Epicyclic gear design handbook

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Recent articles in Gear Solutions have discussed epiccyclic transmissions, but often in the context of experienced engineers. As more and more of these engineers reach retirement age young engineers have to pick up where they left off, and for many epiclical gear is an area where they lack experience. Epicyclical transmission requires a step-by-step process to make it work, and some steps are not necessarily intuitive. Thus, this article aims to provide assistance and guidelines for people designing epiccyclic train transmissions for the first time, and perhaps, if you like, to alleviate their degree of suffering. We'll start by identifying the types and mechanisms, and then discuss why epicyclical gear kits are used. Next we look at what is unique to epiccyclic gears, including relative speed, torque splits, and a few grid considerations. Finally, we'll discuss dos and don'ts and share some design tips and pitfalls related to epicyclical transmissions. Fig. 1: Planetary, with ratios between 3:1 and 12:1 Types and Arrangement Let's start by studying some basic terms. Epicyclic gears consist of several components: sun, carrier, planets and rings. The sun is the central gear, mesh with planets, while the carrier houses the planet's transmission shaft. As the carrier rotates, the planets rotate along the planet's shaft of gears, orbiting the Sun. Finally, the ring is an internal outfit that meshes with planets. Epicyclical transmission systems can be divided into three types: a simple planetary epicyclical; Epicyclical compound; and connected epicyclical sets. There are several possibilities for epiccyclic arrangements: Planetary, with a ratio between 3:1 and 12:1 (see Figure 1) with a ratio between -2:1 and -11:1 (see Figure 2) - Solar, with a ratio between 1.2:1 and 1.7:1 (see Figure 3) pic. 2: Star, with a ratio between -2:1 and -11:1 Why epiccyclic transmission? The reasons why the epicecyclic transmission used have been covered in this journal, so we will expand on this topic in several places. Let's start by studying an important aspect of any project: cost. Epiccyclic transmission is usually cheaper when the tool is correct. Just as one might consider taking 100 parts of a lot of gear on an N/C milling machine with a form cutter or ball-end mill, one should not consider taking 100 parts of a lot of epicyclical carriers at the N/C mill. To keep carriers within reasonable production costs, they must be made of molding and instrumented on disposable machines with multiple cutters while removing the material. Size is another factor. Epicyclic gear kits are used because they than shifting gear sets, as the load is split between transmission plans. This makes them lighter and more compact compared to countershaft gearboxes. In addition, with the correct setting, epicyclic gear kits are more effective. The following examples illustrate these benefits. Let's say that Designing a high-speed transmission to meet the following requirements: The turbine provides 6,000 horsepower at 16,000 rpm in the entry shaft. Exit from the gearbox should control the generator at 900 rpm. Fig. 3: Solar, with a ratio between 1.2:1 and 1.7:1 With these requirements in mind, let's look at three possible solutions, one involving one branch, a two-night heli transmission system. The second solution takes the original set of transmissions and divides the two-stage abbreviation into two branches, and the third requires the use of a two-stage planetary or stellar epicyclic. In this case, we chose a star. Let's take a closer look at each of them, looking at their ratios and the resulting weights. The first solution - one branch, a two-fold set of heli gears - has two identical ratios derived from the acceptance of the square root of the final ratio (7.70). (See Figure 4.) In the process of considering this decision, we notice its size and weight is very large. To reduce weight, we explore the possibility of creating two branches of a similar mechanism, as seen in the second solution. This significantly reduces the loading of teeth and significantly reduces both size and weight (see figure 5). We finally come to our third solution, which is a two-stage star epiccyclic. With three planets, this gear train significantly reduces the loading of teeth from the first approach, and a slightly smaller number from the solution is two (see methodology at the end, and figure 6). The unique design characteristics of the epic gear are a significant part of what makes them so useful, but these very characteristics can make their design a challenge. In the following sections we will study relative velocity, torque splits, and grid considerations. Our goal is to make it easy for you to understand and work with the unique design characteristics of the epiconic gear. Fig. 4: Odds 1 x 4.216, Odds 2 4.216, Weight 5293 Relative Speeds Let's start by looking at how relative speeds work in conjunction with different mechanisms. The stellar location is fixed carrier, and the relative speed of the sun, planet and ring is simply determined by the speed of one member and the number of teeth in each transmission. In the planetary location, the ring is fixed, and the planets rotate around the Sun while spinning on the wall of the planet. At the same time, the relative speed of the sun and planets is determined by the number of teeth in each transmission and the speed of the carrier. Things get a little more difficult when dealing with two epicyclical transmissions, since relative speeds can't be intuitive. Therefore, it is always necessary to calculate the speed of the sun, planet and rings relative to