This technical information has been contributed by

Stoffel Polygon Systems, Inc.

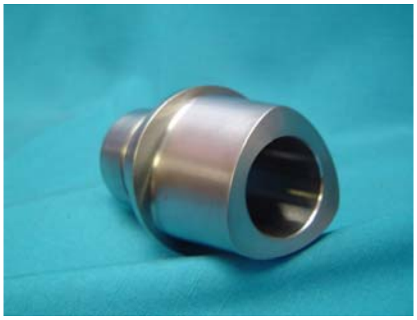
THE ULTIMATE SHAFT-TO-HUB CONNECTION

Polygon Shapes - Multi-Faceted Problem Solvers

Kinematically ground polygonal shapes have been used as drive connections for more than 45 years. What is now referred to as Polygon Systems was developed by Fortunawerke, Stuttgart, West Germany, who patented a grinding machine capable of producing matched polygonal shaft and bore diameters.

The unique feature of the machine which made this possible was its wheelhead. Using a mechanical drive system, the wheelhead could be set to move the grinding wheel in an elliptical path to keep the wheel to the norm of the centerline of the workpiece as the work was rotated. By setting a ratio between the cycles of wheelhead movement and part rotation, polygons could be generated with any number of "sides" beginning with two, an oval shape.

The most commonly used shapes today have either three or four lobes, or sides. The three-lobed polygon can also be ground with a taper on the shaft and in the bore for an interlocking engagement. Three and four lobe forms can be press or sliding fits. Originally intended as a substitute for drive connection, using splines, keys, flats and serrations, polygons have now found their place in many other applications.

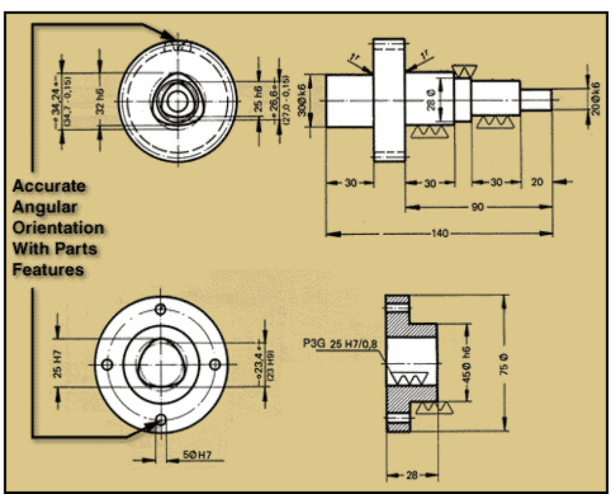


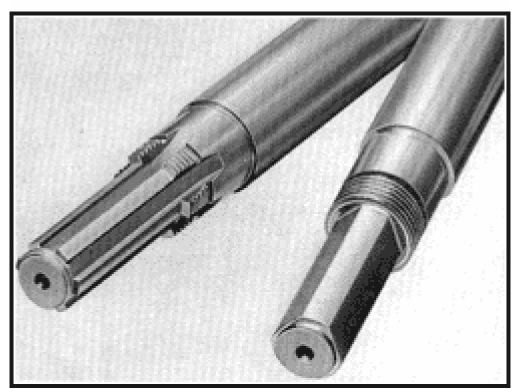
Our company is a contract shop providing the specialized grinding service. In the past years, few manufacturers had sufficient production to justify purchasing a Fortuna Polygon Grinder, although a number are being used proprietarily.

Polygon systems are also widely employed for repair of damaged drive connections. When costly shafts and hubs incorporating spline drive connections have failed through damage to the teeth, it is no longer necessary to totally replace them. This will also be discussed and illustrated later.

Why, Where, And When To Use Polygons are not the answer to all problems. They provide optimum results, but are not usually considered when less than optimum performance is satisfactory. Often, less costly methods will do. Generally, these are the reasons designers turn to polygons:

- To overcome the problems usually found with spline connections, such as failure caused by various torsional effects.
- To eliminate stress risers which cause part failure.
- To provide maximum concentricity and low clearance, when required on connections such as "floating shafts".
- To reduce backlash, which is near-zero with Polygon.
- To provide optimum control of angular positioning, especially on long shafts. Grinding after hardening provides for this. Typically, parts can be oriented within 2 seconds of arc over a 24" shaft length, essential in many cam and gear assemblies.
- To permit finish machining of high-torque parts after hardening. In all other methods, post-machining heating treating introduces various distortions in splined shafts.
- To reduce manufacturing costs on large volume production items, especially in the areas of inspection and straightening.

