Tool Steels, Heat Treatment, & Surface Treatment Preparation

DAY TON

Tool Steel Considerations

- ◆ Tool Steel Analyses & Characteristics
- ◆ Tool Steel Components
- ◆ Heat Treat Options
- ◆ Surface Treatments for Added Wear Resistance

Selecting the proper Tool Steels, Heat Treatment, & Surface Treatments for a stamping application can be a complex and confusing process. To simplify this process, a few basic facts should be understood.

This program will present and examine facts using terms familiar to the non-metallurgist.

The objectives of this program are shown.

Typical Analysis

| Steel Type	C	Mn	Si	Cr	W	Mo	V
A2	1.0	0.9	0.3	5.25	0	1.15	0.3
D2	1.5	0.5	0.3	12	0	0.9	0.9
M2	0.85	0.3	0.3	4.15	6.4	5.0	1.9
M4	1.4	0.3	0.3	4.0	5.75	4.5	4.0
CPM 10V	2.45	0.5	0.9	5.25	0	1.3	9.75

Tool steels are vastly different from steel used in consumer goods. They are made on a much smaller scale. Strict quality procedures assure that a given grade of tool steel will perform a specific task such as machining or perforating.

Many different qualities in tool steels are desired based on a particular application. These qualities are provided by adding a particular alloy along with the appropriate amount of carbon. The alloy combines with carbon to enhance the wear, strength, or toughness characteristics. The combination also contributes to the ability to resist thermal and mechanical stress.

The typical analysis shown contains some of the commonly used tool steels and their alloy content. Each of the alloy elements listed contributes to a specific characteristic in the finished steel. They can also create undesirable side effects, particularity when used in excess. Alloy elements can have reactions with each other, which can either enhance or degrade the steel.


Tool Steel Characteristics
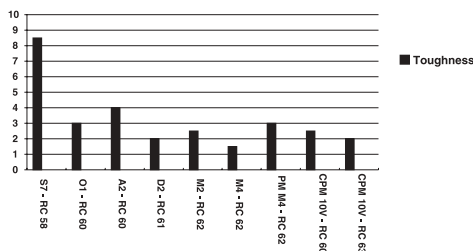
If toughness were the only factor in choosing a tool steel, S7 would be the obvious choice. Unfortunately toughness is achieved at the expense of other characteristics which are also necessary in most stamping applications.

The graph shows a toughness comparison for tool steels commonly used in stamping applications. They are listed in order of increasing alloy content from left to right. There is a tendency for tool steels to decrease in toughness as alloy content increases. The increase in alloy content also demands a higher price.

Toughness is also affected by the manufacturing process of the steel. The PM (Particle Metallurgy) process can greatly enhance the toughness of a given grade of tool steel over its conventional counterpart. Note the difference in toughness between M4 and CPM® M4 in the chart.

Hardness also affects toughness. CPM® 10V is shown twice in the chart. Any given grade of tool steel will have greater toughness at a lower hardness. The lower hardness could have a negative effect on other characteristics necessary to achieve sufficient tool life.

Tool Steel
Characteristics
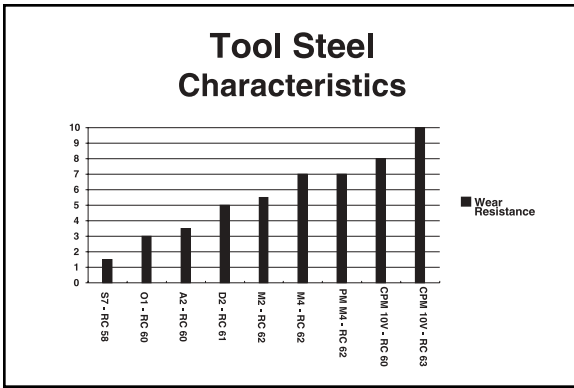
5

Increased alloy content typically results in increased wear resistance as illustrated.

Increased hardness also contributes to wear resistance. Note the increase when the hardness of CPM® 10V is raised from RC 60 to RC 63. This happens with all grades of tool steel.

Tool Steel
Characteristics
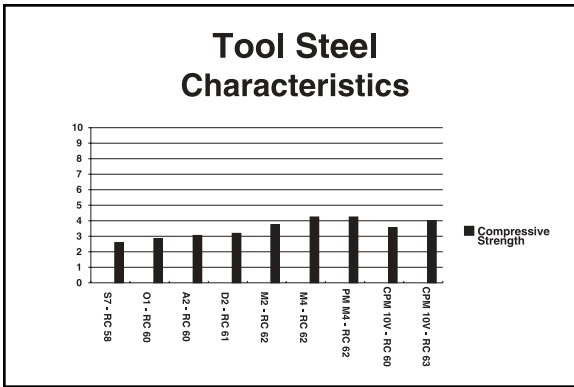
6

Compressive strength is a little known and often overlooked characteristic of tool steels. It is a measurement of the maximum load an item can withstand before deforming or before a catastrophic failure occurs.

Two factors affect compressive strength. They are alloy content and punch material hardness.

Alloy elements such as Molybdenum and Tungsten contribute to compressive strength. Higher hardness does as well.

Radius Blend Breakage

A2 Vs. M2

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A common location for failure from excessive compressive loading is in the radius blend.

Not all radius blend failures are due to compressive load. Grinding burn and lateral deflection of the punch point may also result in similar failures.

The two punches pictured are identical in design with one exception. The left punch is made from M2 tool steel and has lasted through years of use. The right punch is made from A2 and failed after a few hits. Even though both punches are of equal hardness, the M2 punch has a higher compressive strength allowing it to withstand high load applications.

Deformation

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Punch deformation is another form of compressive failure. Deformation can occur at the point or, as in the punch shown, behind the guide in the stripper.

