Is there really high-speed steel in your new turning tools?

Putting the Steel to the Test

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American Association of Woodturners

By Alan Lacer

For several thousand years, a piece of steel (or at least a steel-edged tool) came between the woodturner and the wood. Although the skill of the turner is a huge consideration in woodturning, the properties of the turning tool influence such things as longevity of the cutting edge (how long it holds an edge), whether it tends to break or bend easily, and how the tool reacts to heat (whether in use on wood or while grinding).

Since the 1980s, the transition from high-carbon steel woodturning tools (0.5 to just over 2 percent carbon) to high-speed-steel tools (iron, carbon, and additional alloys) is now nearly complete in the sale of new tools.

Few high-carbon steel tools are now available for sale in the USA (usually only from sources of used items and estate sales). High-speed steel (HSS) was developed for the metal trades and has been around for more than 100 years, but is a relatively new steel for the woodturner.

Although steel manufactured in Sheffield, England, dominated the tool market for decades, there has been a flood of HSS turning tools in recent years coming into the market from the Far East (primarily from China).

This influx of inexpensive imported tools, often at a fraction of the price of the English turning tools, really caught my attention. But with spiraling shipping costs and steel prices, how can these tools be sold as high-speed steel (sometimes stated as M2), some at prices below the price of a handle on the English tools?

I wanted to see if at least the steel was the same. The traditional way of determining whether a tool is high-carbon or HSS was with a spark test at the grinder. This test turned out not to be foolproof, as some tools sparked as HSS, but lacked sufficient quantities of those materials that produce the benefits of the genuine article.

Sections of lathe tools embedded in composite materials and prepared for emission (spark) test.

Tests at certified lab

The tests were conducted at Stork Material Technology (storksmt.com), a certified laboratory in Huntington Beach, California. The warning at the bottom of each Stork test stated: "The recording of false, fictitious, or fraudulent statements or entries on the certificate may be punishable as a felony under federal law."

Stork's process involved the cutting up of each tool and subjecting it to a chemical analysis by optical emissions. This process analyzes the spectra from an arcing area of the sample. In addition, the Rockwell Hardness C Scale (HRC) was measured at three points on the sample to arrive at an average hardness.

Costs for each test ranged from $50 to $150 per turning tool, a fee that most turners would never consider for a tool costing as little as $6 in some instances. The lab's sampling of steel effectively destroyed the tool.

According to Dr. Jeryl Wright of Crucible Materials Corporation, there are no legal definitions of HSS. However, there are American and international standards and definitions. The common understanding of HSS is steel that will resist softening at higher temperatures (usually can withstand a dull red heat, around 1,000˚F) and excellent wear resistance.

More specifically:

"High-speed steels are high-alloy, tungsten, molybdenum, vanadium, and cobalt bearing steels designed to cut other materials efficiently at high speeds, and must stand up to the extreme heat generated at the tool's cutting edge. This heat can reach 1,000˚F and more de-

pending on cutting conditions, coolants used, and other operational factors."

Qualities of HSS

The *Crucible Tool Steel and Specialty Alloy Selector* handbook outlines HSS characteristics for good cutting-tool performance:

- **High attainable hardness**, usually a minimum hardness of HRC 63. Typical metal-cutting tools may be HRC 64–68, depending on grade and application. High carbon content, along with elements to promote a more thorough hardening process, are common to all HSS for this purpose.
- **High wear resistance** to promote edge retention during cutting. Constant abrasion wears away tool surfaces. The high volumes of wear-resistant carbides in HSS micro-structures aids in resisting this abrasion.
- **Sufficient impact toughness** to handle interrupted cutting applications, to avoid chipping during cutting, and to avoid breakage in fragile tools. HSS are notably tougher than carbide or ceramic materials.
- **High hardness at elevated temperatures** involves both red hardness (the ability to stay hard at elevated temperature during cutting) and temper resistance (the ability to resist permanent softening over time due to high temperature exposure). The tungsten and/or molybdenum contents promote these properties. When needed, cobalt further enhances red hardness.