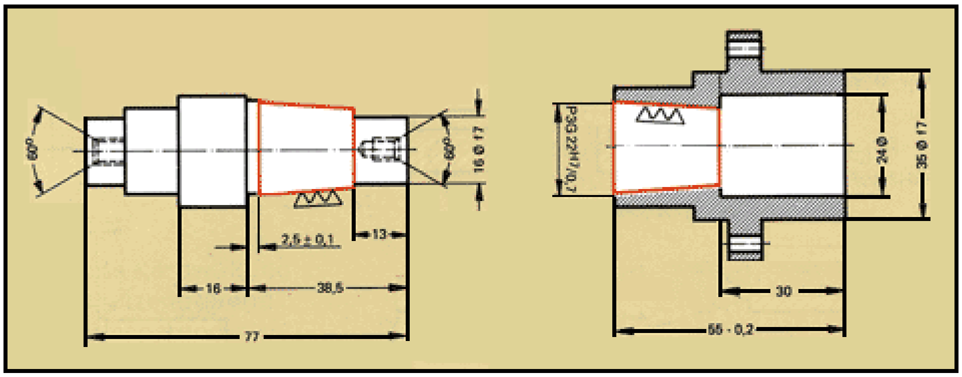




What Are The Functional Advantages?

- Highest possible shear strength in a given section: twice that of involute splines.
- Ability to produce shaft shoulders without runout.
- Highest torque carrying capacity within the shaft diameter, which carries the load over the entire section rather than on a few teeth, as when using splines.
- Concentricity unequalled by any other drive connection form. In addition, single-set-up grinding of Polygons and bearing diameters improves part function.

- Ability to produce within a range of very heavy interference to loose sliding fits, as required.
- Permits connections half the length of splines to carry the same shear load in a given shaft diameter.
- Problem solver where space and/or weight limitations are required.
- Self-centering characteristics, even in close-fit connections, plus simpler assembly and disassembly, and longer life, even with frequent take-apart-and-put-together.
- Reduces or eliminates backlash, or inherent backlash, in gear trains. This is important for longer life, smoother function and quieter operation. This benefit applies even when using sliding connections.
- Provides the optimum possible angular positioning accuracy.



The three-lobed form can also be ground with a taper on shafts and in hubs to provide zero backlash, perfect angular orientation, and simplified repetitive assembly and disassembly. Shafts ends are threaded on hubs locked in place with nuts and washers.

The four-lobed (PC4 polygon) shape is preferred for sliding connections. In one such application, on a die-cutting machine for corrugated board, it provided great cost reduction.

Previously, the rubber covered roller, serving as a platen against which steel rule knives cut the board, simply rotated. Repetitive contact of the knives in the same location eventually cut into the rubber requiring it to be replaced frequently.

A change in shaft design to use a PC4 shape on the drive end of the platen shaft enabled the shaft to be simultaneously rotated and oscillated. The constant shifting of the cutting contact area greatly increased the life of the rubber platen. The only other retrofit operation required was to add a cylinder on the drive end of the machine to oscillate the shaft. The solution to the problem was simple and highly cost-effective.

Let us look at some typical applications for Polygon:

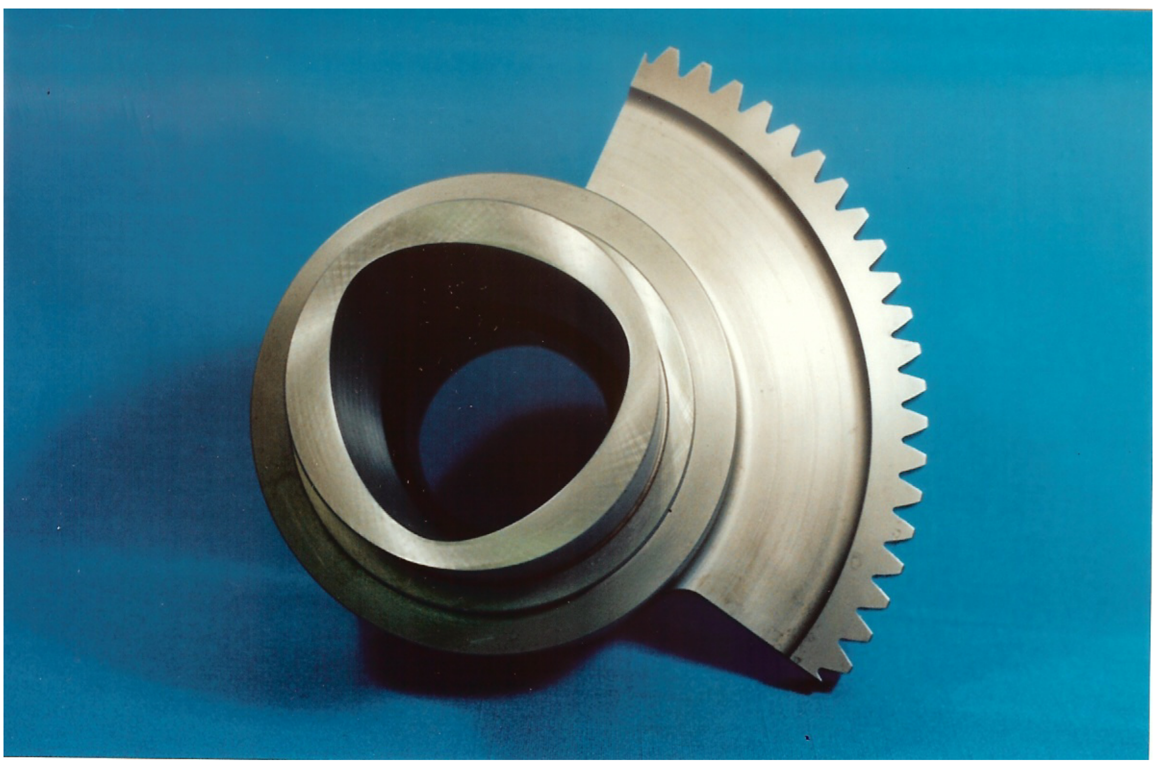
A propeller and its drive shaft ground with a taper locking P3 (3-lobed) polygon form. End of shaft taper is threaded for locking nut. Connection is fast and true with polygons self-centering characteristics.