Properly tempered tool steels can bend or deform before they break.

Tool Steel Characteristics
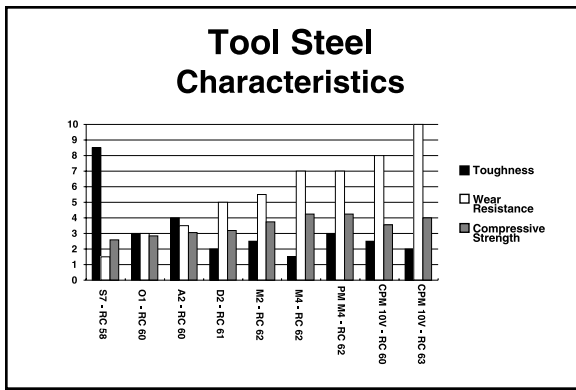
9

This illustration compares toughness, wear resistance and compressive strength. While some steels possess exceptional values with one characteristic, they tend to have low values in one or both of the other characteristics.

High load applications such as punching stainless steel, spring steel and high strength low alloy require tool steels with a combination of shock resistance, wear resistance and high compressive strength. M2 or PM-M4 work best in these applications.
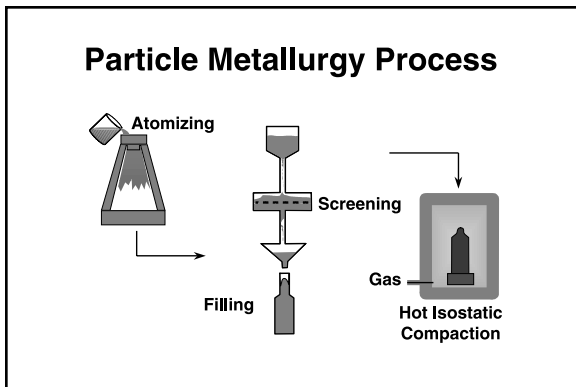
Conventional Metallurgy Process
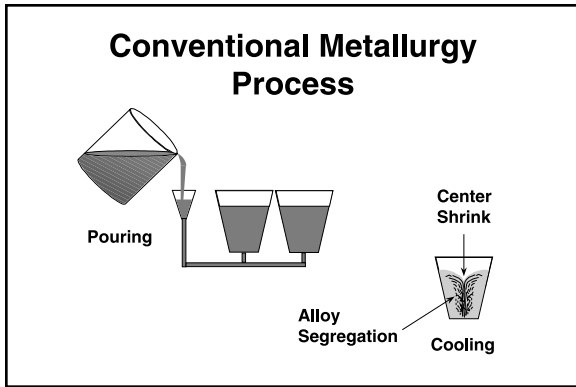
10

The Conventional Metallurgy Process for making tool steels involves melting scrap iron and adding alloy elements as needed. This mix is then poured into ingots where it is allowed to slowly cool.

Because different elements solidify at different temperatures, they begin to segregate as the ingot cools. The alloy elements tend to be found in higher concentration toward the center of the ingot.

Higher levels of alloy content result in an increased chance of segregation. Too much alloy segregation can lead to cracking, resulting in poor quality. For this reason, extremely high alloy tool steels can not be manufactured by conventional means.

## Particle Metallurgy Process

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The Particle Metallurgy Process of steel making begins much like the conventional process with the melting of iron and the adding of appropriate alloy elements.

The alloy is then poured through an atomizing vessel where the stream of molten metal is exposed to high velocity jets of an inert gas. This gas breaks up the stream of metal into small droplets that rapidly cool to form a fine powder.

The sudden cooling prevents alloy segregation. Each grain of the powder contains the entire alloy content.

The powder is screened and filled into a mild steel can, called a compact, where it is mechanically compacted and sealed.

The compact is loaded into a hot isostatic press where it is exposed to high heat and pressure. This process compresses the compact to nearly 100% density to form a solid billet of steel.

Hot Forging Process
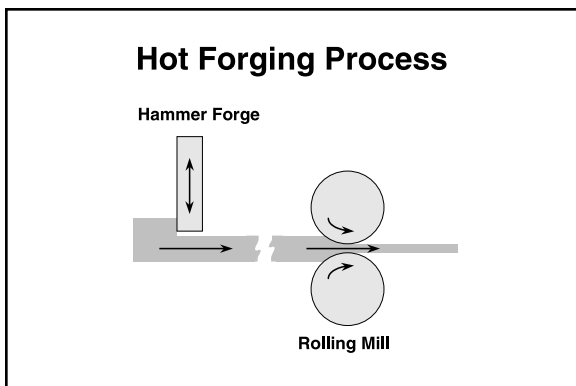
12

The billet is then forged and rolled into plates and bars. This serves two purposes.

One is to bring the steel down to manageable sizes. The other reason is to benefit the steel itself.

Forging and rolling into smaller sizes improves the quality of the steel. The rolling process, also called reduction, breaks up and redistributes the segregated alloys associated with conventional metallurgy. A more homogeneous structure results from rolling. The greater the reduction, the better the structure for conventional metallurgy tool steels.
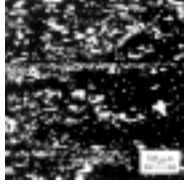
Particle metallurgy steels have a uniform distribution of carbides and therefore are in less need of forging and rolling. This is why higher alloy tool steels in larger sizes perform better when made with the particle metallurgy process.

Metallurgy Comparison

Particle **Conventional**

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This photomicrograph shows a comparison of Particle and Conventional Metallurgy. Both samples contain the same alloy content.

The black area is the matrix. The matrix bonds the steel together and produces most of the steel's measurable hardness.

The white particles suspended in the matrix are the carbides. Carbides are hard particles that give tool steels wear resistance. The amount of carbides is related to the amount of certain alloys such as Vanadium, Molybdenum, Chromium and Tungsten in conjunction with appropriate levels of carbon.

