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Plated limited slip differential explained.

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Almost every car has one or more differentials in their driveline. A differential is used to manage wheel speed differences while taking a corner or while accelerating/decelerating (4wd). When taking a corner, the inner wheel will have a lower speed than the outer wheel. If they have had the same speed, it would not be easy to take that corner and you would have a lot of under steer.

The open differential is great to use on you daily car, but not for motorsport usage. Due to the inherent design of the beveled gear differential, the torque at both wheels will always be the same. This drastically limits the amount of power the car is able to put down on the road. If one wheel loses traction, only a small amount of torque is necessary to drive this wheel. The other wheel will receive an equally low amount of torque, therefore the total amount of torque transmitted to the road is low.

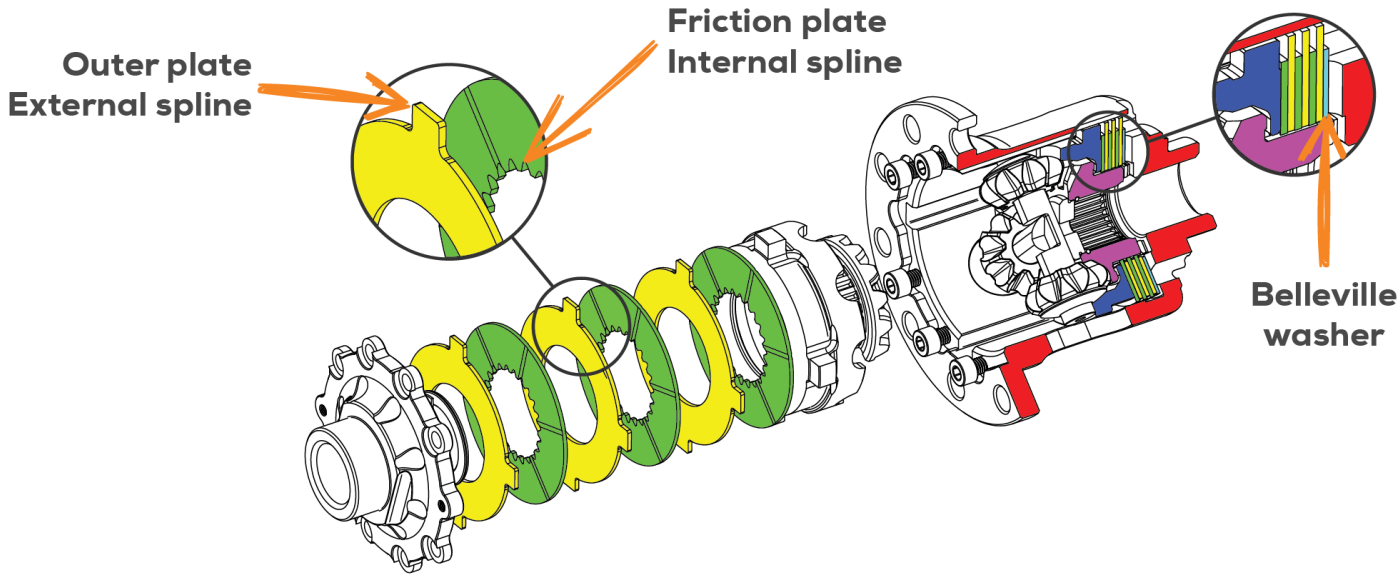
To overcome this downside, most motorsport cars use clutch-pack limited slip differentials. The torque can be transferred directly from the differential housing to the side-gears through the clutch pack, thereby bypassing the differential gear set. This blog will describe in-depth the working of a clutch plated limited slip differential.

Do you want more basic in-depth information about open differentials? Click **here.*

Plated limited slip components

The plated limited slip differential essentially consists of an ordinary bevel gear differential combined with friction plates which can (partially) engage the side gears to the differential cage. The larger the torque, the greater the locking effect.

The friction plates usually have a spline connection with the side gears. The outer plates are usually connected with a sliding connection to the differential cage. The outer plates will always have the same speed as the differential cage, and the friction plates have the same speed as the side gears and drive shafts.



