Understanding, Selecting and Applying Planetary Gearheads

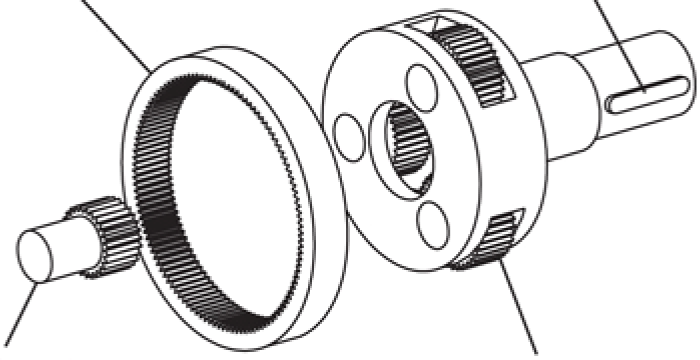

Figure 1 - The basic components of a planetary gearhead.

Basics of planetary gearheads

Planetary gearheads are used on high precision motion control applications that require a high torque to volume ratio (ranging from a factor of two to a factor of 100, depending on the ratio), high torsional stiffness and low backlash the specifics of which will vary by application. Planetary gearheads increase the torque by the factor of the gearhead ratio. A planetary gearhead will also reduce the motor speed by the gearhead ratio, making it possible to run the motor at a higher, more efficient rpm. The inertia reflected back to the motor is reduced for increased stability. Finally, using a planetary gearhead allows machine builders to use a smaller, less expensive motion control package.

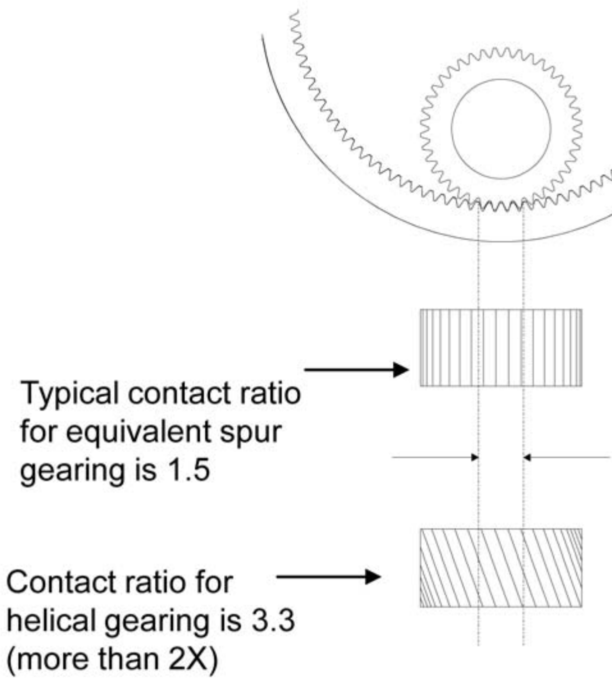

Figure 2 – Micron UltraTRUE™ and ValueTRUE™ design feature a 15° helix angle for higher torque and precision capabilities, and smoother, quieter operation than most competitive options with helix angles of 12° or less.

Helical gearing improves the performance of a planetary gearhead by increasing the contact ratio. The contact ratio is defined as the number of teeth in mesh at any given time. The typical contact ratio for spur gearing is 1.5 while the contact ratio for helical gearing is more than doubled to 3.3. The increased contact ratio provided by helical gearing provides:

- 30% to 50% more torque capacity than spur type planetary gearing
- Increased load sharing which results in longer life
- Smoother and quieter operation
- A reduction in backlash of 2 arc-min

The helix angle of the gearhead also has a significant impact on performance, as the higher the helix angle, the more teeth in the mesh at any one time. So increasing the helix angle from the typical 12° to 15° results in a 17% to 20% increase in torque capacity over conventional helical gearing, and a 40% increase compared to straight cut spur gears. A 15° helix angle also provides smoother and quieter operation.

The helical cut of the gear teeth causes an axial load on the motor shaft. This needs to be compensated for in the bearing design of the gearhead. Many helical gearheads use ball bearings with little or no axial load capabilities. This can contribute to gearing or motor bearing failure. A better approach is the use of tapered roller bearings, such as are used in all Micron Helical gearheads, to completely compensate for this axial load.