Small, evenly distributed spherical carbides, as seen in the Particle Metallurgy steel, offer benefits such as:
- Improved machining and grinding characteristics.
- More consistent hardness response and size change in heat treatment.
- Greater toughness (Shock resistance)

Note the size and directional distribution of carbides in the conventional steel. This is a result of the forging and rolling process. Carbides are broken down into smaller pieces and more uniformly distributed as a bar of conventional steel is rolled into smaller sizes improving its quality.

Heat Treatment Considerations

- ◆ **Segregation by Size & Material Type**
- ◆ **Fixturing**
- ◆ **Preheat**
- ◆ **Soak (Austenitize)**
- ◆ **Quench (Martensite Transformation)**
- ◆ **Freeze? (Cryogenics)**
- ◆ **Temper**

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Tool steels are only as good as the heat treatment they receive. The keys to achieving optimum results in heat treatment are listed.

Each grade of tool steel has specific heat treatment guidelines in order to acquire optimum results for a given application. Unlike cutting tools, the nature of stamping operations places a high demand on toughness. This means that a grade of tool steel should be heat-treated differently for a cutting tool than if it were used in a stamping application.

Segregation in heat treatment by size of product is extremely important. Items of different sizes require adjustments in preheat, soak and quench rates. Fixturing assures even support and uniform exposure to heating and cooling in the heat treatment process.

Heat Treatment Sequence

Harden

Cryogenics

- • Vacuum Harden
- • Cryogenic Treatment
- • Atmosphere Temper

Temper

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Tool steels are exposed to high temperature in the hardening process. This heat is required to austenitize (soak) the steel. High heat can result in oxidation and changes in the level of carburization causing distortion and surface damage to the part. Vacuum furnaces offer the greatest amount of protection from these problems.

Cryogenics aids in the conversion of austenite to martensite, insuring greater hardness response and reduced stress. Tempering is accomplished at a much lower temperature and does not require a vacuum furnace. Radiant heat in a vacuum below approximately 760°C (1,400°F) is not reliable because of inefficient heat transfer. Additionally, thermocouples in a vacuum environment at lower temperatures are not accurate, making temperature control unreliable. Convection tempering (recirculating air) eliminates these problems and provides uniform heating.
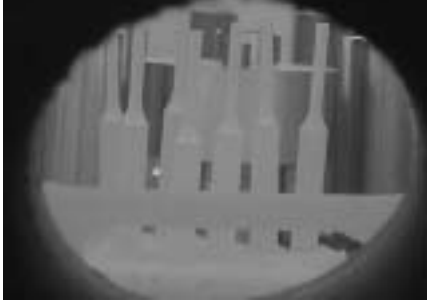
Vacuum Furnace

- • High velocity quench vacuum heat treatment furnace

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This is what a typical vacuum furnace looks like from the outside. This furnace has a two Bar, high velocity quench capability. This is one of four vacuum furnaces used at Dayton Progress' main plant.

Size Segregation

• Different size items heat at different rates

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    This is an example of improper segregation by size. The small parts in the foreground heat up much more rapidly than the larger parts behind them, leading to inconsistent and improper preheat, soak and quench rates. Ideally, parts should be segregated by size and mass to insure optimum tooling performance.

Heat Treatment Support System

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    Heat treatment support equipment is necessary in order for vacuum heat treating equipment to operate up to its potential. The support equipment handles water for cooling and nitrogen or other medium necessary for quenching.
    The large tank to the right is a nitrogen storage unit. The smaller tanks to either side are nitrogen surge units.
    The tower to the left is for water cooling. This tower is part of a dual loop cooling system.

Nitrogen System

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    A closer look at the nitrogen storage tank reveals a series of tubes with heat exchanger fins mounted to its side. This heat exchanger assists in raising the nitrogen from a liquid state at -196°C (-320°F) to a gas at ambient temperature.
    The surge tanks hold enough nitrogen gas to quickly back-fill the furnace and quench the parts.
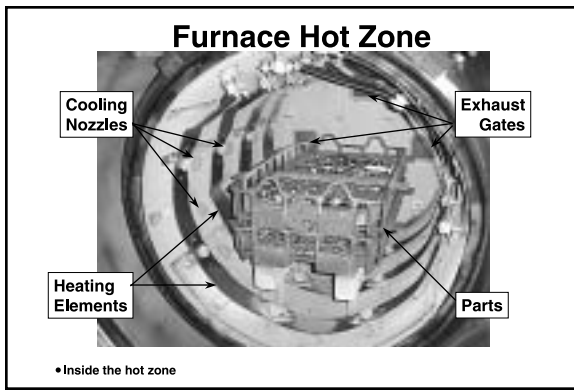
Water Cooling System

20
    The nitrogen gas is circulated across the parts where it absorbs heat. It is then cooled in a water-to-air heat exchanger before being recirculated over the parts.
    The water-cooling tower shown at the left of the picture performs the final transfer of heat. Heat from the water is dissipated into the outside air.

Furnace Hot Zone

Cooling Nozzles

Exhaust Gates

Heating Elements

Parts

• Inside the hot zone

Vacuum Furnace

Hot (1) Zone

Heat (4) Exchanger

Quench (2) Nozzles

Turbine Blower (2&5)

Exhaust Gates (3)

Parts

Cold Work Tool Steel
Heat Treatment Cycle
(A2, D2, Etc...)