Clutch pack loading

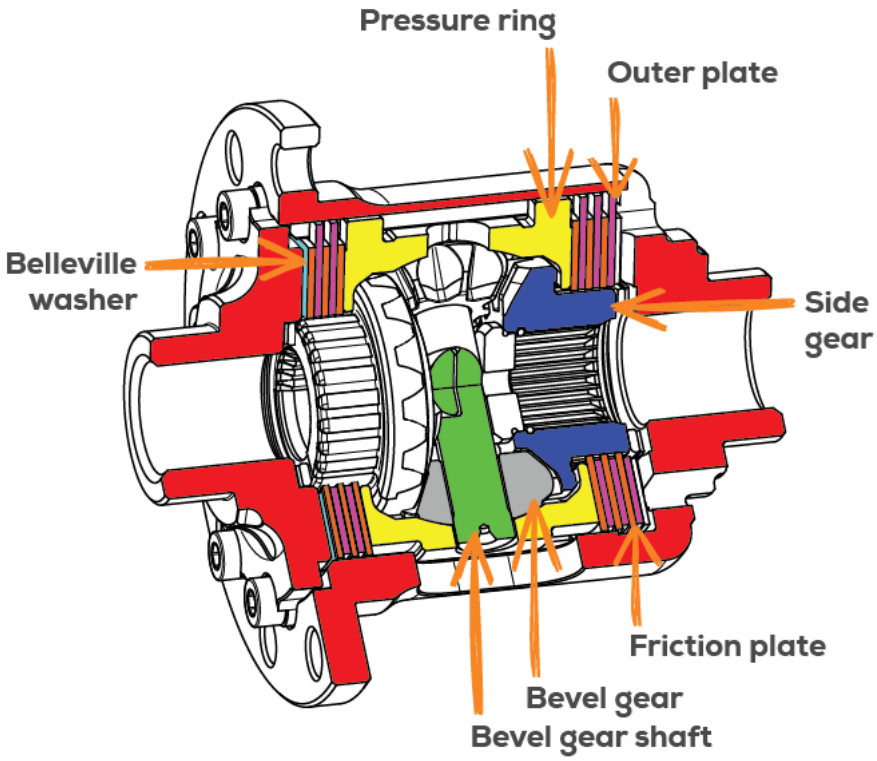
There are three stages of clutch pack loading:
1. Belleville spring action (also named as preload)
2. Bevel gear separating force action
3. Pressure angle action

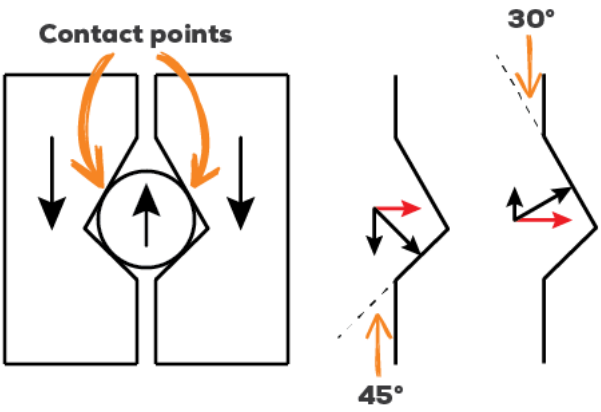
1. Belleville spring action (preload)

The belleville spring action produces an axial loading on the clutch plates. This then produces a small amount of friction which tends to lock the side gear (and drive shaft) to the differential cage when the torque transmitted is very low. This makes sure some drive torque will still be applied to the wheel that is not spinning. The preload produces the basic friction torque of the limited slip differential.

2. Bevel gear separating force action

This arises from the tendency of the bevel planet pinions (bevel gears) in the differential cage to force the bevel sun gears (side gears) outwards. The extra outward force exerted by the bevel pinions when one wheel tends to spin is transmitted via the pressure rings to the clutch plate pack, causing both sets of plates to be clamped together and thereby preventing relative movement between the side gears and cage.