the carrier. Remember that even in a sunny location where Fixed it has a speed relationship with the planet - it's not zero RPM in the grid. Split torque when considering torque involves torque, which will be divided equally between planets, but this may not be a valid assumption. The support of members and the number of planets determine the separation of torque represented by an effective number of planets. This number in epicyclical sets built with two or three planets is, in most cases, equal to the actual number of planets. However, with more than three planets, an effective number of planets is always smaller than the actual number of planets. Fig. 5: Odds 1 th 3.925, Odds 2 4.536, Weight 3228 Let's look at torque splits in terms of fixed support and floating support for members. With fixed support, all members are supported in bearings. The sun, rings and media centers will not match due to production tolerances. Because of this, fewer planets are simultaneously in the grid, which leads to a decrease in the effective number of planets separating the load. With floating support, one or two members are allowed a small amount of radial freedom or float, allowing the sun, ring and carrier to search for a place where their centers match. This float can be as little as 0.001-002 inches. With floating support, the three planets will always be in the grid, which will lead to a more efficient number of planets separating the load. A few grid considerations At this point let's consider a few grid considerations that need to be made when designing epiclical gears. First, we need to translate RPM into grid speeds and determine the number of load cycles per unit of time for each member. The first step in this definition is to calculate the speed of each member relative to the carrier. For example, if a solar equipment rotates at a speed of 1700 rpm and the carrier rotates at a speed of 400 rpm, the speed of solar equipment relative to the carrier is 1,300 rpm, and the speed of transmission of the planet and the ring can be calculated at this speed and the number of teeth in each of the gears. It is important to use signs to represent clockwise and counterclockwise rotation. If the sun rotates at 1,700 rpm (clockwise) and the media rotates -400 rpm (counterclockwise), the relative speed between the two members is 1,700 euros (-400), or 2100 rpm. Since the sun and ring gear mesh with multiple planets, the number of load cycles on the revolution in relation to the carrier will be equal to the number of planets. The planets, however, will experience only one two-direction application of the load on the relative revolution. It meshes with the sun and ring, but the load is on opposite sides of the teeth, resulting in one completely reverse cycle of stress. Thus, the planet is considered a slacker, and Stress should be reduced by 30 percent of the value for a single-directional load application. As noted above, torque on the epicyclical epicyclical Planets. When analyzing the stress and lives of members we need to look at as a result of loading on each grid. We believe that the concept of grid torque is somewhat confusing in the epicyclical analysis of gears and prefers to look at the tangent load on each grid. For example, looking at the tangent load on the solar-planet grid, we take the torque on solar equipment and divide it into an effective number of planets and range. This touch load, combined with peripheral velocity, is used to calculate the power transferred in each grid and, adjusted for the load cycles on the rotation, the lifespan of each component. Figure 6: Odds 1 and 4,865, Odds 2 3.655, Weight 2422 In addition to these issues can also be an assembly of complications that need to be addressed. For example, placing one planet in a position between the sun and the ring captures the angular position of the sun to the ring. The next planet (s) can now only be assembled in hidden places where the sun and ring can be simultaneously involved. The least mesh angle from the first planet, which will hold the simultaneous grid of the next planet, is 360, divided by the amount of teeth in the sun and the ring. Thus, in order to collect additional planets, they must be blurred at multiples by this smallest grid angle. If someone wants to have an equal distance between planets in a simple epicyclical set, planets can be located equally when the amount of teeth in the sun and ring is divided by the number of planets per integrator. The same rules apply as part of the epicyclical, but a fixed connection of the planets adds another level of difficulty, and the proper distance between the planets may require match marking of the teeth. With multiple components in the grid, losses must be considered on each grid in order to assess the effectiveness of the device. The power transferred in each grid, rather than the input, should be used to calculate power loss. For simple epicyclical kits, the total power transmitted through the solar planet's grid and ring grid may be less input power. This is one of the reasons that simple planetary epicyclical kits are more effective than other reduction mechanisms. In contrast, for many connected epicyclical sets, the total power transmitted internally through each grid can be more than input power. What about the power in the grid? For simple and complex epiccyclic sets, calculate step line speeds and tangent loads to calculate power in each grid. Values can be derived from the planet's torque of relative velocity, and the operating diameter of the step with the sun and ring. United epicyclical kits present more complex questions. Elements two sets can be connected in 36 different ways with one input, one