

# Deep Rolling Tooling Technology

## Advantages of deep rolling

Deep rolling significantly improves the surface layer characteristics of metal components subject to dynamic loading. This proven mechanical process has been successfully used for decades across a wide variety of industries to increase fatigue strength and service life. The process is especially well suited for treating rotationally symmetrical parts; however, with modern tooling technology the process can be used to treat free-form surfaces and thin-walled components as well.

Deep rolling can be used to treat:

- material fatigue due to dynamic loading (e.g. rotating bending or torsion)
- stress concentration or notch effect due to sharp-edged transition zones, scoring or grooves from prior processing, pitting or fretting corrosion
- low fatigue strength due to residual tensile stress left by prior processing (e.g. welding or machining)
- stress corrosion cracking
- fatigue due to rolling contact

Deep rolling is the only metal improvement process that induces residual compressive stresses and cold work while burnishing the workpiece's surface to a high quality finish. The deep rolling process combines these three effects to dramatically increase fatigue strength.

In deep rolling, one or more rollers or balls are pressed against the workpiece surface. When the pressure in the contact zone exceeds the material's yield point, the material in the surface layer is plasticized and formed. The resulting compression stress depth profile according to Hertz demonstrates a maximum value just below the surface layer and reaches nearly zero deep in the workpiece. While the surface layer is plastically formed, at deeper levels only elastic formation occurs. The profile of the resulting compressive stresses always cycles toward a minimum value just at or below the workpiece surface where the greatest compressive stresses are induced.

During the process, the rollers subject the surface roughness peaks to the greatest load. As these peaks are pressed down, the material flows to the sides, filling the valleys and raising the valley level. The assumption that this process leads to surface compression is true only for porous materials. Depending on the application, deep rolling changes the workpiece diameter or dimensions only within the  $\mu$ -range. Allowances can be made in the pre-machining stage to accommodate these slight variations.

Because the plastic deformation takes place below the material's recrystallization temperature, cold working is induced. The plastic forming process introduces disruptions into the material's lattice structure. The increased density caused by this structural change increases the surface layer's strength and can also prevent cracks or delay crack growth.

## Deep rolling process

In its kinematics, the deep rolling process is similar to turning or milling. As shown in the illustrations on the next page, deep rolling can be performed as a plunge-in process with in-feed (for small radii), with linear feed, or with a special feed motion to accommodate free-form surfaces. To avoid the formation of steep inclines at the workpiece surface, the deep rolling force and pressure is built up slowly. This gradual increase prevents stress concentration.

Because the kinematics are relatively simple, the process can be applied on conventional machine tools. Deep rolling tools — including the hydrostatic HG "ballpoint" line — can also be used with CNC-controlled lathes and milling machines. On standard machines and machine tools, the components can be deep rolled right after cutting in the same setting. Specialized machines can be used to deep roll components such as crankshafts and piston rods in large series production.

**Deep rolling: plunge-in process**

The profile rollers used in this process are specially designed for the radius of the fillet to be treated. The roller(s) are positioned such that the deep rolling force is concentrated on the area that experiences the highest tension or material fatigue under operating load.

The adjustable rollers incline automatically to match the workpiece form (the fillet radius in this example). As a result, the process distributes residual compressive stresses exactly as desired.

The plunge-in process requires two movements:

- rotation (either the tool or workpiece rotates, depending on machine and workpiece type)
- in-feed (in the axial direction for multi-roller tools; in the direction of the deep rolling force for single roller tools)

This process works well for narrow, hard-to-reach areas, such as screw threads or fillets with radii  $R < 4$  mm.

**Deep rolling: feed process**

This process works well for machining larger surfaces. The rotation and in-feed movements required for the plunge-in process are supplemented here by a simultaneous linear feed.

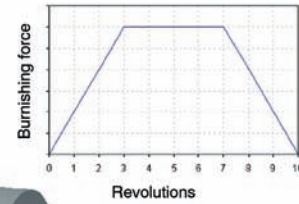
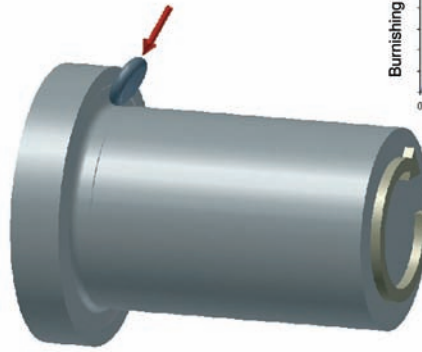
Both mechanical and hydrostatic tools can be used for this process.

**Deep rolling with hydrostatic tools**

Hydrostatic “ballpoint” tools can deep roll not only rotationally symmetrical surfaces, but also flat and curved surfaces or free-form surfaces. The tool moves over the surface such that it creates parallel traces in the shape most advantageous for the particular component — for example, in a spiral or in nested squares. The hydrostatic bearing allows movement in all directions, so the feed direction can be changed even when the tool is fully engaged.

**Monitoring and controlling the deep rolling force**

The most important parameter in the process is the deep rolling force. With mechanical tools, this force is determined by measuring and monitoring spring deflection. Each tool has an individual spring characteristic. A gauge or a sensor records and measures the related spring deflection and thus the force. For tools that operate with a hydraulic system, the deep rolling force can be monitored by measuring the pressure.



Deep rolling with plunge-in