A straight P3 form on motor armature drive shaft has a threaded end for locking the pulley on the shaft.

Close-fitting PC4 (4-lobed) polygon form permits moving drive plate on a variable speed belt-drive pulley to move easily even while rotating.

It should be noted, regarding - torsional and shear strength- of Polygon drive connections, that they can better withstand heavy reversal shocks. This is not the case with splines or other drive connections, which carry a majority of the load on just a few teeth or a narrow key, fine serrations, or short flats in D and double-D connections.

One outstanding use of the P3 form was in a compressor at NASA's Lewis Research Center in Cleveland, OH. This was built back in the early 70's. When we requested photos of the unit, we had to wait several years to get them. The reason was that NASA found the system to be trouble-free, never had occasion to tear down the rig because of trouble with Polygon, but finally were able to disassemble it for photography when it found a compressor wheel change was needed.



We mentioned earlier that Polygon is often not considered when an effective spline can be used at lower manufacturing cost. It is important, when comparing costs, to think long term.

How long does the spline have to last?

When extruder screws, large or costly gears and cams, and other types of components can be expected to fail, or have previously been shown to have drive connection failures, using a "more expensive" Polygon connection can effect a considerable savings. The Polygon will "run forever". Parts will not have to be scrapped because the drive connections have failed. Downtime due to need for replacement will not occur.

Repairing Damaged Splines

When other drive connections, especially splines, have failed, the most functional and cost-effective method of repairing them is to have them rebuilt with Polygons. We do this frequently, by several methods.

Damaged parts can be simply salvaged. The teeth on the shaft and in the hub had fretted and cracked. Since Polygon is able to carry twice the load in the same section, we were able to produce a smaller-section Polygon having the same torsional strength as the original spline on the shaft. We bored out the hub, press-fit in a bushing and produced a mating form in it. Quite often, we do not remove all of the damaged teeth on the shaft. We simply grind off enough of the spline to provide a perfect form. This is usually the case when actual loads were higher than calculated and the largest section possible should be maintained.

More Applications

We earlier mentioned use of Polygons on rods and glands of cylinders to provide non-rotation.

Ordinarily, non-rotating cylinders are made incorporating outriggers to prevent rotation. Or, square or hexagonal cylinder shapes are used to achieve the same purpose.

In the former instance, manufacture is very costly. The units often require provisions for more space to be allotted to them, which may introduce other problems. Weight is usually increased considerably. The problem with square or hex cylinders is in sealing them against leakage. Getting the rods and glands to fit closely and slide smoothly may also be a problem.

Using Polygon for the shape of the rod and gland solves many problems. Both parts can be produced easily and accurately. Sliding fits can be obtained with clearances as low as 0.0001". Either rod or gland, or both can be finished in the hardened condition. They can be plated to suit operating environments before finish grinding.

Most important, the P3 form can be sealed almost as easily as well as a round shape, using standard 0-rings and packing.

Incidentally, we are able to take any standard or special cylinder and convert it to non-rotation. We open the bore in the gland with a P3 form and manufacture a new rod with a mating form.

We have solved a problem for a paper and foil manufacturer. It involved the drive connection for a machine used to wind up four rolls of material at onetime. Four paper cores were slipped over a carrier shaft. The shaft was replaced every five minutes as the rolls were filled. The roll shaft was driven by a keyed connection. It was necessary, each time, to align the key on the drive shaft with the key slot on the roller shaft. Not only was care required but the keys failed regularly.

We used a tapered P3 (three-lobed) drive connection, which will self-center as it engages, without manual attention required, regardless of the position of the roll shaft hub as it is loaded.

While a friction clutch drive would be another solution, it would not be able to deliver the same torque or allow speed to be increased at the same rate as does the Polygon. Also, constant application of pressure, hydraulically or pneumatically, would be more costly from the standpoint of energy required. The Polygon connection can be mechanically clamped once engaged, although in this application the user has not yet made this modification.

Polygon systems are widely used in every industry. In Europe, DIN standards have been approved for them. We have our own American standards which are employed by users here for designing and manufacturing Polygons.

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