Serv-O-Link · 5356 West Vickery · Fort Worth, TX 76107 · (817) 732-GEAR
Email: sales@servolink.com · WWW: http://servolink.com

SERV-O-LINK Corp.

DRIVE DESIGN HANDBOOK

HISTORY

George S. Bohannon was a machine designer for Crown Tool & Machine Company during the mid 1940's. His employer was one of many sub-contractors producing machined parts used specifically in the construction of the legendary Norton Bombsight, the device that gave our bomber crews a distinct advantage during WW II. Bohannon's talents for designing machines to produce precision parts gained Crown top recognition as a government sub-contractor. Crown was the only company to receive a "Zero Defects" citation for their performance in the Norton Bombsight program, quite an accomplishment since there were over forty other companies producing the very same parts.

By the end of WW II, Crown Tool & Machine had grown in both size and capabilities and was looking for new products to replace their military business. Bohannon had developed an interest in a relatively new process called 'injection molding'. He was convinced that injection molded plastics would change the way we produce products in the future, management agreed. Within the next two years Bohannon designed three different models of an early injection molding machine known as the Crown Moldmaster. Bohannon was awarded a number of US patents for innovative features he incorporated into these early machines. During the following decade, Crown Moldmaster machines were used across this country and were considered by many to be 'the workhorse' of the plastic industry.

In 1958 Bohannon, eager to pursue his on his own goals, founded Bohannon Industries. Using several newly designed and improved molding machines, his new company began producing a variety of small precision parts for the electronic industry. Sensing a need for a 'family' of products, he introduced the chain & sprocket line in 1960. These products found immediate applications throughout the industry. The company became incorporated and the name was changed to SERV-O-LINK Corporation. To compliment the chain and sprocket products the company introduced their series of 32 pitch and 48 pitch spur gears in 1975.

TODAY

SERV-O-LINK'S precision molded gears and chain drives are employed in a wide variety of quality instruments throughout the world. We maintain a complete factory inventory of all gear, sprocket and chain products we produce. By doing so, we offer our customers the cost advantages of injection molded gears, sprockets and drive chain along with "off the shelf" availability.

QUALITY BY DESIGN

All of our mold cavities are purposely tooled to produce an oversize product. Once molded, the finished parts are placed in specially temperature programmed ovens which "heat treat" the finished product. Heating the product over time accomplishes several very important things. First, the oversize part will shrink to it's proper dimension. Secondly, the oven heat will relax many of the stresses introduced during the molding process, thereby lessening the possibility of premature failure due to stress fractures.

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DESIGN ASSISTANCE

Designing SERV-O-LINK gears or chain drive into a new product in the 60's and 70's, required one to work with a series of curves and graphs. Those curves and graphs represented an accumulation of data derived from many hours of testing the physical characteristics of our products such as elasticity, yield and wear factor. To compute the perfect center distance for a two sprocket chain drive could take a half hour, IF one had one of those new calculators that could perform trig functions. During the 80's, the widespread application of desktop computers prompted SERV-O-LINK to develop and introduce a software program known as 'DRIVE DESIGN PC.' DRIVE DESIGN PC, was introduced in 1988 as a 'freeware' program and distributed widely.

CONFIDENCE

The service life calculations generated by DRIVE DESIGN PC are extremely conservative figures, giving the user quick results with an excellent margin of confidence. Most chain drive applications incorporate a drive sprocket which transfers power to a load sprocket and less than half of the chain is actually under load at any time. Our life test fixture used to established wear data on the chain, subjected the entire chain test sample to 100% of the load for 100% of the time.

The **DRIVE DESIGN** software program has now been implemented as an online design tool to assist the designer in using SERV-O-LINK gears, chain and sprockets. Many of the formulas used were derived from standard engineering reference books. **DRIVE DESIGN** will make the task of designing drive mechanisms easier and more reliable.

DISCLAIMER

SERV-O-LINK Corporation does not assume any liability arising out of the application of the **DRIVE DESIGN** software program or the use of any product described herein, nor does it convey or extend any license to the user which might infringe the patent rights of others.

Each of these programs assumes that gears or chain and sprockets will be used at 75 degrees Fahrenheit. Operating at higher temperature will necessitate appropriate de-rating due to the reduced yield strength of **Delrin®.**

CHEMICAL RESISTANCE

DuPont Delrin® material used to produce all SERV-O-LINK drive components exhibits phenomenal resistance to most chemicals, particularly to commonly used solvents and cleaning solutions. Salt water, oils and even strong solvents have no adverse effect on our products.

