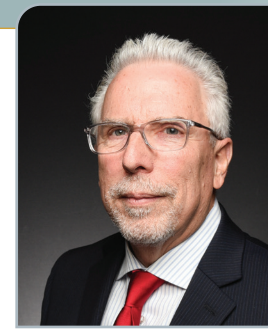
PMPA PRECISION MACHINED PRODUCTS ASSOCIATION

Cold Work, Work-Hardening, and Your Precision Machining Shop

The pros and cons of cold work, work-hardening.



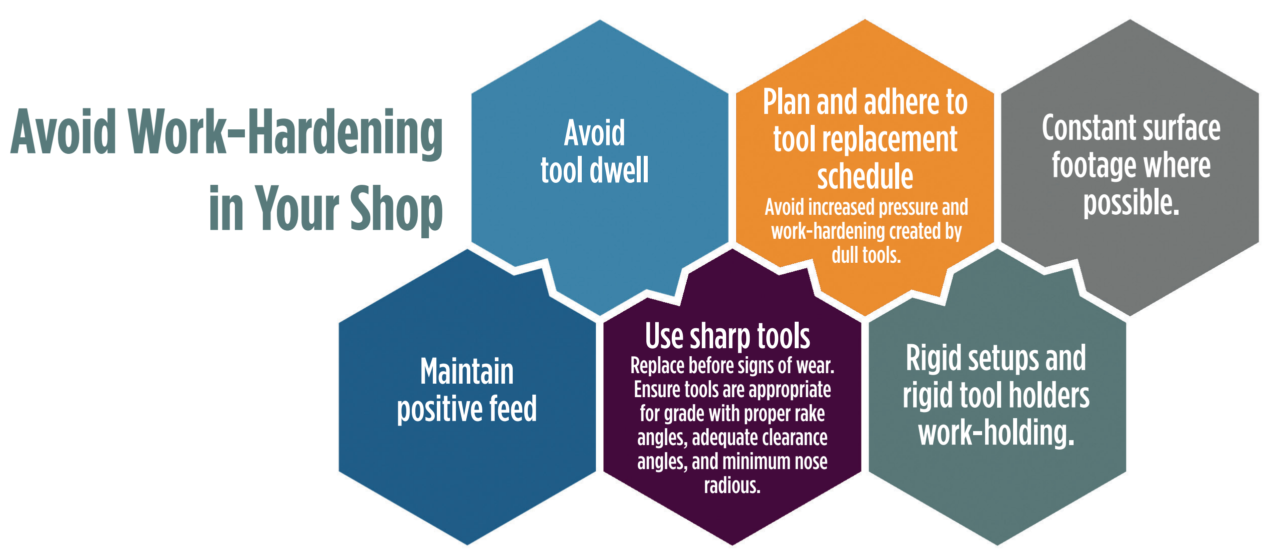
Miles Free III
Director of Industry Affairs

Cold work is defined as the plastic deformation of a metal below its recrystallization temperature. In our suppliers this is done intentionally by cold drawing through a die or cold rolling. In our shops, cold working processes can include thread rolling, thread forming swaging, crimping, staking planishing, metal spinning, and process failures such as unsharp tools, insufficient clearance, unstable setups and tool dwell.

Pros

Cold work (via process of cold drawing or cold rolling)

