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**Planetary Gear Trains**

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Planetary gear trains are one of the main subdivisions of the simple epicyclic gear train family. The epicyclic gear train family in general has a central "sun" gear which meshes with and is surrounded by planet gears. The outermost gear, the ring gear, meshes with each of the planet gears. The planet gears are held to a cage or carrier that fixes the planets in there orbit relative to each other.

There are five distinct advantages to using an epicyclic gear train as opposed to a single load path parallel gear train:

1) Because they share load between several gear meshes, epicyclic trains take up less space and have a lighter weight.
2) Because they share load between several meshes, epicyclic trains have smaller and stiffer components that lead to reduced noise and vibration while increasing efficiency.
3) The input and output shafts of epicyclic trains are concentric so no bending moments or torques are created from radial forces that develop from the change of the force's line of action.
4) The input and output shafts of epicyclic trains are concentric so driver and driven equipment can be mounted in line, providing additional space savings.
5) The reduced size of epicyclic components often offsets the cost of additional parts, especially when manufacturing many gear trains. In very high horsepower units the components of parallel shaft designs become so bulky that epicyclic trains gain a further economical advantage.[2]

As with all design choices, there are disadvantages to epicyclic gear trains:

1) Complexity.
2) Assembly of gear trains is limited to specific teeth per gear ratios.
3) Efficiency calculations are difficult.
4) Driver and driven equipment must be in line to avoid additional gearing.

The three main types of simple epicyclic gears are the planetary, the star, and the solar. These three types differ only in arrangement. The arrangement is changed by the gear that is fixed. A planetary train has a fixed ring which allows the planets to output an input from the sun. A star train has a fixed cage; inputs to the sun gear rotate the individual planets, which allow the ring to output the torque. The solar train holds the sun gear fixed; input from the ring causes the planets and cage to rotate about the sun to produce the output. Modifications to the fixed arrangement will have large effects on gear ratios, speeds, and torque.[1]

| ***Arrangement of epicyclic train*** | Fixed Member | Input Member | Output Member | Over-all Gear ratio | Range of ratios normally used |
|---|---|---|---|---|---|
| Planetary……………………… | Ring | Sun | Cage | (N_r/N_s)+1 | 3:1-12:1 |

| | | | | | |
|---|---|---|---|---|---|
| Star……………………………. | Cage | Sun | Ring | (N_r/N_s) | 2:1-11:1 |
| Solar…………………………… | Sun | Ring | Cage | (N_s/N_r)+1 | 1.2:1-1.7:1 |

N_s=number of sun teeth, N_p=number of planet teeth, N_r=Number of ring teeth (per gear)
Table re-created from "Gear Handbook" By: Darle W. Dudley, McGraw-Hill books, pg. 3-15, 1962

Epicyclic gear trains are gaining in popularity and have found use in a variety of applications over the past 300 years. James Watt patented a sun and planet gear to be used with one of his early engines in 1781. More recently, the aircraft industry has made extensive use of epicyclic arrangements as virtually all propellers and turbine driven planes can makes use of them. Automatic transmissions use a series of complex epicyclic gears to provide gear ratio changes. Epicyclic trains can even be combined to produce power feedback systems that allow for free rotation if an extreme feedback load is applied; such combinations have been implemented on lawn mower self propulsion units.[1]

The advantages of an epicyclic gear train can be readily seen in an example shown in ref 2:

> "Let us take a 1000-hp electric motor at 1800 rpm driving a compressor at 7200 rpm. The required American Gear Manufactureres Association (AGMA service factor is 1.6.
> A hardened and ground, helical, parallel shaft gear set would have the following dimensions:
>
> Pinion pitch diameter: 4.0in
> Gear pitch diameter: 16.0in
> Face width: 4.0in
> Gearbox envelope: 24x12x12in.
> Gearbox weight: 650 lb
>
> The equivalent planetary gear set with a stationary ring gear and rotating carrier would have the following dimensions:
>
> Sun pitch diameter: 3.5in
> Ring pitch diameter: 10.5in
> Planet pitch diameter: 3.5in
> Face width: 3.0in
> Gearbox envelope: 15in diameter x 10 in length
> Gearbox weight: 250 lb"[2]

So you've decided to implement an epicyclic gear train in your design, there are a few steps you need to follow:

1) Determine the required output gear ratio.
2) Determine an arrangement that satisfies the ratio requirement.
3) Determine the number of ring and sun teeth from the table above.
4) Determine the number of planet teeth and planets needed to assemble the ring and sun.

5) Consult one of the following references to conduct a stress analysis.
6) Consult one of the following references to conduct a fatigue analysis.
7) Consult one of the following references to determine machine-ability and methods there of.
8) Have your new epicyclic gear train manufactured.

The following books were used in completing this report and will be beneficial to the design of your epicyclic gear train:

1) Dudley, Darle. "Gear Handbook: The Design, Manufacture, and Application of Gears." Pgs. 3-14/3-20, The McGraw-Hill Book Company, Inc. 1962.
2) Lynwander, Peter. "Gear Drive Systems: Design and Apllication." Pgs. 293-323. Marcel Dekker, Inc., 1983.
3) Parmley, Robert O. "Illustrated Sourcebook of Mechanical Components" pgs. 1-22/1-31, The McGraw-Hill Book Company, Inc.