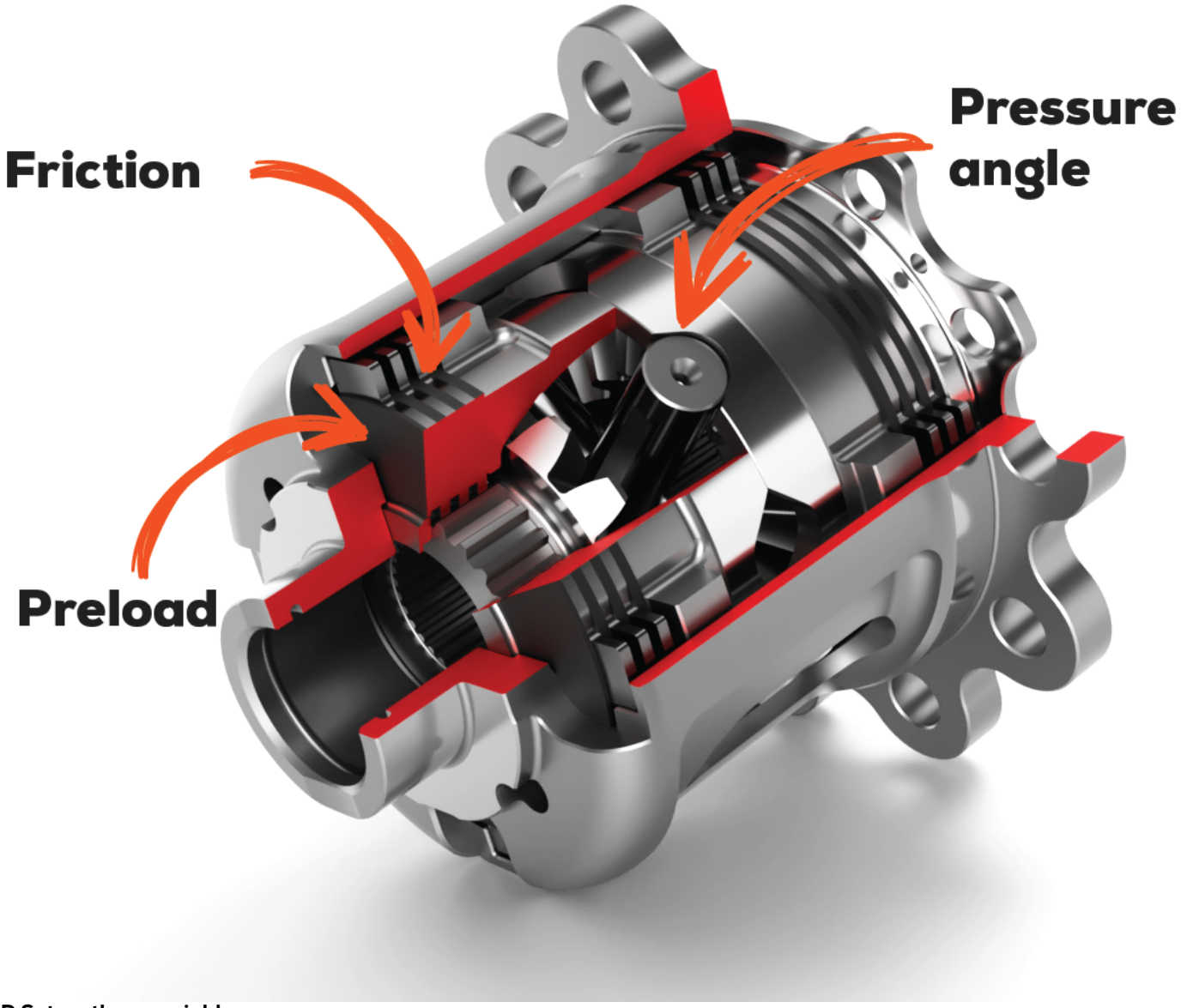


3. Pressure angle action

When torque is increased even further, a third stage of clutch pack loading comes into play. When engine torque is applied, the drag reaction of the bevel gear shaft will force the pressure rings to slide outwards and each set of clutch plates is therefore squeezed together increasing the locking effect.
The lower the angle, the higher the axial force outwards. Pressure angles are often not the same for driving and braking (drive and coast). The chosen pressure angles depend on many factors, such as car weight, dimensions, engine torque, racing purpose and many other. It should be noted that the braking torque applied to the differential is only the engine braking torque.

Friction

Friction force is the frictional resistance x the reaction force. A high friction force results in under steer, the left and right wheel will try to have the same rotational speed. Depending on the friction material, there is a difference between static friction (speed is 0) and kinetic friction (objects are moving). There is more force needed to get the objects to move, compared to when they are moving already. When the force applied is around the station friction, it will result in a so called stick-slip state (stuttering). Friction plates in limited slip differentials are often coated with a sinter or Molybdenum surface. Both coatings have very good stick-slip properties and a high friction coefficient.



LSD Setup: three variables

So, basically there are 3 variables to 'set up' a plated limited slip differential. The preload, the (number and material) of friction plates and the pressure angle. Unfortunately there is not such a thing as a basic formula, giving you the best setup possible. The setup is car, track and driver dependant.

There is a lot of experience involved with choosing the best setup for the right purpose. A specialist could give you a good basic setup when all car details are provided.

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