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Roll It

Thread rolling can produce helical forms accurately and economically.

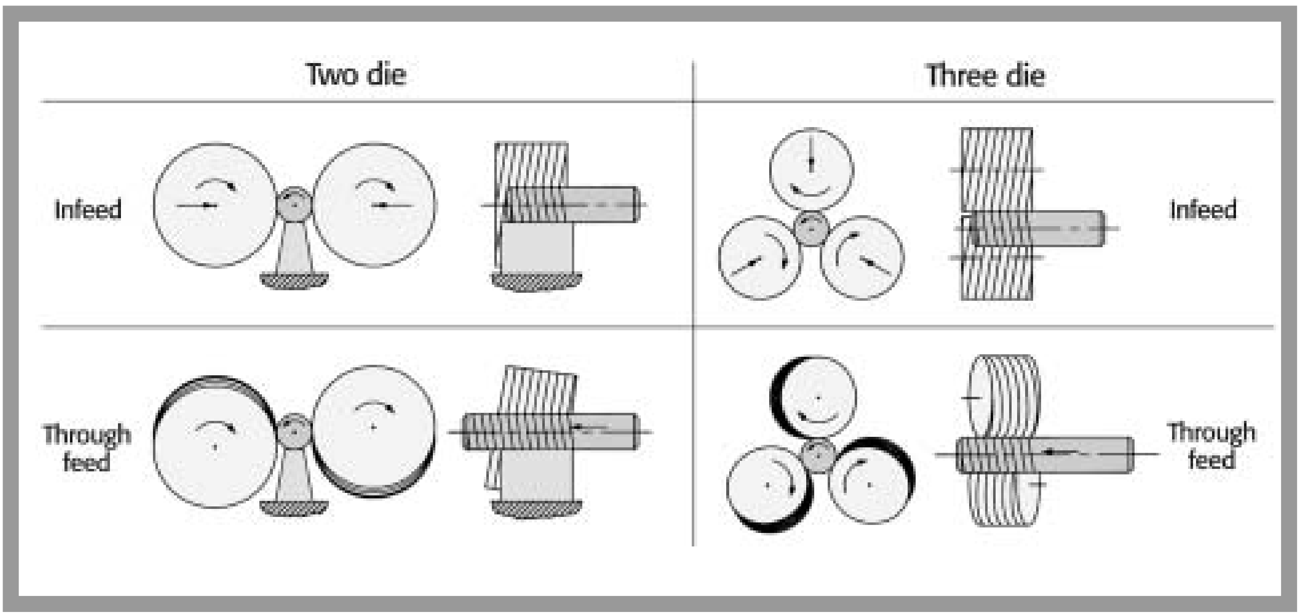
Deciding which manufacturing process to use when making parts is generally easy. But for helical forms, such as special bolts, studs, lead screws and actuator screws, it is much more complicated. The part specifications may define the tooth form, the diametral tolerance, the lead tolerance and the material, but they don't say how to make it. Specifically, should you roll or cut the threads?

Sometimes, there is not much difference between the two. For a given material of a given hardness, there is no significant difference between the static tensile strength of a rolled thread and a cut thread. But, when a part must be highly fatigue-resistant, rolling would be a better choice. The uninterrupted grain flow under the rolled root and the workhardening that occurs during rolling in most alloy steels retards the nucleation of fatigue cracks, which can form when the workpiece is subjected repeatedly to high stress.

The decision to cut or roll usually cannot be based on tooth-form requirements either, because cutting and rolling tools both replicate themselves precisely in the material being processed.

One area where there is a significant difference between the two processes is the surface finish produced. With virtually no special effort, a rolling die imparts an 8μin., or finer, surface finish. A cutting tool generally imparts a much coarser surface finish. In addition, the asperity shape created by rolling is generally rounded over, whereas the asperities created by cutting have a tear-like, or sharper, form. Because of this, rolled surface finishes provide a lower coefficient of friction. This is particularly useful in lead screws, actuator screws and motor shaft journals that will be in contact with a plastic or other bearing material mating form.

Rolling does generate one form characteristic that may prevent its use. As the die penetrates the blank, the material being formed generally flows more rapidly at the flanks of the die than in the middle of the form. This results in a small seam in the crest of the helical form. This seam rarely has any structural or functional effect on the part, but its appearance may be undesirable.



All images: Kinefac

Cylindrical die rolling machine configurations.

The Rolling Process

Rolling produces helical forms by displacing material. It is a constant-volume process. Therefore, its diametral tolerance capabilities are a function of the rolling machine's stiffness, the tooling and, in some cases, the preprocessing of the blank's diameter to control the volume to be displaced by the penetration of the die. If the rolled form is left open at the crest, then a rolling machine with adequate stiffness can control the final diametral position of the die, even if there is some variation in the blank diameter. The basic form diameter typically can be maintained to a tolerance of ±0.001", with the volumetric variation of the blank resulting only in changes in crest fullness, such as a seam.

When the form must be rolled full, without any visible seam, then the pitch diameter generally follows the blank diameter. Even a stiff rolling machine cannot overfill the die. By holding the blank diameter to a tolerance tighter than 0.001", it is possible to attain an equally precise pitch-diameter tolerance.

