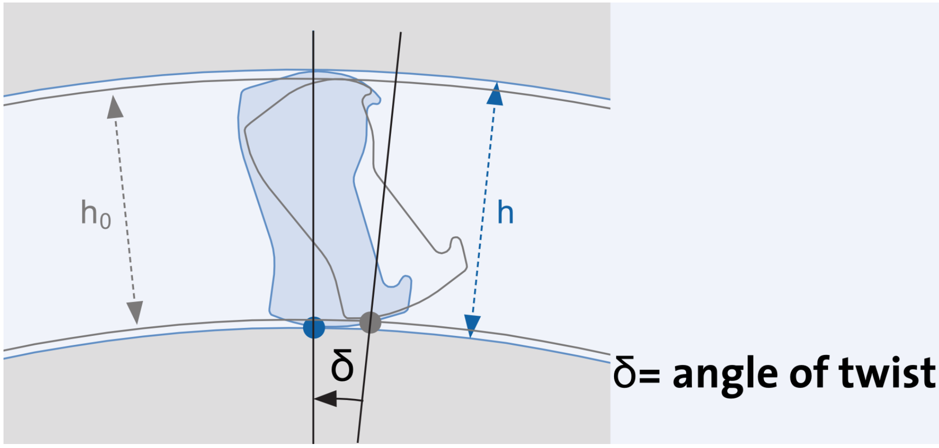
Angle of Twist



Sprags do not go from freewheeling to fully engaged instantaneously. When the sprags are freewheeling, they are still in contact with the mating surfaces, but that contact point is outside the engagement curve. As the relative rotation changes, the sprags start to rotate and move the contact point into the engagement zone.

Once in that zone, elastic deformation starts to take place between the sprag and mating surface, and torque is transmitted. Depending on how much torque is applied, the sprags will continue to rotate until an equilibrium is achieved between the torque transmitted and the elastic deformation and pressure between the sprag and mating surface. That means:

- If the torque is **low**, the sprags will rotate less and the contact point will be lower on the engagement curve.
- If the torque is **high**, it will take more elastic deformation to reach equilibrium so the sprags will rotate more and the contact point will be higher on the engagement curve.

The mating components don't lock up instantaneously the moment the call to transmit torque is made. While the sprags are rotating to reach the equilibrium point, the mating components are also rotating relative to each other, but this time in the torque transmission direction, not the freewheel direction.

The amount these mating components rotate until the sprags reach equilibrium is called the **twisting angle**. The twisting angle is very small and is typically under 3° for nominal torque values, but if the torque is small that twisting angle can be close to 0. However, relative to other clutch mechanisms, even 3° is considered quite small.

For applications where precise twisting angle is needed, the value can be calculated based on application gap heights, mating surface hardness, and application torque.

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Indexing Frequency

Indexing applications are when an oscillating motion is converted to a unidirectional rotation. One direction will drive the clutch and the opposite direction will cause the clutch to freewheel. An easy application to grasp the concept is a socket wrench. The wrench will turn the bolt in one direction but if the wrench needs to be turned back to regain leverage, it ratchets instead of turning the bolt the opposite direction. It can also be used in production lines where a product moves a step, it stops, an action is performed, and then it moves again. This start-stop action can be accomplished by an indexing clutch timed with the oscillating motion of an input device like a piston. In industrial or automation applications, this can happen really fast. That means a sprag clutch needs to be able to keep up with the indexing operation.

For a sprag clutch, the indexing frequency is the number of times the sprags are able to go from being disengaged to fully engaged and back to fully disengaged per second, in other words to make one full cycle. It is measured in cycles per second, or Hertz. If the application indexing frequency is above the maximum value for the clutch, there will not be enough time for the sprags to fully engage and transmit torque before disengaging again.