Single-stage planetary gearheads provide possible gear ratios ranging from 3:1 to 10:1. The gear ratio can be no higher than 10:1 because the pinion gear can be made only so small. Gear ratios of less than 3:1 are not possible with a planetary design since the pinion and outer ring gear would need to be nearly the same size, which would not leave room for the planet gears. A gear ratio range between 4:1 and 8:1 provides optimal pinion and planetary gear size, higher performance and longer life. Gear ratios of greater than 10:1 can be achieved with an additional planetary stage, although this will normally add to length and cost.

Crowning is a modification of the gear tooth profile that optimizes gear mesh alignment in order to increase torque capacity and reduce noise. It also enhances load distribution on the tooth flank, thereby reducing high stress regions that can result in surface pitting.

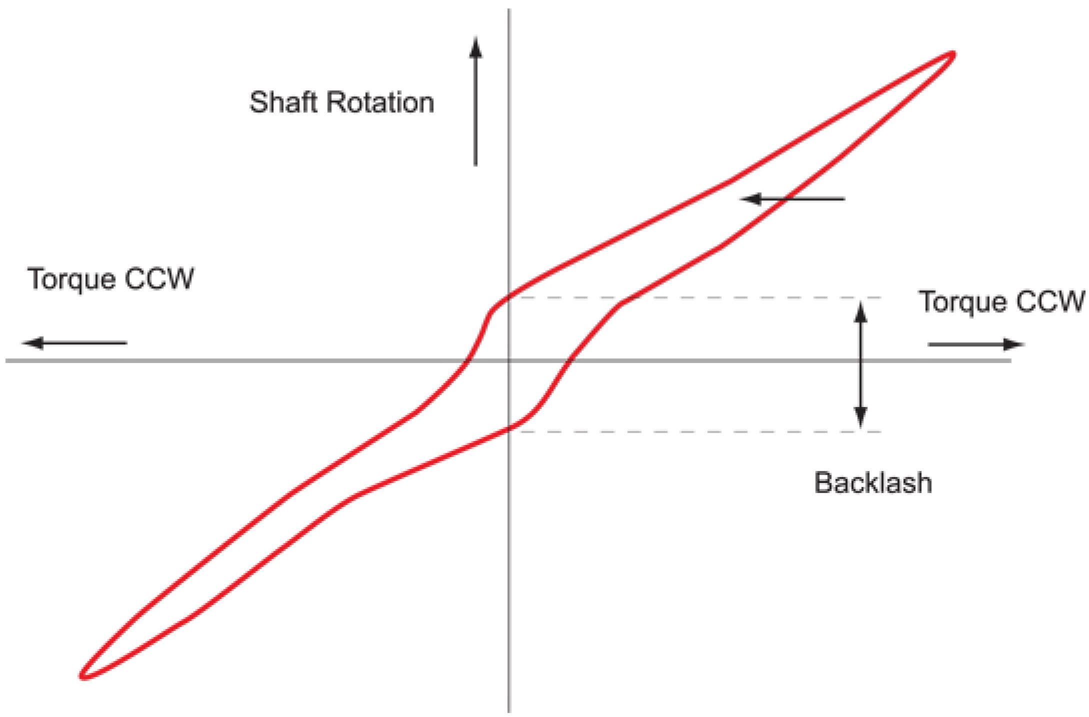

Figure 2 - Lost motion.

A certain amount of clearance is needed for a planetary gearhead to function effectively. Clearance helps avoid excessive heat and wear in the gearing and ensures proper lubrication. But the small gap between the gear teeth leads to lost motion. Real-world gearheads also cannot have infinite torsional stiffness, so additional lost motion is generated by windup in the gearhead. Figure 3 shows the rotation of the input and output shafts of a planetary gear. The vertical distance between the two lines is lost motion.

There is no strict standard regulating how gearhead backlash should be measured. This leads to some confusion and misconceptions. Some manufacturers may take an average of four or more points on the output shaft to provide a backlash specification. For example, using this method a unit with backlash measurements of 4, 6, 10 and 12 arc-min. would have a rating of 8 arc-min. This author takes the position that backlash should be rated at the highest point on the output shaft so the measurements stated above should yield a 12 arc-min measurement. Additionally, some manufacturers measure backlash by applying less than 2% of the rated torque, which produces a lower backlash measurement and doesn't provide true backlash ratings over the entire life of the product. Other manufacturers measure backlash by using 2% of the rated torque as standard to provide backlash ratings that are true for the life of the product.

Backlash will increase over time. A planetary gearhead might have a backlash of 8 arc-min out of the box but increase to 15 arc-min over six months of use, for example. So the accuracy of a planetary gearhead over its lifetime is an important specification for most users.