OPERATING TEMPERATURE

SERV-O-LINK drive components are designed to provide continuous service from -40° F to 180° F and intermittent service to 250° F. Prolonged use above 180° F is not recommended. **Delrin®** exhibits a yield strength of 10,000 psi at 75° F. For applications above 75° F we can expect the yield strength to decrease by approximately 10 percent for every 32° F increase in temperature. This reduction in strength means that load ratings which assume 75° F operation should be reduced by the same proportion, based on the maximum operating temperature. Another factor which should not be ignored for elevated temperature is the thermal expansion coefficient of **Delrin®**: (4.5 X 10^{-5} / ° F).

While this is of little importance in most chain and sprocket applications, some designs using gears at elevated temperatures may require slight correction of shaft center distance to maintain gear tooth clearance.

INSPECTION AND QUALITY ASSURANCE

SERV-O-LINK products are molded exclusively from DuPont **Delrin®** acetal resin using 100% virgin material. Each part is subjected to rigorous inspections from start to finish. For example: SERV-O-LINK chain is 100% inspected for width, thickness and pitch tolerance. The chain must then pass a 7 pound momentary break strength test. Precision gauging equipment and testing instruments are used to monitor each step of the production cycle to insure a reliable and consistently uniform product.

SERV-O-LINK CHAIN AND SPROCKET FEATURES

- **Versatile**

SERV-O-LINK chain and sprockets provide the designer with a unique and highly versatile means of transmitting rotary power. SERV-O-LINK's unit-link chain design eliminates the need for a master link. The snap-together feature also makes the chain adjustable to any loop length without the need for special splicing tools.

- **Ease of Installation**

Since SERV-O-LINK's chain requires no special tools or fixtures, installation can be accomplished by unskilled personnel. Should field replacement be required, this again can be accomplished with minimal effort and disassembly of associated components.

- **High Operating Speeds**

The chain can be operated to 1000 feet per minute (12,000 RPM) around the 8 tooth sprocket. The limiting factor in the case of the 8 tooth sprocket is pivotal friction generated as the chain passes around the small diameter. Centrifugal force contributes little to the total load tension due to the low mass of the chain. Example: the centrifugal force on a chain link running around a 48 tooth sprocket at 12,000 RPM is approximately 1/6 pound or 2.66 oz.

- **Elastic Properties**

SERV-O-LINK chain will provide excellent service in applications requiring operating load tensions of 2 pounds or less. Momentary load tensions of 4 pounds can be tolerated during rapid acceleration and deceleration. The elastic properties of the chain provide excellent recovery characteristics from such overloads.

Table (1) describes the elastic properties of the chain.

TENSION (oz.)	**ELONGATION** (percentage)
1	0.1%
2	0.16%
4	0.26%
8	0.40%
12	0.53%
16	0.66%
32	1.10%
64	2.00%

TABLE (1) – Elastic Properties of SERV-O-LINK Chain

PRELOADING

Continuous static tension such as that provided by preloading or spring loaded idlers is recommended only if these tensions are kept low, (0.2 pounds or less). Spring loaded idlers cushion the high starting and stopping torque, but they also subtract from the total tension rating of the chain.

SERVICE LIFE

In any application, the total service life of the chain is determined by the amount of permanent elongation that can be tolerated. Life tests were conducted on chain samples in order to establish the rates of elongation at various tension loads. Each test was performed using 1 foot lengths of chain operating at .5 pound, 1 pound, and 2 pound tension loads. In all tests, the chain was running at 650 feet per minute. Tests were conducted using sprocket sizes which varied from the smallest 8 tooth to the 48 tooth. The 8 tooth sprocket subjects the chain to worst case pivotal wear. Each was concluded once an elongation of 2% had occurred. While 2% elongation by no means represents the end of the service life of the chain, it does represent a point where noticeable slack in the chain has occurred and adjustment in some applications might be necessary.

From this data a software program was developed to assist the designer in estimating service life of the chain. Keep in mind that static load produces no measurable pivotal wear; only running loads produce pivotal wear.

SPROCKET CENTER DISTANCE

One of the software programs included computes the ideal shaft center distance for sprockets. The ideal center distance being a dimension that provides minimum slack in the chain without preloading. The designer must first select the sprockets which generate the desired ratio. Next select an approximate center to center dimension. You'll find this program quite user friendly.

When center distance between shafts is fixed and cannot be changed, the designer should consider using an adjustable idler to remove excessive slack in the chain. Since either side of the chain can run against a sprocket, physical placement of an idler leaves several choices, but ideally the idler should be near the midpoint of the two main sprockets.

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DESIGNING WITH SERV-O-LINK'S DELRIN® SPUR GEARS

GEAR PRIMER - UNDERSTANDING GEAR PITCH

When describing spur gears, the term **'Diametral Pitch'** or simply **'Pitch'**, is used to define tooth spacing, tooth height and tooth width. **Pitch** also defines the diameter of a gear having a given **N**umber of teeth. When using the term **Pitch**, be aware that all dimensions are expressed in inches.