When transitioning from engaged to freewheeling, the inertia (the resistance to change in motion) of the sprags disengaging causes them to want to lose contact with the mating surfaces because they want to continue to lay down. To minimize this effect, GMN-designed sprags have the lowest possible inertia. Additionally, springs are used to resist the inertia and keep the sprags in contact with the surfaces.

The FE 400 M series insert elements have a meander spring that weaves in and out of each sprag. This spring pushes between the cage and the toe of each sprag creating independent spring forces for each individual sprag. This is ideal for high indexing frequency applications. It is rated for 60 Hz, but tests have been successful up to 120 Hz.

The FE 400 Z, FE 400 Z2, and FE 8000 Z insert elements use a tension spring that goes around the outside of all the sprags. This produces a slightly lower spring force than the M series. The resultant maximum indexing frequency for these insert elements is 10 Hz for the FE 400 sprag and 5 Hz for the FE 8000 sprag.

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RPM Effects

Sprag clutches operate in either an engaged or freewheel state. In the engaged state, the sprags are locked against the shaft and housing and torque is being transmitted. Because the sprags are firmly pressing into the shaft and housing, there are no speed effects that would limit the sprag operation, which means *there is no limiting speed from the clutch.*

When the sprags are in the **freewheeling state**, speeds typically become an important factor to consider. Most sprag clutches have a limiting speed. This value is not a ceiling indicating that if the sprags freewheel above that speed, they will fail. Rather, it's the *maximum freewheeling speed where the sprags can still engage*. That's because of the balance between the centrifugal forces acting on a sprag and the spring trying to counteract the centrifugal forces.

CALCULATING MAXIMUM RPM

Most sprags have a center of mass out in front of the pivot point. So, the centrifugal force creates a torque that causes the sprag to want to lay down and lose contact with the shaft and housing. This torque can be calculated as the distance from the pivot point to the center of mass (s_z) multiplied by the centrifugal force (F_z). The spring will work against this torque by applying its own torque in the opposite direction calculated as the distance from the pivot point to where the spring pushes down on the sprag (s) multiplied by the spring force (F). There is a point where the torque from the centrifugal force becomes larger than the torque from the spring force and the sprags lose contact. That's where the maximum RPM value comes from.

** An important note: These limiting speeds are not the shaft or housing speeds but the sprag clutch speed. When sprag clutches are floating, they will be rotating at some speed between the shaft and housing speeds. It's difficult to calculate exactly what speed that would be because it is highly dependent on sliding friction.*

MAXIMIZING RPMS

To overcome the lift-off effects, some clutch manufacturers put *drag clips* on the cages to encourage the sprags to stay connected to the component that doesn't rotate or rotates at the slower rate of the two between the shaft and housing. However, drag clips encourage increased wear on the surface acting against the other component.

It is also possible to *increase the spring force* in high-speed applications, but there is a trade-off between increased maximum RPM ability and freewheeling wear. As the spring force increases, the amount of force the sprag exerts against the shaft and housing surface during freewheeling increase, which will decrease the sprag life due to the sliding wear.

Lift-off speed

$$n = \frac{1}{2\pi}\sqrt{\frac{Fs}{mr \times s_z}}$$

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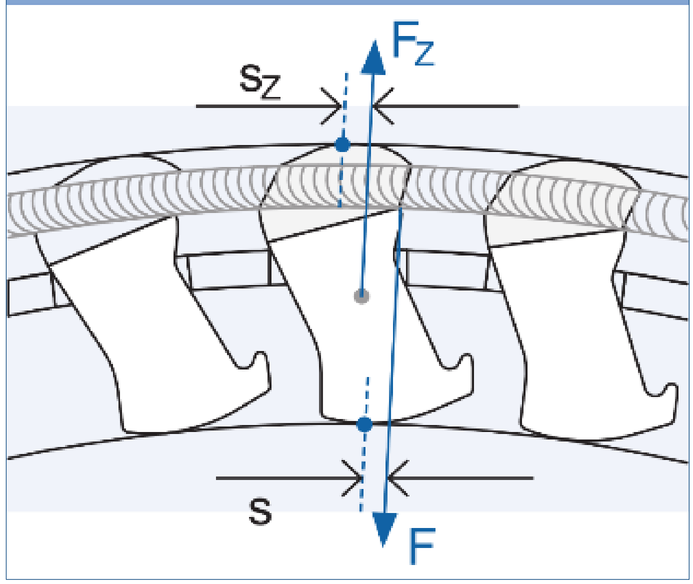
THE GMN SOLUTION: FE 8000 SERIES