Lead precision is a function of basic cutting or rolling variables. In helical forms that are cut, the lead is created by a cutting tool that is moved axially in precise reference to the rotation of the machine spindle driving the workpiece. The resultant lead accuracy is determined by the stiffness of the cutting system and the accuracy of the machine's lead screw and is not cumulative. With precision turning or thread milling systems, a lead accuracy of ±0.0005 in./ft. can be produced.

For rolled forms, different process elements come into play when creating the lead. Worms and threads with form lengths of 3" or less are generally rolled by the infeed method, where the full form length is produced in a single cycle by the radial penetration of the die into the blank. With infeed rolling, the lead of the form produced substantially follows the lead of the die. If the depth of the form is less than 5 percent of the OD, the axial springback after rolling is generally insignificant for most materials that elongate 10 percent or more.

Typical infeed rolled helical forms.

As the ratio of form diameter to OD increases or the ductility of the material decreases, it may become necessary to design springback compensation into the lead of the die. This is generally determined by actual tests. Once compensation is defined and applied, it is practical to achieve a lead repeatability of 0.0001in./in. by infeed rolling.

Lead screws and actuator screws are generally longer than the available die face and cannot be rolled by the infeed method. In this case, the through-feed method of rolling is performed. In through-feed rolling, the die is skewed at low angles and held at a fixed radial position with respect to the helical-form axis. As the blank rotates and passes through the die, the tooth form on the die progressively penetrates the blank until the die form is full. The form is then rounded by a short dwell (constant form diameter) area of the die, after which it passes out of the die.

During penetration by the die, if the form is deep relative to the OD, there is a tendency for some of the material under the penetrating ribs to escape axially. After the die form is filled, the

Typical through-feed rolled helical forms.

dwell area of the die works to stabilize the lead. However, there is invariably some axial springback, which results in the lead of the rolled form being shorter than the lead of the die. This causes some cumulative lead error, which for shallow forms and short form lengths does not require compensation.

For ballscrews, long lead screws and actuator screws for which the form depth approaches 20 percent of the OD or for other uses in which the form is long, lead compensation of the die is generally required. For standard Acme and similar balanced forms and rollable materials, the lead compensation is somewhat predictable. For precision lead screws, it must be determined by testing. Once determined and applied, a lead accuracy of ±0.003 in./ft. is achievable by through-feed rolling.

Material Considerations

For most unhardened carbon steels, alloy steels, copper and aluminum, cutting and rolling work equally well to achieve the required form. However, because most metal flow occurs in shear, as a general rule, materials that form well cut poorly, and those that cut well form poorly. Therefore, provided the elongation is greater than 10 percent, rolling is better for forms that require a fine surface finish and high tooth-fatigue strength.

Because the die/workpiece interface is analogous to a gear mesh, some specific limitations arise. First, the contact must be conjugate, meaning that the velocity ratio between the rolled form and the die must be constant, as in a gear mesh. This generally limits flank angles to a low of 12° and lead angles to a maximum of 30°. Angles outside those parameters generally must be cut.

The cutting process has no significant size limitation. Theoretically, the rolling process also has no size limitation. However, the rolling force goes up rapidly as the blank diameter increases, whereas the cutting forces stay constant. It is common to see lathes turning diameters up to several feet, but most rolling machines are designed for forms 4" in diameter or smaller.

Another material consideration is the effect of workhardening. That occurs during rolling but not during cutting. For high-alloy steels such as stainless steel, the hardness can be increased as much as 7 HRC. Therefore, for helical forms that can benefit from being made from a harder material, rolling provides a significant advantage. However, this same characteristic can limit the depth of the rolled form.

The final geometric consideration is the length of the rolled form. The unbalanced side load of a cutting operation limits the length-to-diameter ratio of the form to be cut. Once that limit is exceeded, rolling is the best option. For continuously threaded parts, long lead screws and actuator shafts, rolling is probably the only low-cost production option.

Where a helical form can be either cut or rolled, nongeometric considerations affect the process selection. Cutting helical forms by turning generally requires multiple passes of a single cutting tool, whereas rolling them on all of the tooth forms simultaneously, in a single infeed rolling operation, generally requires less than 2 seconds. The moving of the part in and out of the dies almost always takes more time than the actual rolling operation. By automating that step, production rates of 10 to 20 per minute are achievable.

Cost Considerations

The economic considerations in threadmaking are tooling costs and capital costs. Typical thread-rolling die life when producing a 1 to 8 tpi thread that is 2" long in 1040 steel exceeds 250,000 parts. At a die cost of approximately $600, the tool cost would be less than ¼ cent per part. A typical 3-edge thread-cutting carbide insert costs about $10 and might produce a total of 500 parts. That equates to a tool cost of about ½ cent per part, with respect to capital costs.

Infeed rolling a multistart actuator screw.

A typical automated, 2-cylindrical die rolling machine costs $120,000 and might produce 15 forms per minute. The capital cost per thread per minute would be $8,000. Cutting a 1" to 8" thread on a CNC lathe as part of a shaft-turning operation might require 5 seconds for the threading cycle. If the CNC lathe also costs $120,000, then the cost for one thread per minute would be $10,000.

About the Author

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