There are two important dimensions frequently used when designing gear mechanisms – **Outside Diameter** and **Pitch Diameter**. **P**itch **D**iameter or **'PD'** - is the circle that describes the contact point at which one gear engages another gear. **PD** is used to calculate the **C**enter **D**istance or **'CD'** between two mating gears **Outside Diameter** or **'OD'** is the circle described by the outer tips of the gear teeth. The **OD** of a gear is easily measured using calipers while the **PD** measurement generally requires special procedures and equipment.

The following parameters will become more meaningful as we examine their relationships.

P = Diametral **P**itch
N = **N**umber of teeth
PD = **P**itch **D**iameter
OD = **O**utside **D**iameter
CD = **C**enter **D**istance

P = **N**umber of teeth **/** **P**itch **D**iameter

P = (**N**umber of teeth + 2) / **O**utside **D**iameter

CD = (**PD**1 + **PD**2) / 2 *where PD1 & PD2 = PD of mating gears*

CD = (**N**1 + **N**2) / 2 **P**itch *where N1 & N2 = Number of teeth of mating gears*

SELECTING PITCH

When selecting SERV-O-LINK spur gears for any drive mechanism, the designer should first define certain operating conditions which will effect gear performance. These conditions include operating torque, RPM, stall torque, and operating life. Once these conditions are defined, the **Pitch** can be selected. When torque and shock loads are high, select the 32 pitch. When torque is low and RPM is high, the 48 pitch gear can offer equal or better performance since tooth friction (wear) decreases.

The procedures and equations used in this software (which computes **Gear Life Approximations**) assume that only one tooth of each gear is carrying the entire load. By making this assumption, a much simplified approach may be applied when making these computations.

STALL TORQUE LOADS

Certain applications require a gear to withstand stall torque loads which are significantly larger than actual running torque. To compute the maximum stall torque load, choose the **Gear Life Approximations** utility. Enter the **Pitch**, number of teeth and torque. Compute the **Gear Life Approximations** and observe that the results are greater than zero. Continue to this procedure while increasing the torque parameter until the results indicate a **Life Cycles** equal to or near 0.01 million.

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SHOCK AND IMPACT LOADS

The designer must use good judgment when applying stall torque calculations to gears that are subject to high shock or impact type loads. In any case the shock or impact load should never exceed the maximum stall torque load by more than 20%.

BACKLASH

Backlash is the amount by which the width of tooth space exceeds the width of the engaging tooth on the pitch circle. This is frequently encountered with ***poor quality*** gears because no compensation was made for tooth width shrinkage. A minimal amount of backlash must be incorporated on any design simply because of tolerances in mounting, tooth shape, and position. A typical method of providing backlash is to extend the center distance of meshing gears. SERV-O-LINK gears have a pitch circle tolerance that is + 0.000" and – 0.010". This has the additional advantage of allowing more clearance between the outside diameter of one gear and the base diameter of the mating gear such that the gears can expand at high temperatures without radial interference.

Since plastic gear teeth deflect more than metal teeth, backlash is not as critical when considering gear errors. However, sufficient backlash must be provided to prevent gears from binding where expansion due to heat is a factor. Heat can be due to ambient conditions as well as friction due to high speed operation.

For gears operating at moderate loads and speeds in room temperature environments, performance does not appear to be affected by reasonable variations in backlash. Suggested backlash (measured at room temperature) for both 32 and 48 diametrical pitch is typically between 0.002" and 0.004". Obviously for higher speed and higher load demands, additional backlash should be provided to compensate for thermal expansion.

METHODS OF FASTENING SERV-O-LINK GEARS

PRESS FIT

SERV-O-LINK gears are designed to press fit on standard fractional inch shaft sizes. This method works very well in many applications requiring low to moderate torque. In addition, producing custom shaft sizes is quite simple provided the maximum O.D. of the custom shaft size is no larger than our standard shaft sizes. These typically include metric dimensions or any dimension in between.

SHAFTS WITH FLATS

Since most custom shaft sizes require limited tooling changes, shafts with flats can be accommodated as well. SERV-O-LINK routinely provides "D" holes in addition to other custom configurations to customer requirements.

KNURLING

SERV-O-LINK gears can be pressed onto knurled shafts or knurled bushings. This provides much higher torque fastening method. The shaft or bushing should have a straight knurl of typically 120 to 160 diametrical pitch. If a knurled bushing is used it can also incorporate a set-screw or other securing methods.

PINNING

Roll pins have been used very successfully to secure gears to shafts. The cost is low, however two of the most common objections are: the addition of a hole in the shaft tends to weaken the shaft and disassembly becomes difficult.

HUB CLAMPS

Hub clamps work very well and the cost is moderate. They are generally limited to use on larger sprockets and gears.

Delrin® is a registered trademark of E. I. du Pont de Nemours and Company for its brand of acetal resin.