Gearhead sizing and selection

Proper gearhead sizing and selection is critical to achieving long and reliable life. The following approximate method can be used as a starting point.

Application Torque (Tr) – Continuous Motor Torque (Tm) x Ratio x Efficiency (e)

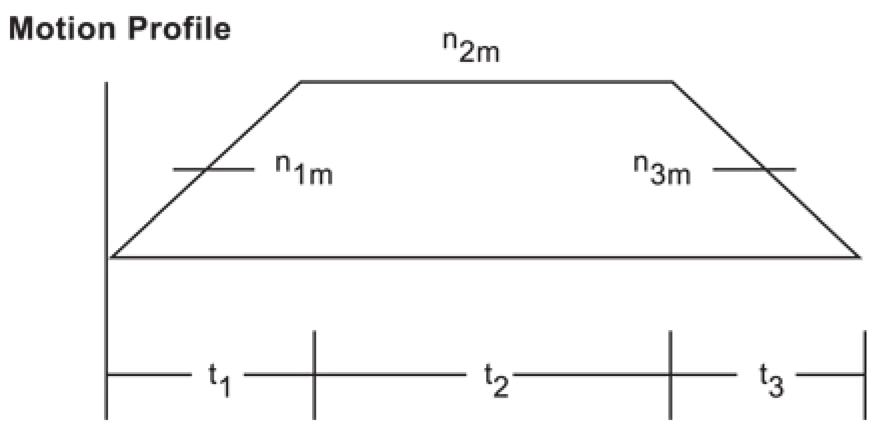

Figure 3 - Complete motion profile.

Determining the exact gearhead sizing requirements requires consideration of the complete motion profile including speed, torque, acceleration, deceleration and cycles. A de-rating factor can be used to reduce the rating to take high cycling into consideration.

De-rating Factor	Cycles per hour
1.0	Less than 1000
0.9	1000 to 2499
0.7	2500 to 4999
0.5	5000 or greater

The de-rating factor is not applicable to continuous duty applications that run 24 hours a day, 7 days a week, because there is no cycling so the exact sizing method cannot be used. The most common cause of failure in continuous duty applications occurs when the gearhead heats up, the lubrication breaks down and the gearing fails. High performance gearheads, such as Micron EverTRUE™, are available that are designed to run 24 by 7, operate under 140F and last more than 30,000 hours.

Online selection and sizing

Online gearhead sizing and selection tools are available that provide a quick and easy way to find the right gearhead for most any application. A very comprehensive sizing tool, Micron MOTIONEERING® (www.micronmotioneering.com) provides a quick and easy way to find the right gearhead for most any application. The "Sizing and Selection" mode allows users to enter application parameters such as RPM, output torque, radial and axial load, etc. The tool takes this information and recommends possible solutions suited to the specific application needs. Users can use things like price, torque capacity and other specifications to choose between different solutions.