1000˚ C

Soak

Preheat

500˚ C

Quench

Temper

Optional Temper

Room Temp

Time →

Optional Cryogenics

-500˚ C

Tempering Furnace

21
    The shape and size of the hot zone plays a critical part in the hardening process. A small round hot zone assures a uniform temperature throughout.
    Heating elements and cooling nozzles in this furnace are positioned on all sides to provide even heating and cooling.
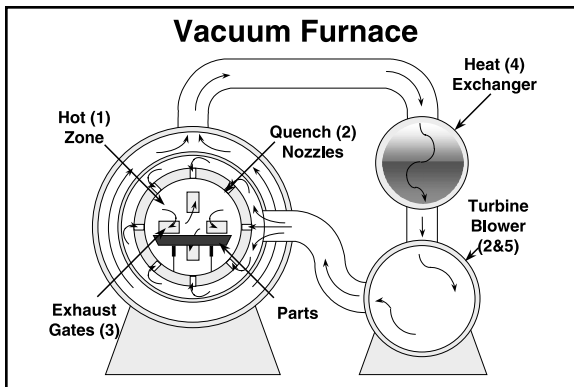
22
    This diagram identifies the major components of a high velocity vacuum furnace used in the process of vacuum hardening tool steels.
    1) The process starts by removing the atmosphere (vacuum) and electrically heating the parts in the hot zone.
    2) After the parts are properly heated (austenitized) the system is backfilled with nitrogen. Nitrogen is used as a means of conducting heat away from the parts. A large turbine blower forces room temperature nitrogen across the parts, cooling (quenching) them through the martensite transfer range.
    3) Hot nitrogen exits the hot zone through gates at the front and rear of the chamber.
    4) The nitrogen circulates through a heat exchanger where it is cooled.
   5) The cooled nitrogen is recirculated over the parts until they reach room temperature.
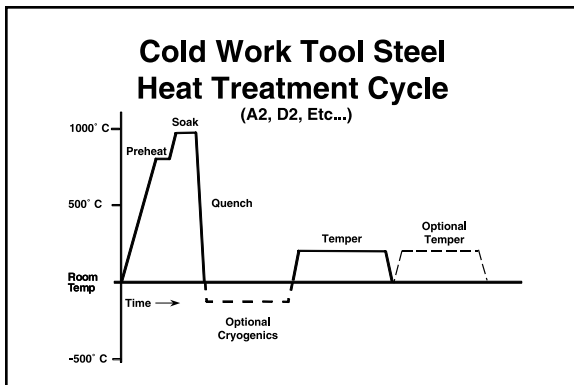
23
    The first step for achieving optimum heat treatment begins with preheating. For cold work steels such as A2 and D2, this is accomplished by heating the parts to just below the critical austenitizing temperature of approximately 788°C (1450°F), long enough to allow the part to be evenly heated. This is necessary because when the part enters the austenitizing temperature range, the steel is restructured on an atomic level creating a volume expansion. If this volume expansion does not occur uniformly, the part will distort and possibly crack.
    Soaking (austenitizing) is heating the part into the carbide phase region for a specified period of time. The intention is to force some of the alloy elements into the matrix. Soaking cold work steels such as A2 or D2 at or above the high end of their austenitizing range (overheating) will result in excessive levels of retained austenite and generate a coarse grain structure. This will result in inferior toughness in the finished product.
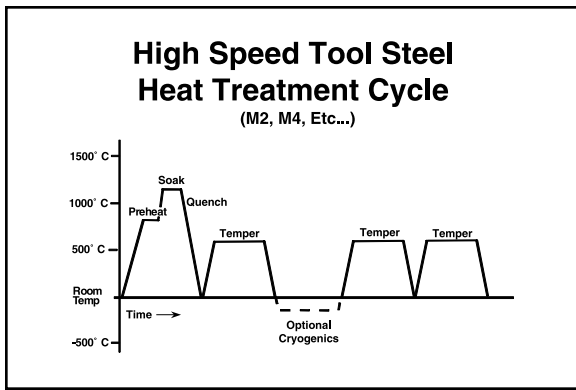   Quenching is the sudden cooling of parts from the austenitizing temperature through the martensite transfer range. The steel is transformed from austenite to martensite, resulting in hardened parts. Unfortunately cold work steels have a transformation range that goes well below room temperature. This is one reason why cold work steels benefit from freezing (cryogenics).
    Tempering is necessary to remove stress associated with the hardening process. Cold work tool steels are generally tempered at or below 204°C (400°F). Due to the low tempering temperature involved, one temper is generally adequate for cold work tool steels.
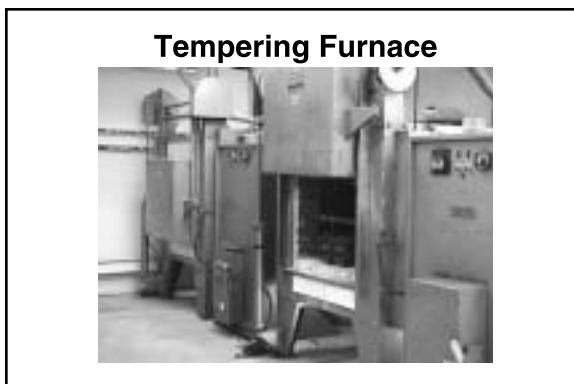
24
    Due to the limitations of thermal couples at low temperatures in vacuum, most tempers are performed in atmosphere.   This picture shows two atmospheric furnaces at Dayton Progress.

High Speed Tool Steel
Heat Treatment Cycle
(M2, M4, Etc...)

Tempering Effects
High Speed & High Alloy Tool Steel (M2, M4, Etc...)

Punch Head Draw

Table rotates clockwise

WILSON CYLINDRICAL CORRECTION CHART #53
Rockwell® Hardness Testing

CYLINDRICAL WORK CORRECTIONS TO BE ADDED TO OBSERVED ROCKWELL NUMBER

These CORRECTIONS are APPROXIMATE ONLY and represent the averages, to the nearest 1/2 "ROCKWELL" number, of numerous actual observations by different investigators and also mathematical analyses of the same problem.