- **Cold work improves the machinability** of low carbon steels by increasing the strength and reducing the high ductility of the hot rolled product. Cold working of the hot rolled bar by die drawing or cold rolling increases the Tensile and yield strength of the material, while lowering its ductility, (reduction in area and % elongation). This change in properties results in chips that are harder, more brittle, and curled, producing less built up edge on the tool's cutting edge. The improved Yield to Tensile ratio means that your tools and machines have less work to do to get the chip to separate. Steels between 0.15-0.30 wt.% carbon are best machining; above 0.30 wt.% the machinability decreases as carbon content (and hardness) increase.
- **Cold work improves the surface finish** attainable (up to a point). Cold drawn bars typically run 50 microinches max and usually arrive at 25-30 microinches in modern processes.
- **Cold work holds dimensions and concentricity to a tighter tolerance.** Cold work reduces the variability and so dimensions are able to be routinely held at plus 0.000', minus 0.002" or 0.003" for the low and medium carbon steels that we usually encounter.
- **Cold work provides for straighter material**. Cold drawn bars are held to straightness deviations as low as 1/16" in ten feet, in standard mill runs, compared to the 1/4" max deviation in five feet that we can expect in a hot rolled bar.
- **Cold work improves your shop productivity** (throughput) by improving machinability. The result of these advantages is that your cycle time is decreased, your need for secondary operations to



remediate lousy surface finishes is eliminated, your process uptime and efficiencies increase. These all result in more parts, and more conforming parts in the bin at the end of the shift.

These improvements in your operations justify the additional price you pay for a cold drawn bar over a hot rolled bar.

Cold work In your raw materials can be affected by your supplier's drafting practice, availability of material to draw to your needed size, original melt and cast process and chemistry- both intentional additions and residuals that can have an effect.

Standard draft or heavy draft can result in differences in hardness achieved, and thereby reduction of the ductility that makes it difficult to separate the chip. Heavier draft makes the material more machinable, but may make subsequent cold working processes problematic, as we will discuss below.

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Steels melted in Electric Furnace (EF or EAF) processes and cast into billets are generally found to be less ductile than those from Basic Oxygen Process (BOF or BOP) shops and typically cast into larger Bloom sections. The greater hot working reduction in area of the larger section blooms provide more ductility in the as rolled hot rolled bars.

Similarly, chemical differences reflecting these different process paths include higher Nitrogen and residual elements in the EAF steels compared to BOF steels which are melted in and Oxygen saturated vessel with lower percentage of scrap.

Cons

Work-hardening can make the steel or the finished part that you produce unsuitable for further processing. Work hardening can make your in-process workpiece unmachinable, resulting in failed tools, or destroyed setups, resulting in hours of down time, lost production, missed shipments, and higher cost per part.

What contributes to work-hardening in our shops, and how can we address it?

Cold work is plastic deformation of a metal below its recrystallization temperature.

Whenever a tool rubs or fails to cut, it creates a strain in the workpiece material under the tool. If the material is amenable to work hardening- its mechanical properties can change, altering the material's response to the tool edge. Chips can become more problematic and increase built up edge on the tool, as well as require even greater force to separate. The resulting chip can also become more abrasive and create greater wear on the tool.

In extreme cases, the cold work of the operation can exceed the ductility of the material, and stress cracks can be the result.

What are some clues to suggest that work-hardening could be an issue and you need to take especial care with your process setup?

Nickel present as a specified ingredient. When you see Nickel as a major ingredient in steel, avoid tool dwell and light cuts. Nickel contributes to a material's work-hardening ability.

Nitrogen present as a specified (or implied) ingredient. Nitrogen can be intentionally added to boost mechanical properties (strength and hardness) as well as to improve surface finish. However, it can work against you if subsequent cold work is needed. Nitrogen is "implied" if the steel is produced by an Electric furnace scrap fed steel making process. Billet cast with lower rolling reductions can exacerbate this effect.

Nickel-base alloys. iron and cobalt-base alloys, titanium alloys. Each of these can severely work harden upon tool dwell or use of dull tools. Failure to have proper rake angles and or clearance angles can also impart cold work and thus work hardening, minimize nose radii in these grades to minimize chance for work-hardening. PMPA

Miles Free III is the PMPA Director of Industry Affairs with over 40 years of experience in the areas of manufacturing, quality, and steelmaking. He helps answer "How?," "With what?" and "Really?" Miles' blog is at pmpaspeakingofprecision.com; email: mfree@pmpa.org; website: pmpa.org.