GMN has designed the FE 8000 series sprags in a special way that eliminates the possibility of sprag lift-off at any speed. For this series, the center of mass is moved behind the pivot point, which means that the centrifugal forces have the opposite effect on these sprags. The torque direction is reversed. Instead of creating a torque that works against the spring and makes the sprags want to lay over, the torque now encourages the sprags to want to stand up more. This eliminates the need for drag clips and removes any speed limit.

Note: If the sprag clutch has integrated seals, then the speed limit no longer represents the lift-off speed but rather the maximum speed the clutch can operate with the contact seals. Operating above that limit would produce excessive wear on the seals and cause them to fail prematurely.

Example tension spring



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Drag Torque

The primary function of a sprag clutch is to transfer torque in one direction and freewheel in the other direction. Most of the design attention is rightfully focused on selecting the best clutch for the torque transmission to maximize number of engagements and prevent over-torque situations. However, it is also important to consider the sprag clutch interaction when in the freewheel state.

The sprag clutches use springs acting on the sprags to ensure that they maintain contact with the inner and outer race when freewheeling to be ready for the transition to torque transmission with minimal rotation. The only time the sprags can lose this contact is if the clutches use the FE 400 series sprag and the speed gets high enough that the centrifugal forces cause the sprags to lift off the races. (This does not happen with the FE 8000 series sprags due to their center of gravity and pivot point.) With that exception, there is always going to be a pressure exerted by the sprags on the raceways.

This pressure results in a **drag torque**, providing some resistance to the freewheel rotation. Depending on the magnitude of the drag torque, it can have a sizeable impact on the system. *Often in the design process, consideration must be taken to overcome the drag torque which could factor into the specification of motors or other components.*

<u>Fortunately, GMN's FE 400 and FE 8000 series clutch insert elements have virtually no drag torque.</u> They rely on a thin film of lubrication between the sprags and the races to keep a boundary layer preventing metal-to-metal contact in the freewheeling state. This means that they are able slide with ease and have minimal wear throughout the life of the clutch. In fact, the drag torque on these GMN clutches is so low that it is virtually impossible to even measure it. Lubrication choices will have a greater impact on the drag torque than the insert elements themselves. For design considerations, it is safe to assume a near 0 drag torque.

The drag torque is a little more notable in units that have built in bearing support and some sort of seal to keep the lubrication inside the clutch.

GMN has two sealed clutch options:

- The FK series ball bearing clutch uses grease lubrication and has contact seals. These seals result in a drag torque of 0.01 to 0.05 Nm.
- The FPD and FND complete units have oil lubrication. They require heavier contact seals to prevent the oil from egressing. This results in a slightly higher drag torque of 0.1 to 0.3 Nm.

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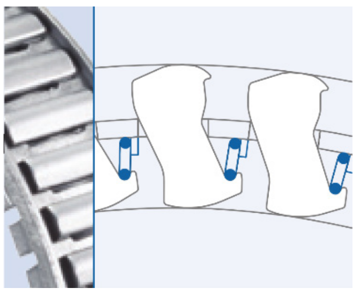
Springs

For sprag clutches to function properly, the sprags must maintain contact with the mating surfaces while in the freewheeling state. That way they can be ready to engage as soon as the relative rotation changes and torque transmission is required. If the sprags don't maintain that constant contact, the clutch could slip. If some sprags aren't in contact but others are, those sprags could experience excessive torque which could cause permanent damage to the clutch.