When testing cylindrical work, the accuracy of the test will be seriously affected by alignment of the elevating screw, Vee anvil, penetrators, surface finish and the straightness of the cylinder.

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AMERICAN CHAIN & CABLE COMPANY, INC., N.Y.

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High speed and high alloy steels such as M2, CPM-M4 and CPM-10V require a somewhat different approach to heat treatment.

Although the process initially appears similar to cold work tool steels, the temperatures and number of tempers differ.

Preheat temperatures begin at approximately 830°C (1525°F) and soak temperatures can be above 1,093°C (2,000°F).

Because the soak temperature is approaching the melting point, control of both time and temperature are critical. Over soaking the part can result in incipient melting. This is when the alloys with lower melting points begin to melt within the item, damaging the steel structure.

Higher temper resistance found in high speed and high alloy tool steels allow tempering temperatures to be much higher than with cold work steels. The higher tempering temperatures are high enough to transform retained austenite left over from the quench as well as temper the untempered martensite, eliminating the need for freezing (cryogenics). It typically takes three tempers above 538°C (1000°F) to reduce the levels of retained austenite and untempered martensite to acceptable levels.
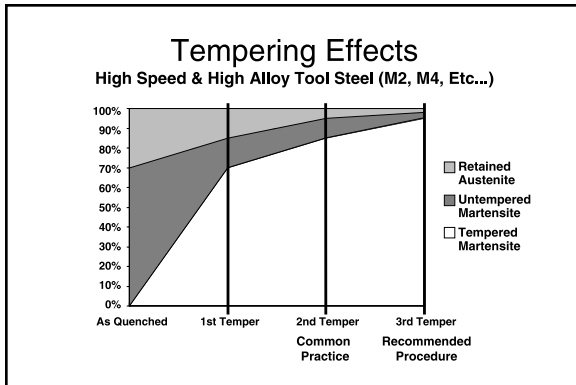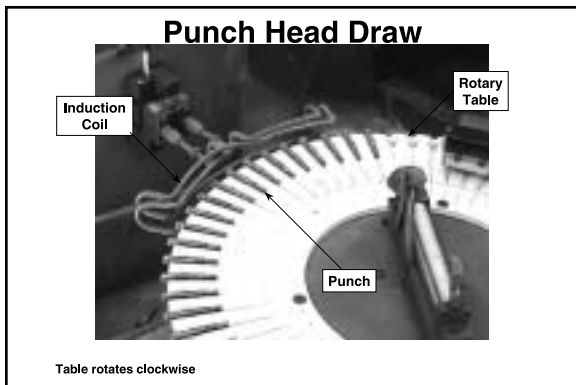
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This graph illustrates the effects of multiple tempering on high-speed tool steels.

Tool steels as quenched contain a majority of untempered martensite and approximately 30% retained austenite. Retained austenite and untempered martensite contain a great deal of stress which must be relieved or the tool will fail.

High speed and high alloy tool steels have good temper resistance, which allows them to be tempered at higher temperatures. Tempering at or above 538°C (1,000°F) will temper the untempered martensite and as the part cools, convert about half of the retained austenite into untempered martensite without reducing the part hardness below HRC 60. The effects of the higher tempering temperatures are enough to convert retained austenite to martensite reducing the need for cryogenic treatments on high speed and high alloy tool steels.

Standard heat treatment practice for high speed tool steels calls for at least two tempers. However, three tempers are necessary to bring the levels of retained austenite and untempered martensite to acceptable levels for stamping operations.

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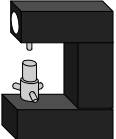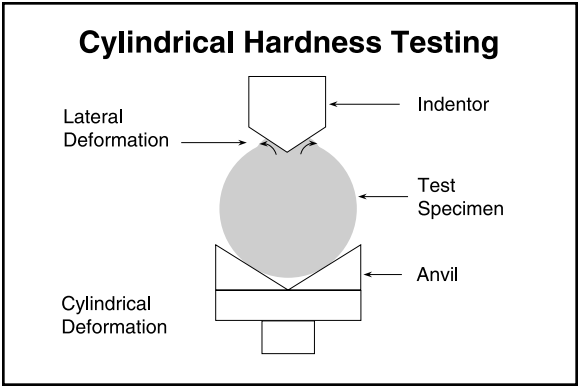Head breakage is a one of the more common problems encountered in stamping applications.

Precise induction heating and slow cooling as shown in the illustration above draws the heads down to a lower hardness (HRC 45 - 55) adding toughness to that area of the punch.

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Rockwell Hardness Testing is the most common test for the results of heat treatment. Checking hardness on a cylindrical surface will provide less lateral support, resulting in a lower hardness reading.

The Wilson Instrument Division of the American Chain & Cable Company published the Wilson Cylindrical Correction Chart #53 in 1953. This chart provides approximate correction values based on observed readings from various hardnesses and diameters.

It is important to note that "the accuracy of the test will be seriously affected by alignment of the elevating screw, "V" anvil, penetrators, surface finish and straightness of the cylinder"
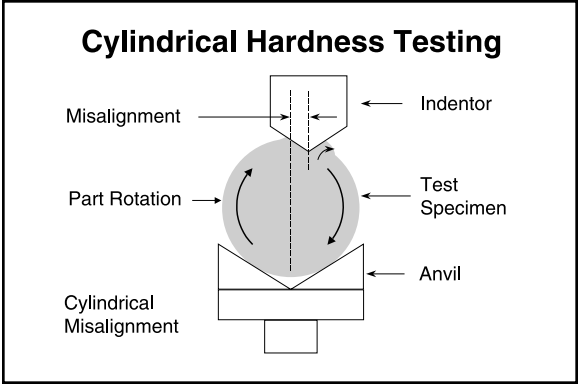
Rockwell scales can be used on diameters down to $1/4$ inch. Superficial scales can be used down to $1/8$ inch diameter. Diameters smaller than $1/8$ inch should be checked using a Knoop indentor at very low pressures.

