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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortiz@vnet.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

DIFF DIFFERENCES

Which differential would be best for road racing, in my 300hp Porsche? The question arises because a supplier suggests that a plate-type limited-slip is better suited to road racing than a worm gear style torque bias diff. I have used both and found Iliked the torque bias diff. I thought it was a better design, from what I read. The supplier states that the lsd will be better in corner entry and exit. What is your opinion?

Clearly, both worm gear and clutch pack differentials have their adherents, and both are used successfully in racing. You say you have experience with both types, and have already formed a preference. The most obvious answer would be that you've already answered your own question, and don't need advice.

However, the situation is actually a bit murkier, because the behavior of both types of differential can vary according to design and tuning details. Both types are similar in that they generate a locking torque in response to the total torque being transmitted. In both types, the locking torque depends on pressure angles. In a ZF-style clutch pack design, the angles are those of the ramps on the spider shaft and the housing halves. In a worm gear design, it's primarily the helix angle on the gear teeth, and secondarily the pressure angle of the tooth profile. Lubricant choice also influences behavior.

Consequently, all clutch pack diffs don't act alike and neither do all worm gear diffs. A lot depends on how a specific example is tuned.

That said, the clutch pack design probably offers a greater range of tuning options, and probably greater wear resistance. With the worm gear designs, we are trying to make gear teeth act as a friction device. Clutch discs are designed to be a friction device; gear teeth can be made to act as a friction device, but they are less comfortable in that role.

This affects the ability of the differential to maintain consistent properties over time, and its longevity.

The pressure angles determine how rapidly locking torque builds as transmitted torque increases. The preload in the diff determines how much locking torque there is when no torque is being transmitted. A clutch pack is easily preloaded, and it maintains its preload relatively well, especially if the preload is applied by springs or some other compliant system such as dished clutch plates. Worm gears can also be preloaded, but because they are not very compliant, the preload rapidly goes away as the teeth wear.

One limitation in worm gears is that the pressure angle is generally the same for forward torque and rearward torque (as when engine braking, or when transmitting brake torque from a single rear brake, as seen in FSAE cars). In a clutch pack diff, we can use different ramp angles for power and decel.

Another peculiarity of worm gear designs is that because power and decel apply force to opposite sides of the gear teeth, preload doesn't have identical effects in both directions. If we preload the gears in the direction they're loaded under power, what happens under decel is that we have diminishing friction with increasing reverse torque, until the preload is overcome, at which point locking torque is zero. As reverse torque increases beyond that point, locking torque builds again. With a clutch pack, preload has similar effect in both drive and decel modes.

This does mean that we can make a worm gear diff act different in drive and decel, but not in a manner that's independent of preload.

One interesting, though uncommon, trick we can use in a worm gear diff is to use plain thrust washers to absorb the thrust of the worm gears in one direction, and needle thrust bearings to absorb the forces in the other direction. This can afford us some limited measure of difference in friction depending on torque direction. Last year's North Carolina State University FSAE car had a diff like this.

It will be clear, however, that using these tricks is not nearly as straightforward as varying the ramp angles in a clutch pack diff.

Finally, neither option is ideal, because neither is speed-sensitive. Both clutch pack and worm gear diffs rely on Coulomb friction, which is largely dependent on normal force and not speed. We would rather have the locking torque vary with the speed difference between the wheels, either entirely or at least in part. This argues for either a pure viscous limited-slip, or a design that uses a pump, driven by relative ouput shaft rotation, to load a clutch pack, or a design that combines viscous effects with a clutch pack.