GMN uses a spring to keep each sprag in contact. There are two different types of springs that have unique operating characteristics:

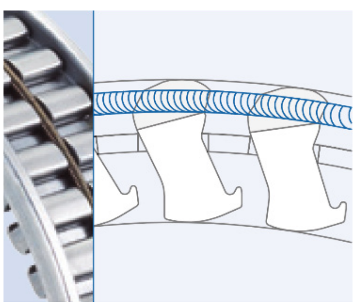
MEANDER SPRING



The meander spring uses a wire that is bent into a 3D pattern to weave in and out of each individual sprag and around the cage so that the spring pushes between the cage and the toe of the sprag. That means each sprag has an independent spring force acting on it. Because of the precise spring engagement, clutches with the meander spring are suitable for high indexing applications and are guaranteed to operate at indexing frequencies up to 60 Hz.

Also, sprags that use the meander spring have more surface area because they don't require the notch that is needed for the Z spring. That means they have a higher torque capacity. The meander springs produce a slightly higher spring force on the sprags. For applications that are mostly in the freewheeling state, they may not be the best option as they could produce more wear than the sprags that use the Z spring.

Z SPRING



The Z spring is a tightly wound coil spring that goes around the outside of every sprag. The sprags have an angled notch in the middle of the outer surface of the sprags where the spring engages the sprag. That allows the spring to be nested inside the sprag to prevent it from rubbing against the housing bore. In this design, the spring acts on all the sprags together as it tries to push the angle of the sprag notch tangential.

Because the Z spring pushes on all the sprags together, it is not as ideally suited for high indexing applications. However, it is still guaranteed to operate in indexing frequencies up to 10 Hz. Since the Z spring requires there to be a notch in the outer sprag surface, there is less surface contact area between the sprag and the housing bore. This results in a slightly lower torque capacity. The Z spring has a slightly lower spring force than the meander spring. It is better suited for applications where the clutch is in the freewheeling state most of the time as it will produce less wear.

SPRING AVAILABILITY

The following GMN product lines are available with either spring style:	The following GMN product lines are *only* available with a Z spring:
• FE 400	• FE 400 Z2
• FR, FRN	• FE 8000
• FN, FND, FP, FPD	• FK, FKN, FKNN

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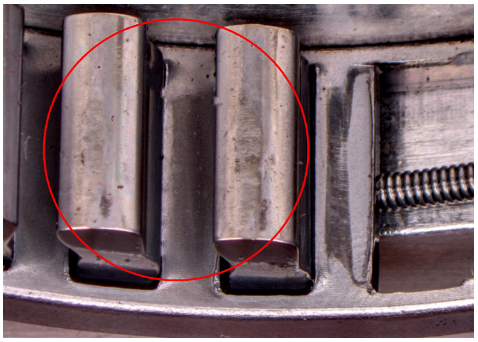
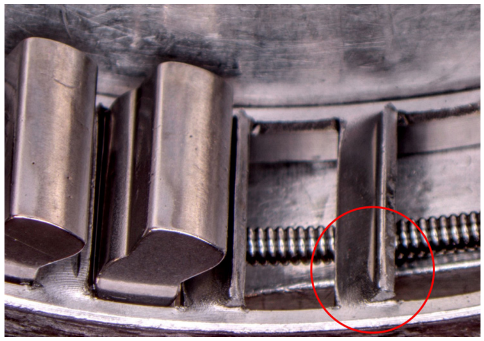
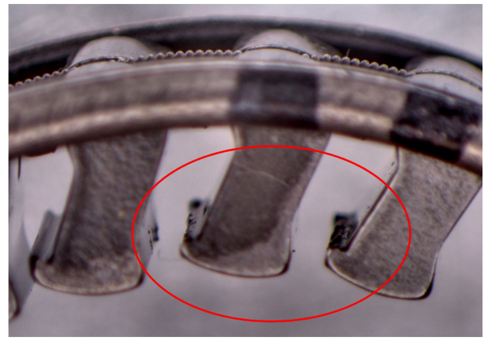
Failure Mechanisms