Cylindrical Hardness Testing

Lateral Deformation

Indentor

Test Specimen

Anvil

Cylindrical Deformation

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Hardness testing accuracy will be improved by grinding parallel flats on the part. Care should be taken when grinding these flats to not generate heat which can affect the hardness. The test must be conducted with a minimum distance of two and one half diameters of the test result from the edge of the flat.
Cylindrical corrections can be used when flats can not be ground on the part. These corrections can be found on the Wilson Cylindrical Correction Chart #53.

Cylindrical Hardness Testing

Misalignment

Indentor

Part Rotation

Test Specimen

Anvil

Cylindrical Misalignment

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Misalignment of the elevating screw and "V" anvil to the indentor will result in low readings and could possibly damage the diamond indentor.

WILSON CYLINDRICAL CORRECTION CHART #53
Rockwell® Hardness Testing

CYLINDRICAL WORK CORRECTIONS TO BE
ADDED TO OBSERVED ROCKWELL NUMBER

Observed Dial Reading	"C" "D" "A" Scale	DIAMOND "BRALE" PENETRATOR Diameter of specimen - inch						
		1/4	3/8	1/2	5/8	3/4	7/8	1
	80	O.5	0.5	0.5	0	0	0	0
	70	1.0	1.0	0.5	0.5	0.5	0	0
	60	1.5	1.0	1.0	0.5	0.5	0.5	0.5
	50	2.5	2.0	1.5	1.0	1.0	0.5	0.5
	40	3.5	2.5	2.0	1.0	1.0	1.0	1.0
	30	5.0	3.5	2.5	1.5	1.5	1.5	1.0
	20	6.0	4.5	3.5	2.0	2.0	1.5	1.5

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Values from the Wilson Cylindrical Correction Chart #53 are to be added to the observed readings taken from tests performed on $1/4$ inch to 1 inch diameters when using the "A", "C" & "D" Rockwell scales.
Tests performed on smaller diameters are invalid when using these scales.

Surface Treatment Considerations

◆ **Commonly used Coatings**
◆ **Process Temperature**
◆ **Substrate Material**
◆ **Coating Thickness**
◆ **Coating Hardness**

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Surface treatments are often used as a means of improving tool life. These treatments increase surface hardness and wear resistance while reducing the coefficient of friction.
Important considerations when selecting a surface treatment are substrate material, coating process temperature, coating thickness and coating hardness.
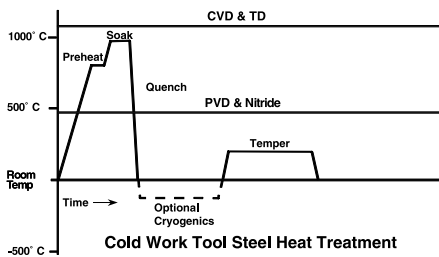
Common Surface Treatments

- Fluidized Bed Nitride
- Salt Bath Nitride
- Gas Nitride
- Amorphous Boron Carbide
- AIN (Aluminum Nitride) PVD
- TiN (Titanium Nitride) PVD
- XNM (MoST™)

- TiN (Titanium Nitride) CVD
- TiCN (Titanium Carbonitride) PVD
- CrN (Chromium Nitride) PVD
- TiC (Titanium Carbide) CVD
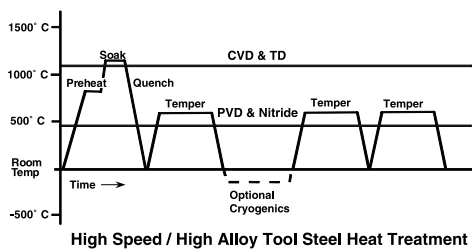- TD (Thermal Diffusion)
- XND (DayKote™)

Coating Failure

• Excessive heat due to tight clearance

Surface Treatment Process Temperatures

Cold Work Tool Steel Heat Treatment

Surface Treatment Process Temperatures

High Speed / High Alloy Tool Steel Heat Treatment

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There are many surface treatments and treatment processes to chose from. Nitride is a treatment that case hardens the surface of the substrate material. This treatment can be applied by numerous processes. Fluidized Bed, Salt Bath and Gas are the most common and economical processes to apply nitride. Ion nitride is a good process but tends to be more expensive. Nitride surface treatments work in a broad range of applications. Salt Bath nitride is the best from an application point of view but has lost favor due to environmental concerns.

Titanium Nitride, Titanium Carbonitride and Chromium Nitride applied using Physical Vapor Deposition (PVD) work well on precision tooling when used in specific applications. Titanium Nitride offers better wear resistance than Nitride and MoST coating but experiences some difficulty when working with copper and stainless steel applications. Titanium Carbonitride and MoST provide even greater wear resistance and will work in stainless and copper applications.

Titanium Nitride and Titanium Carbide applied using the Chemical Vapor Deposition (CVD) process and Thermal Diffusion do well in forming applications. These coatings work best in forming applications that do not require a high level of precision. Due to the high processing temperatures involved, precision is limited by distortion and changes in size.

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Coatings and surface treatments enhance wear resistance and reduce surface friction above and beyond the capabilities of the substrate material. They do not, however, eliminate the cause for wear and galling. Applications with tight punch to matrix clearance or punch over entry may not see a significant improvement in tool life when adding surface treatments.

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Surface treatments can be applied to a wide variety of substrate materials (tool steels) with varying results.

