High Gear Ratio Epicyclic Drives

THE QUESTION

Referencing a June 2014 Article, "High Gear Ratio Epicyclic Drives Analysis," by Dr. Alex Kapelevich:

I have designed a small compound epicyclic gearbox with common planets.

Sun = 10 teeth

Planet = 14 teeth

Ring Gear stationary = 38 teeth

Ring gear output = 41 teeth profile shifted onto a 38 tooth pitch diameter.

Carriers are simply cages for the planet alignment and location.

According to your article, and according to my calculations and the prototype I have built, my input-to-output ratio is a reduction of 65.6:1. I am using a ~ VG1 viscosity grease and Nylatron materials for the gears and carriers.

I am driving the system with a small DC motor that is driven by 120 VAC with a full bridge rectifier. Max no-load motor speed of 18,000 ± 10%. Current at stall is 2.56 A, and output torque at stall is 1.82 in-lbs.

Ok. So that is all good. Now, since I am reducing output motor speed by 65.6:1, I should also get a torque increase of 65.6:1. Thus my output torque for the rotating 41T ring gear should be 119.392 in-lbs (in a perfect world). Assuming losses in the system, this number will of course be lower.

However, I am not getting even close to that output torque level. More like 40–45 in-lbs — I cannot figure it out. I have reduced sliding friction as much as possible (I am not using rolling bearings however). I have improved gear tooth surface finish as much as possible (50–100 RMS likely).

Any direction would be appreciated. Or even directed to a person who could help would be great!

I am testing output torque by using a dual compression spring assembly. I connect my output to one side of a large fine thread bolt. When I energize my motor my output begins to screw down the bolt, which then engages with the spring assembly until it eventually stalls the motor. I then use a digital torque wrench to measure how much torque I need to further tighten the bolt, as well as loosen the bolt.

I have used this "torque tester" method on other parallel axis systems and the results are as I expect and calculate — at least that's to say they are approximately in the range of what I calculate for the expected output torque.

Expert Answer Provided by Dr. Alex Kapelevich:

In this case, the low gear efficiency does not have much to do with the gear tooth surface finish. A reason for low gear drive efficiency (33–38%) is the Nylatron planet cage.

In the article you reference I wrote:

"In differential-planetary arrangements, tangent forces applied to the planet gear teeth from the stationary and rotating ring gears are unbalanced, as they lie on different parallel planes and have opposite directions. A *sturdy planet cage is required* to avoid severe planet gear mesh misalignment."

The Nylatron planet cage is not sturdy enough to avoid planet gear mesh misalignment; it creates an angular tooth contact and increases friction. It could be aggravated if the planet cage is not supported on its own bearings (or bushings) and is wobbling. This results in low efficiency. I would suggest considering the machined aluminum cage supported by the ball bearings. The gaps between the planet gears and their steel pins should be minimized as much as possible.

Besides, plastic gears have naturally lower efficiency because of increased tooth deflections under the load in comparison to metal gears. However, the 60–70% efficiency should be achieved with plastic gears.

Please contact me with more questions.

Best regards,

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