Overrunning by poor lubrication



Cage failure



Popping caused by excessive torque

Sprag clutch failure can be broken down into three types:

- Overrunning failure,
- Loading failure, and
- Cage failure

OVERRUNNING FAILURE

The most common reason for overrunning failure is wear between the sprags and the mating surfaces. The sprags require a lubrication film to maintain separation between the sprag and the mating surfaces so that wear is minimized. However, if the lubrication is not sufficient to maintain a thick enough oil film to overcome the microscopic surface roughness of the sprag and the mating surface, then there can be some metal-to-metal contact. This can happen with lubrication that doesn't have a sufficient viscosity to work at the application operating temperatures. Additionally, if contamination is present in the application, the contaminants will bridge the oil film gap and can act as sandpaper against the sprag speeding up the wear. The wear will result in flat spots on the sprag that are towards the back of the sprag engagement curve. Methods of correction include using proper lubrication with sufficient viscosity and ensuring the environment remains free from contamination.

Another potential cause for sprag failure in overrunning conditions can come from excessive application vibrations. The springs in the sprag clutches are intended to ensure contact between the sprags and the mating surfaces. But, if the vibrations are significant enough, the forces generated from the vibrations can overcome the spring force and cause the sprag to hit the back of the sprag in front and possibly damage the cage. This can result in broken sprag toes and marks on the backs of the sprags in front as well as twisted cage separators. If heavy vibration is unavoidable, the spring force can be increased on the sprag clutches to help overcome the vibration forces, however this may result in increased overrunning wear.

LOADING FAILURE

Sprag loading failure is generally one of two types: Excessive torque or Popping.

Excessive Torque:
If the application generates a torque that is above the maximum torque limit, the sprags will want to extend past the maximum point on the engagement curve and roll over. This will result in permanent destruction of the clutch. This would be indicated by sprags laying down in the overloaded position, cage separators twisted or removed, and sprag toes damaged. To rectify this, the application needs to be designed to ensure that the maximum possible torque required is below the torque limit of the clutch.

GMN sprag clutches have a built-in safety to help prevent sprag rollover in excessive torque applications. At the point of maximum torque transmission, the engagement angle starts to increase, which causes the sprags to lose friction contact and slip instead of rolling over. Even though this is part of the sprag design, it is still possible for the conditions to cause the sprags to roll over in an excessive torque situation, especially if it is a rapid torque transmission. (The sprags should not be relied upon to slip.)

Popping:
The other type of loading failure is a phenomenon called popping. This happens at the point of transmission when the sprags go from overloading to transmitting torque. As the sprags start to engage they elastically deform the mating surface, building up potential energy. Something can happen to cause the contact to not be maintained and that built-up energy acts as a spring that rapidly propels the sprags forward creating a "popping" sound. This can result in damaged sprag toes, marks on the back of the sprags from the toes of the sprags behind hitting the sprags in front, and twisted cage separators.

The most common cause for popping is improper lubrication, mainly the presence of extra pressure additives. If the sprags are unable to break through the oil film when they engage, that film will cause the sprags to slip and spring forward.

Other potential causes for popping and overloading failure can be improper mating surface tolerances as well as incorrect mating surface material, hardness, and hardness depth.

CAGE FAILURE

Cage failure is almost never due to a problem with the cage. The purpose of the cage is to evenly space out the sprags to enable proper torque transfer. No loading should ever be placed on the cage. If the application is designed correctly, the cages should never experience conditions that cause it to fail. If cage failure occurs, it is typically the symptom of one of the failures mentioned above. If the conditions that are causing the cages to fail are unavoidable, it is possible to make alterations to the cage design to help ensure clutch success. This can include making the cage thicker or changing cage materials.

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