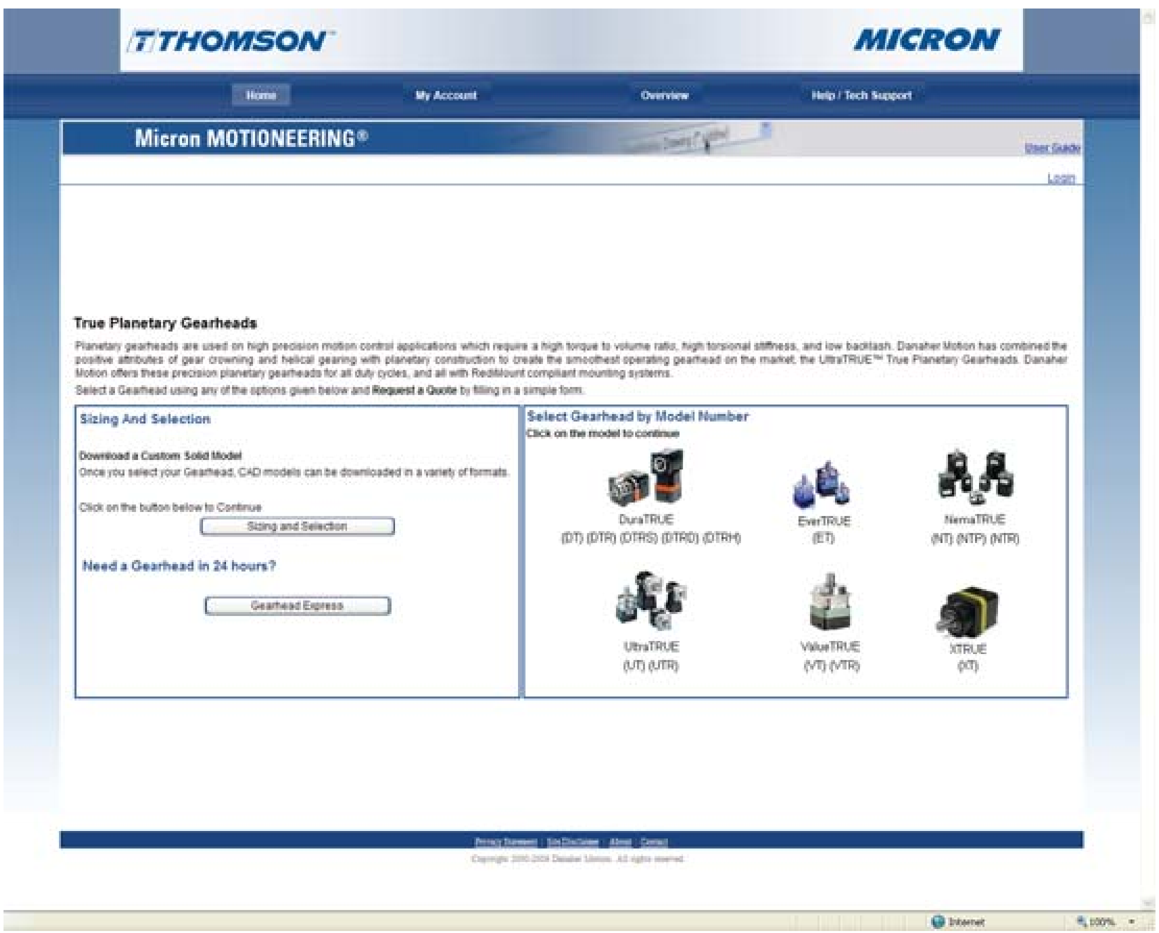

Figure 4 - First screen of "Sizing & Selection" process.

On the first screen of the sizing and selection process, four critical pieces of information need to be entered:

1) Gearhead type or orientation (in-line or right angle)

The right angle gearhead type has three separate options available: standard shaft, dual shaft and hollow shaft.

2) Application type

Choose between “Cyclical Operation” and “Continuous Duty”. Any application that is running in one direction for four hours or more without stopping or changing speeds is considered continuous duty. All other applications, including those that run for more than four hours but change direction, are considered cyclical operation.

3) Backlash requirement

- Ultra Precision” class has a maximum backlash specification of 4 arc-min for single stage and 5 arc-min for double stage.
- “High Precision” class has a maximum backlash specification of 8 arc-min for a single stage and 9 arc-min for a double stage.
- “Precision” class has a maximum backlash specification of 13 arc-min for a single stage and 15 arc-min for a double stage.

4) Ratio

After choosing the first three variables, the tool shows users the ratios that are available for those combinations. For example, if one selects an in-line orientation, the 1:1 and 2:1 ratios will be “grayed out” since they are only available in a right angle.

Next, there are two ways to enter the torque and speed requirement. The first option is to enter these as maximum torque requirement and RPM. Either input or output RPM can be entered and the tool will calculate the other. For more complex applications, users also have the option to build a complete motion profile. Each segment of the motion profile requires entry of: the speed at the beginning of the segment, the speed at the end of the segment, the segment time and the torque during the segment. After these requirements are entered, users then have the option to enter any radial or axial loads that may be present in a given application.

The final step is to select the motor mount. Mounts are available for over 300 of today’s most popular motor manufacturers and model numbers. Users simply select their motor from the pull-down menu and the tool automatically generates the motor mount part number. The motor dimensions will also be populated on the screen for reference.

Although a large selection of motors is available, there will be times when one cannot find the motor they are using on the list. For this reason, the tool has an option to manually input motor dimensions. The critical dimensions such as the shaft diameter and length, the bolt circle and the pilot diameter are used to generate the motor mount kit number needed for the gearhead. Users can enter these dimensions in either English or metric.

After entering all application parameters, the tool provides a summary all of the available gearheads that meet the application criteria, sorted by price from the most economical solution to the most expensive. The safety factor between the required torque and the gearheads rated torque will also be listed for every solution. After a given solution is selected, users have the option to download a 2D or 3D model, request a quote or save the application.