output, and one reaction. Some mechanisms split power, while some recycle power within the country. For these types of epiccyclic kits, tangent loads on each grid can only determined by free body diagrams. In addition, elements of two epiccyclic sets can be connected by nine different ways in a series, using one input, one output and two reactions. Let's take a look at a few examples. The split-strength combined set is shown in Figure 7, 85 percent of the transmitted energy flowing ring gear #1 and 15 percent of the gear ring #2. The result is that this connected set of gears may be smaller than a number of connected sets because the power is divided between the two elements. When epicyclical sets are connected in a series, 0 percent of the power will be transferred through each set (see Figure 7). Our next example is a power recycling kit. This set of gears occurs when torque is locked into the system in the same way as what happens in the four square test procedure to drive the car a pose. With torque locked in the system, the horsepower on each grid in the loop increases as the speed increases. Consequently, this set will experience much higher power loss in each grid, resulting in significantly lower unit efficiency (see Figure 8). Figure 9 shows a diagram of the free body of the epicyclical arrangement, which experiences power recycling. A cursory analysis of this free body chart explains the 60 percent efficiency of the recycling kit shown in Figure 8. Because the planets are tightly connected to each other, the summation of forces on two gears should be zero. The strength on the sun's mesh gear is the result of putting torque on sun gear. The force on the transmission grid of the second ring is the result of output torque on the ring gear. The ratio is 41.1:1, the output torque is 41.1 times higher than the input torque. Adjusted for the difference in the pitch radius of, say, 3:1, the force on the second planet will be about 14 times the force on the first planet in the solar grid. Thus, in order for the summation of forces to equate to zero, the tangent load on the first ring should be about 13 times the tangent load on the sun. Assuming that the speed of the step line will be the same on the solar grid and the ring grid, the loss of power on the ring grid will be about 13 times higher than the loss of energy in the solar grid (see figure 9). Additional considerations as the speed of the carrier increases, centrifugal forces on the planet become more and more significant; especially if they have a relatively large mass. These forces need to be solved on the planet bearing and often they are higher than the forces that transmit torque to the carrier. They should be considered on the planet with calculations. Lubricating the bearings of the planet can be challenging, especially at higher media speeds. These led to many very creative solutions. The study of patents on this subject would be useful. Keeping planet pins in heavily loaded sets can also be quite challenging. There will be deviations The press fits and cracks the welds. Free seizures can roll out of wells in the carrier, causing more than you would like to swim. Again, the study of patents will be fruitful. The final check that needs to be done, especially in the high ratio of planets, is the tip of the gap between neighboring planets. The time to find this answer is at the design stage... not when it adds complications to assembly. Figure 7: Split Nutrition United Set, Ratio - 40.9, Efficiency 97.4%. Calculations obtained using Gear's integrated software. Dos and Don'ts Now that we've looked at the epicyclical types of gears and mechanisms and their unique design characteristics, as well as a few examples, let's discuss the dos and don'ts of epiccyclic gear design. W: - Calculate the location of the planet - Identify the assembly match marks on the drawing - Address relative speeds - Divide the torque correctly - Analyze the planets as idling in simple epiccyclic sets - Check the planets for od-interference - Use free body charts Not: - Strictly correct all members if the app doesn't require it. 8: Set with recycling power, ratio 41.1, efficiency 61.6%. Calculations obtained using Gear's integrated software. Design Tips and Pitfalls In conclusion, here are some design tips to cover and trap to avoid as you design epicyclic gears. Keep in mind that designing on standard centers will result in higher specific slip and lower efficiency. If you deal with mesh, removing one tooth from the planet gear will enhance both the sun and the mesh ring. Be sure and allow you to swim or specify a very dense location and unloading tolerances or load sharing will be smaller than expected. Finally, use tangent loads and line speeds to determine grid energy transfer and loss. Fig. 9: Free body chart system, like any skill, designing epiccyclic gear is something that becomes easier with practice. As the outing engineers take their know-how with them, younger engineers remain to pick up where they left off. While this short primer may not cover all the nuances of epiccyclic gear, hopefully it will serve as a jumping-off point for engineers tasked with designing their first epic series of gears, and perhaps even acting as a casual retraining for a more experienced designer. The UTS Integrated Gear Software (IGS) methodology was used to perform the calculations shown in Figure 7 and Figure 8. IGS is a comprehensive gear knowledge system that helps designers optimize their designs, noise and premature failures, reduce design and production costs, and reduce time to market. For more information on epiccyclic gears, visit ANSI/AGMA 6023-A-88 or ASME Paper 68-MECH-45. Gear. Gear.