Heat-treating HSS

The heat treating of HSS is an involved process. The *Crucible Tool Steel* handbook referenced *above* also outlines the recommended process for M2 HSS (the most common steel used in English-made tools):

- Preheat to 1,500–1,550˚F.
- High-heat to 2,100–2,225˚F for 2 to 5 minutes.
- Quench in salt bath or oil to 1,000–1,100˚F, then air-cool to hand warm (150˚F). Temper immediately.
- Temper at 1,000˚F or higher two times for at least two hours. Tempering at 1,025˚F yields a 63.5 HRC, while tempering at 1,050˚F yields a 62.6 HRC. Both are optimum for maximum toughness and effective stress-relieving.
- Air-cool to room temperature between tempers.

The experts I spoke to believe that the lower-than-normal levels of hardness in some of the samples in the test may have been due to errors in the heat-treating process rather than a conscious choice to make a softer tool. The heat treating of HSS is a most critical part of the toolmaking process—one that must be done precisely and with great care.

Confusing terms

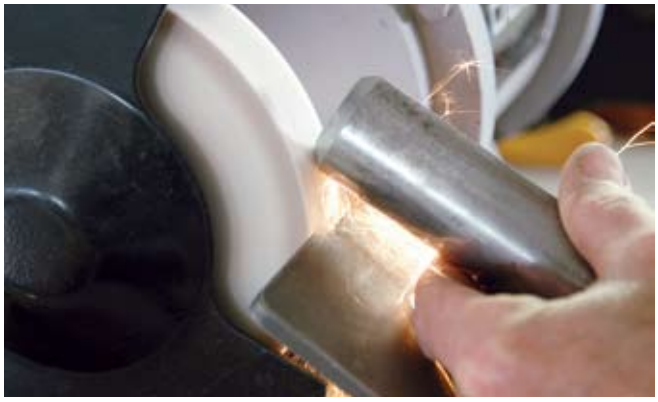
There are two terms related to turning tools that confuse many turners.

First is the use of **powdered** or **particle metals (PM)**. This is a process in steel making that yields

WOODTURNING TOOL-STEEL ANALYSIS

BRAND	COUNTRY OF ORIGIN	CARBON BY %	MANGANESE BY %	PHOSPHORUS BY %	SULFUR BY %	COBALT BY %	SILICON BY %	CHROMIUM BY %	NICKEL BY %	MOLYBDENUM BY %	COPPER BY %	VANADIUM BY %	TUNGSTEN BY %	IRON	HARDNESS (HRC)	PROBABLE STEEL[4]
Packard (Hamlet)	UK	2.30	0.00	0.00	0.00	10.70	0.77	4.00	0.00	7.10	0.00	6.60	6.50	B[1]	68.0	2060[5]
Sorby	UK	0.91	0.27	0.02	0.00	0.00	0.24	4.03	0.00	4.79	0.00	1.75	5.96	B[1]	65.0	M2[6]
Apprentice (Craft Supplies)	CHINA	0.87	0.40	0.03	0.02	0.00	0.30	3.95	0.00	4.55	0.00	1.83	5.99	B[1]	64.0	M2[6]
Benjamin's Best (eBay[2])	CHINA	0.85	0.35	0.02	0.02	0.02	1.18	4.50	0.07	0.29	0.11	0.12	2.41	B[1]	65.0	UN[7]
Benjamin's Best (Penn State)	CHINA	0.86	0.62	0.03	0.02	0.05	0.36	3.91	0.11	4.73	0.15	1.93	6.34	B[1]	58.0	M2[6]
Bodger (Highland Hardware)	CHINA	1.05	0.39	0.03	0.01	0.02	0.50	4.11	0.05	0.45	0.12	0.40	2.46	B[1]	57.0	UN[7]
Grizzly	CHINA	0.85	0.37	0.02	0.01	0.23	0.61	4.13	0.15	2.18	0.15	0.97	4.37	B[1]	62.0	HSS[8]
Harbor Freight	CHINA	0.74	0.17	0.02	0.01	0.00	0.27	4.11	0.00	0.00	0.00	1.04	17.61	B[1]	62.2	T1[6]
Pinnacle (Woodcraft)	CHINA	0.87	0.70	0.03	0.02	0.00	0.36	4.21	0.00	4.81	0.00	2.03	6.23	B[1]	61.7	M2[6]
Sears Craftsman	CHINA	0.82	0.26	0.0	0.00	0.03	0.56	4.10	0.11	3.97	0.09	0.97	0.05	B[1]	61.0	M50[9]
Shopsmith[3]	CHINA	0.94	0.11	0.02	0.01	0.09	0.22	4.02	0.11	4.50	0.14	1.68	5.84	B[1]	64.0	M2[6]