The "Select Gearhead by Model Number Mode" is used when one already knows which gearhead is desired. It allows users to view list pricing, catalog specifications and download a CAD model. From the home page one can access this tool by clicking on any of the gearhead families listed. From here users can pull down product type, frame size, ratio and the desired motor mount kit. If the motor mount kit is unknown, the user can enter the dimensions as explained above. From here the tool takes the user directly to the solutions screen where you can view pricing, lead time and catalog information for the given gearhead. Again, after a given solution is selected users have the option to download a 2D or 3D model, request a quote or save the application.

Troubleshooting

Factors that contribute to gearhead noise include input speed, gearhead ratio, output torque, radial and axial loads and mounting errors.

Noise

Following the proper mounting procedure is critical to minimizing noise and maximizing performance. Many gearheads need to be mounted to the servo motor in a vertical orientation first. This allows the motor shaft to center the gearhead. After being mounted to the motor, the gearhead can be used in any orientation.

Friction

High gearhead friction and drag may be caused by grease volume, gear quality, component dimensional accuracy and bearing quality. Look for a gearhead manufacturer that tests every gearhead for input drag before shipment. Each size and ratio has an acceptable range for drag. Drag should be measured in both directions for peak drag and speed.

Figure 5 – Micron AquaTRUE™ Planetary gearhead with IP67 protection.

Sealing

For applications that require IP65 or IP67 protection, be sure to note that an IP65 motor and an IP65 gearhead in combination do not always provide IP65 protection. Look closely at how the interface between the motor and gearhead are sealed. The best approach is to use an O-ring seal between all housings for IP65 protection on the full assembly. A new type of planetary gearhead meets the requirements of food and beverage handling, packaging and dispensing by providing a round stainless steel housing with no external seams and IP67 protection. Such gearheads can handle caustic cleaning chemicals and high pressure washdown, so engineers can place the gearhead anywhere regardless of environmental factors, eliminating the cost of additional components such as enclosures, shielding and mechanical transmissions.

Lubrication

Either oil or grease may be used to lubricate planetary gearheads. Grease has the advantage of providing lubrication for the lifetime of the gearhead, eliminating the need for maintenance. Grease enables the gearhead to be mounted in any orientation and eliminates concerns about leakage. Oil requires maintenance and re-lubrication, usually every few thousand hours. Leakage is always a concern with oil lubrication. The orientation of gearhead with oil lubrication is usually restricted, must be known at the time of the order and usually cannot be changed. A common misconception is that oil filled units always run cooler than grease-filled units. Actually, the sealing required for an oil-filled gearhead generates more heat than the oil saves.

Applications

Here are some typical planetary gearing applications:

A high speed planetary gearhead makes it possible to automatically slice meat, bread and frozen foods at speeds up to 4 slices per second. The slim right angle design fits into the machine envelope and provides quiet and smooth operation.

In a cartoning application, a planetary gearhead runs at high speeds 24 hours day, 7 days a week for 30,000 hours. The high torque/size ratio of the gearhead reduces the envelope size and footprint of the machine. The gearhead is lubricated for life so no maintenance is required.

Figure 6 – Plasma cutting machine.

A planetary gearhead can help achieve cutting accuracy down to a few tenths of a thousandth of an inch on plasma cutting machines by providing exceptionally low backlash. Helical crowned gearing provides fast positioning and smooth cutting. The gearboxes are sealed to avoid exposure to the abrasive dust generated by plasma cutting.

A manufacturer of cardio vascular scanning patient tables selected planetary gearheads that were supplied mounted to the motor, shipped and tested as one part number. The result was a simplified Bill of Materials and reduced assembly time. The planetary gearhead passed the customer's noise and vibration test on the first try, and also met a strict backlash requirement.

Conclusion

Planetary gears provide an excellent solution for a wide range of precision motion control applications. Understanding the backlash measurement used by the gearhead manufacturer is important to selecting the best gearhead for the application. Online selection and sizing tools can save design engineering time by making it easy to compare the planetary gearheads that fit a particular application, and new planetary gearheads with IP67 protection make it easier than ever before to apply this power transmission technology in food and beverage and other critical applications.

Linear Motion. **Optimized.**

[redacted] years of motion control innovation and quality, Thomson is the industry's premier producer of Linear Ball Bushing® Bearings and Profile Rail Bearings, 60 Case™ Shafting, ground and rolled Ball Screws, Linear Actuators, Gearheads, Clutches, Brakes, Linear Systems, and related accessories. Thomson invented the Linear Ball Bushing Bearing in 1945, and has set the standard ever since with an unsurpassed set of mechanical motion control solutions serving global commercial and aerospace & defense markets. Thomson Industries, Inc. has facilities in North America, Europe and Asia with over 2000 distributor locations around the world.