Note the relatively low tempering temperature for cold work tool steels such as A2 and D2. These temperatures are below the PVD and Nitride processing temperatures. Exposure to these temperatures will draw the hardness of cold work tool steels down to a hardness below HRC 58. Hardness below HRC 58 will leave the substrate steel vulnerable to deformation beneath the coating, creating adhesion problems for the coatings.

Part growth and distortion will also become factors which affect assembly of the tooling and precision of the finished product.

CVD process coatings are applied at the high end of the austenitizing range of cold work tool steels. Course grain structure and size change are to be expected in these circumstances. Precision and toughness will be questionable.

Thermal diffusion is a unique process that utilizes the carbon content within the substrate material to form the coating and quenches the tool as part of its coating cycle. It can be applied to D2 steel but the substrate hardness typically falls below HRC 58, potentially reducing the strength of the part.
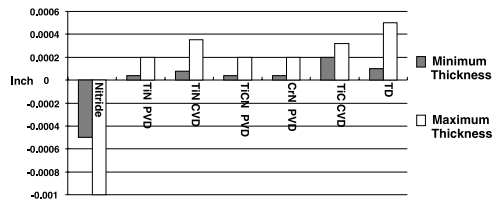
36

PVD process coatings and nitride work well with high speed and high alloy tool steels such as M2, M4 and CPM-10V. The PVD process temperatures fall more than 30°C (50°F) below the tempering temperature of high speed and high alloy tool steels, nearly eliminating distortion and growth in the part.

Due to the high processing temperature of CVD coatings and thermal diffusion (TD), post-heat treatment is commonly required to achieve acceptable hardness of the substrate material. Distortion and growth are to be expected.

Because of its utilization of carbon within the substrate material, TD will work well on steels with high carbon content such as M4 and CPM-10V in low to moderate precision applications. Thermal diffusion is not recommended on M2 due to its relatively low carbon content.

Thickness of Common Surface Treatments
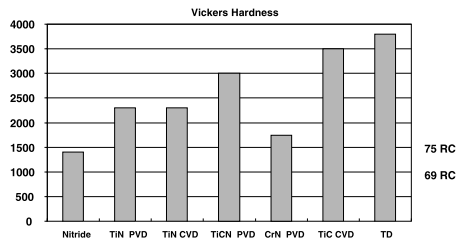
Bar chart with categories: Nitride, TiN PVD, TiN CVD, TiCN PVD, CrN PVD, TiC CVD, TD. Y-axis "Inch" ranging from -0.001 to 0.0006. Legend: ■ Minimum Thickness, □ Maximum Thickness.

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Coating thickness becomes an issue in high precision applications.

Nitride is a process of case hardening the existing surface of the part. Although nitride does not build up on the surface, the heat involved may cause slight growth in the part as a result of the matrix accommodating the diffusion of nitrogen.

PVD coatings are relatively thin and only cover areas within the line of sight of the coating source. Precision of the coated area is generally maintained and fit at tool assembly is typically not affected by this process.

CVD and TD coating processes are thicker and cover the entire part affecting precision of the working end and fit in a retainer. Stripping and reworking portions of punches may be necessary to assemble the tooling.

Hardness of Common Surface Treatments

Vickers Hardness bar chart with categories: Nitride, TiN PVD, TiN CVD, TiCN PVD, CrN PVD, TiC CVD, TD. Y-axis from 0 to 4000. Annotations: 75 RC, 69 RC.

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Like tool steels, hardness is an indication of wear resistance and lubricity for a given coating. PVD process coatings and nitride enhance the life of precision high speed and high alloy tool steels but will not cure wear problems caused by tight die clearance or punch bending problems due to high load.

Higher hardness coatings such as titanium carbide and thermal diffusion tend to be thicker and require a great deal of heat to apply, eliminating them from use in many precision applications.

The hardness values in the above graph are of the coatings themselves. Because these coating are extremely thin, their values can not be measured using a Rockwell hardness tester. The coating hardness is virtually undetectable on the Rockwell "C" scale.

Tool Steel Maintenance

◆ **Grinding & Sharpening Considerations**

◆ **Welding Tips**

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The following pages cover considerations and recommendations regarding the sharpening and welding of tool steel components.

Grinding Burn

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Care should be taken when sharpening punches and matrixes. Heavy passes with a grinding wheel, use of the wrong grinding wheel, an undressed grinding wheel or lack of coolant are just some of the causes of grinding damage.
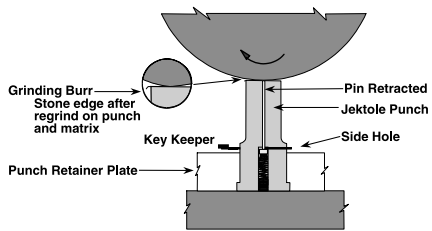
Grinding Burn

41

A closer look at the points of these punches reveals several types of grinding damage.

The discoloration, surface cracks and flaking are the visual results of grinding damage. Internal stress and changes in hardness also affect the tool life.

The face has begun the flake off of these punches due to rapid surface heating. The surface has expanded at a much faster rate than the rest of the punch, causing it to separate.

Point Chipping
Sharpening

Grinding Burr
Stone edge after regrind on punch and matrix

Key Keeper

Punch Retainer Plate

Pin Retracted

Jektole Punch

Side Hole

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Sharpening punches and matrixes requires grinding the face of the component with a grinding wheel. This process generates a burr as illustrated above. The burr must be removed before use to prevent the cutting edge from chipping.

The side vent hole in Jektole® punches serves two functions. One function is to minimize the suction at withdrawal that can cause slug pulling.

The other function is to allow the use of a keeper key to lock the Jektole in the retracted position. This function makes it possible to sharpen the punch without disassembly.