1. Balance of tool composition is iron.
2. Purchased new via eBay auction.
3. Part of a 4-piece bowl-turning set (not the standard 5-piece Shopsmith turning set).
4. Interpretations contributed by Stork laboratory technicians, Dr. Jeryl Wright, and Jerry Glaser.
5. 2060 is a particle or powdered metal (PM) HSS with extremely high wear-resistance properties.
6. M2 and T1 are long-established HSS compositions with good track records.
7. Unknown steel. Failed high-speed steel (HSS) test as defined by the American Society for Testing Materials (ASTM). HSS must contain specified amounts of carbon, chromium, vanadium, tungsten, and molybdenum.
8. Meets the minimum amounts to be called an intermediate HSS.
9. M50 is a HSS, primarily used for bearings, but with low-wear resistance.



As a general guideline, high-carbon steel sparks remind some turners of sparklers. At the grinder, you should notice a complex shower of sparks.

As a general guideline, high-speed steel (HSS) sparks remind some turners of tracer bullets and tend to be individual sparks. Note: This test is not always conclusive for HSS.

tiny rounded particles rather than a large ingot of steel. The particles are then compressed under heat and high pressure. This process yields a more consistent steel and one with greater toughness (a steel's ability to resist breaking under stress or shock).

The other term is **cryogenic treatment** of steel. This is a cold treatment of between 100–300˚F below zero. According to Dr. Wright and Jerry Glaser, cryogenic treatment done as a step in the tempering process (after the first temper, but before the second) yields a tool that is more uniform in its heat treating and will offer increased steel toughness.

Some experts question whether cryogenic treatment performed after the heat-treating process produces any improvement in the steel's properties.

Observations, conclusions

First, beware of generalizations because the test results were for a single tool from the company's inventory. All tools were purchased in the last two years through regular retail catalog channels or new through Internet sales.

Second, let's not forget that a turner can achieve gallery-quality work with any of the tools listed on *page 53*. With that said, some tools will hold an edge poorly compared to other steels and some will not hold up to heating as low as 525˚F (bluing occurs around 570˚F).

The more serious problem resides in purchasing tools sold as HSS but are in fact not. If a company spot-checks its supplier and discovers that the tools don't meet HSS standards, it has several choices. It can relabel that shipment, deleting the HSS claim. Or it can refuse the batch, insisting that the supplier correct the problem.

As a turner, I am afraid "buyer beware" does not work with steel content and how well it was heat treated. I may have to use a tool to find out its properties. This is a challenge for the inexperienced turner to judge.

There are some good buys among the legitimate HSS turning tools. And, many tools are a sound choice for someone just entering the world of woodturning.

Other tool shortcomings

The design adequacy of the tools (shape and thickness of the steel, not the edge profile) is a hard one for the beginner to judge. Some of the tools were lightweights or had designs that were not well thought out. Also, proper heat treating is an unknown.

For consistent and predictable tools, true HSS must be performed correctly. One of the Sheffield, England, toolmakers reported that his company performs a hardness spot test on each batch of tools delivered from its heat-treating facility. If even one sample doesn't measure up to the company standards, the entire lot is returned to the heat treater.

Remaining questions

Important questions remain about steel for turners:

- How would each of the steels react to "bluing," which can easily occur at the grinder and even while in use.
- Much has been made about differences of sharpness in steels: Some turners believe high-carbon steel gets sharper than HSS, others believe M2 gets sharper than the high-wear steels such as A11, M4, 2030 and 2060.

These topics are ideal for a follow-up article.

Special thanks for assistance with this test to Jerry Glaser, retired toolmaker of 45 years and AAW Honorary Liftetime Member, and Dr. Jeryl Wright, vice president of Technology for Crucible Materials Corporation and one of the largest makers of specialty tool steels in the USA. Both men are woodturners, so knowledge of both steel and woodturning are special strengths of these two individuals.

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