Grinding Damage

Grinding Burn

Grinding Burr

Thermal Expansion of Workpiece Surface

Magnetic Grinding Chuck

• Use mist or flood coolant.
• Keep depth of cut at a minimum.
• Dress grinding wheel often.

43

Grinding damage occurs when the surface temperature of an item becomes significantly hotter than the rest of the part. Thermal expansion of the surface creates stresses that may exceed the yield strength of the steel, resulting in grinding cracks.

Minor damage can occur even before it becomes visible. This damage will affect service life.

In severe cases, microstructure changes such as conversion of retained austenite, rehardening or annealing introduce additional stresses.

Once the damage is done, it is nearly impossible to remove.

Grinding Burn

• Punch split in the center due to surface cracks

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Improper sharpening can lead to a catastrophic failure as shown here.

The punch has split due to load and surface cracks from grinding heat. Cracks such as these occur when heat builds up in the punch. Unlike flaking, these cracks are the result of a much deeper heating.

Grinding Burn

• Heat check cracks and burn

Norton Grinding Wheel Selection

Tool Steel Grade	Hardness	Surface Grind Good	Surface Grind Better	Surface Grind Best
S7	50-58 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
H13	48-55 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
A2	56-62 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
D2	56-63 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
M2	58-63 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
	64-65 RC	32A60-IVBE	32AA60-IVTR	5SG60-IVS
PM M4	58-63 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
	64-66 RC	32A60-IVBE	32AA60-IVTR	5SG60-IVS
PM T15	58-64 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
	65-68 RC	32A60-IVBE	32AA60-IVTR	5SG60-IVS
CPM 10V	58-62 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS
	63-65 RC	32A60-JVBE	32AA60-IVTR	5SG60-IVS
CPM 15V	58-63 RC	32A60-JVBE	32AA60-JVTR	5SG60-JVS

This chart furnished in cooperation with the Norton Company

Welding Effects
With Preheat

- ☐ Weld (As Cast)
- ◼ Coarse Grain (Rehardened & Untempered)
- ◻ Refined Grain (Rehardened & Untempered)
- ■ Transition (Under Hardened & Tempered)
- ☐ Original Material
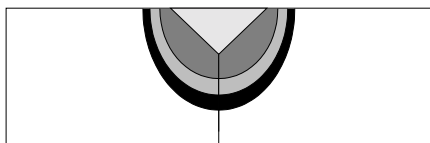
Welding information compliments of T & R Welding Systems, Dayton, Ohio.

Repairing Chipped Punches & Matrixes
(Filling With Weld)

- ◼ Tool Steel Weld
- ◼ Stainless Steel Weld
- ☐ Original Material

Welding information compliments of T & R Welding Systems, Dayton, Ohio.

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A closer look illustrates grinding burn and a heat-checking pattern. Grinding damage occurs when the temperature of the part comes within 50° of that part's tempering temperature.

The initial indication that the part has exceeded this temperature is color. A color change from brown to blue and then black gives an indication of burn severity. Cracks appear in severe cases such as the one shown here.

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Grinding wheel selection will have a significant influence on surface finish and potential grinding burn.

The above chart suggests grit size and wheel bond to finish grind commonly used tool steels. Grit size selection is usually first. This decision is based on the surface finish requirement and the amount of material to be removed.

A coarse grit selection will remove material faster while producing a rougher finish. A fine grit wheel produces a smoother surface finish but will burn the part much easier.

Wheel bond determines the hardness of the grinding wheel. Changes in bond selection offer fine adjustments.

A soft bond allows the wheel to break down relatively quick but will retaining a level of sharpness suitable for removing large amounts of material between wheel dresses.

Hard bonds help to hold the grinding wheel geometry while in use. These wheels will need to be dressed more often to maintain sharpness and prevent being loaded up with chips and debris. Failure to dress hard bond wheels will result in grinding burn.

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Welding is often done to repair large or expensive details. It is important that the detail be preheated prior the welding. Preheat reduces the temperature differential between the welded area and the rest of the part, therefore minimizing thermal stress.

The weld-affected area can be broken down into three main zones of transition.

The weld itself will produce an "as cast" structure. Carbides in the weld will be highly segregated. This non-uniform structure may have limited heat treatment response. Mechanical properties of "as cast" material are lower than that of wrought or forged materials.

The temperature of first transition zone (coarse grain) exceeds the normal hardening range of the original part material. The high heat produces a coarse grain, lowering the toughness wear and strength in this area.

The next area of transition (refined grain) obtains temperatures within the normal hardening range, therefore obtaining sufficient hardness. This area is under tempered, retaining high levels of stress that can lead to failure.

The final transition layer is the heat-affected area meets the non-heat-affected portion of the part. This layer tends to be over-tempered, reducing its hardness and inherent strength.

The major areas of transition are covered in the example above. There are subtle variations in their characteristics within and between each area.

To achieve a more uniform hardness in all of the transition layers as well as reduce stress, the part should be annealed and reheat treated after it has been welded.

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Repairing a chipped detail can often be accomplished by filling with weld. This process requires several steps.

The first step is to lightly grind the damaged area to remove surface cracks and loose debris.

Before applying weld, the detail should be preheated. Caution: small items should not be pre heated and typically do not tolerate being welded.

The next step is to apply a layer of stainless steel weld. The weld helps in the adhesion and shock absorption. 312 and 309 stainless steel welding rods are commonly used for this type of application. Diffusion of the base metal into the stainless steel weld should be kept to a minimum.

Hard weld is then applied to build up the chipped area. Care should be taken to not overheat the part. Small items will be the most difficult to weld. Replacement instead of weld should be a strong consideration for small items.

It is important to take the time to prepare and apply the weld per the above instructions if optimum performance is to be achieved. Keep in mind that each case will be slightly different based on steel type, part size and amount of weld required.

Contact a reputable welder for specific details regarding your application.