

CUTTING TOOL MATERIALS, MANUFACTURING PROCESSES, AND THEIR EFFECT ON SHEETING AND SLITTING QUALITY

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HARDNESS, WEAR RESISTANCE, AND IMPACT STRENGTH ARE ALL CONSIDERATIONS WHEN SELECTING MATERIALS FOR SLITTING AND CUTTING TOOLS.

SINCE THE CHINESE DISCOVERED HOW TO INTERTWINE fibers of cloth strips, bark, and hemp thousands of years ago, the paper industry has been in a constant state of change. Since the advent of modern-day papermaking equipment, some of these changes have been more gradual and subtle. Within the last decade or so, they have been presenting themselves on a dual basis: from the manufacturing side and the customer side. On the manufacturing side of things, sheets that were being produced just five years ago have changed due to the need to produce a more cost effective sheet to improve profit margins, as well as increased use of post consumer recycled fiber. From the customer side, the need to have a more cost effective sheet was also an important factor, but another consideration was the need for a brighter product. Factor into these changes the need for better slit cuts to accommodate high technology, high speed printing, and labeling and packaging equipment. Also, consider the way we slit our product needs to change along with the rest of the industry. This need has driven slitting tool manufacturers to investigate the materials as well as the processes used for manufacturing and sharpening slitting and cutting tools.

The material numbers presented in this article are AISI (American Iron and Steel Institute) numbers and are the steel industry standards in the United States. If a material has a trade name or number, it is a U.S. requirement to also have an AISI number. This ensures that if anyone requires specific information, it is readily available from a multitude of resources.

When there are discussions regarding cutting tool material, one of the first questions asked is how hard the steel is. Although hardness is very important, it is only one of three components required to make the proper choice. The other components concern themselves with the wear resistance of the steel and impact strength. If the material is hard but very brittle, it would be of little value, and it would also be a primary safety hazard. The optimal hardness level is relative to its wear resistance and impact strength. For example, many tool steels have an optimal hardness level between the range of 58-61 on the Rockwell C scale. If the hardness level is greater than this, the impact strength will be greatly affected.

MATERIALS

For many years, when paper was primarily virgin fiber and acid in content, and the slit quality standards from customers were not so stringent, it was quite easy to slit. During this time the cutting tool manufacturers made the vast majority of slitters from alloy steel, usually 52100. It was inexpensive to buy and easy to machine as well as grind. It produced adequate slit cut quality, and because of the machine speeds during this era, downtime to change slitters was not a high priority. It had adequate hardening capabilities as well as impact strength, but its wear resistance was only fair. When the change in customer needs began to involve a better slit cut and longer knife life, a better cutting tool material was needed.

**AISI T-15
High Speed Steel
Typical Analysis**

Carbon	1.5%
Chromium	4.0%
Vanadium	5.0%
Tungsten	12.0%
Cobalt	5.0%

**AISI T-1
High Speed Steel
Typical Analysis**

Carbon	0.75%
Chromium	4.0%
Vanadium	1.0%
Tungsten	18.0%

**AISI M-2
High Speed Steel
Typical Analysis**

Carbon	1.0%
Chromium	4.0%
Vanadium	2.0%
Tungsten	6.0%
Molybdenum	5.0%

**AISI M-4
High Speed Steel
Typical Analysis**

Carbon	1.3%
Chromium	4.0%
Vanadium	1.5%
Tungsten	5.5%
Molybdenum	4.5%

**AISI D-2
Cold Forming Tool Steel
Typical Analysis**

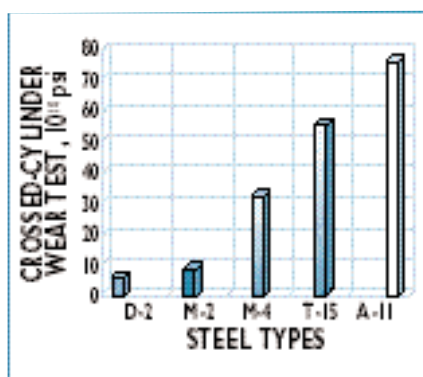
Carbon	1.55%
Manganese	0.35%
Silicon	0.45%
Chromium	11.50%
Molybdenum	0.90%
Vanadium	0.80%

**AISI M3:2 (ASP-23)
High Speed Steel
Typical Analysis**

Carbon	1.28%
Chromium	4.20%
Vanadium	3.10%
Tungsten	5.40%
Molybdenum	5.00%

**AISI A-11 (CPM-10V™)
Cold Forming Tool Steel
Typical Analysis**

Carbon	2.45%
Manganese	0.50%
Silicon	0.90%
Chromium	5.25%
Vanadium	9.75%
Molybdenum	1.30%
Sulfur	0.07%

I. Composition of seven different types of high speed and cold forming tool steels

1. Reciprocal of the wear rate in an unlubricated cross-cylinder wear test in contact with a rotating tungsten carbide cylinder.

Manufacturers began experimenting with different tool steels. A cold forming tool steel called D-2 started to become more widespread. It had a high chromium content (11.5%) as well as a slight vanadium content (0.8%) for wear resistance, and it had about the same impact

would be any danger from loss of hardness, except in areas such as stationary core cutters. This could happen, however, if the tools were sharpened improperly and heat was generated from the grinding process.

The primary advantage of high speed steel in the sheet metal area is its ability to withstand impact. Because it has been designed for the machining industry, it needs to have the capacity to withstand a fair amount of impact due to interrupted cuts produced by, for example, a milling cutter. In the sheet metal, this is exactly what is produced, but it should be on a very small scale. From a performance standpoint, these materials work very well.

There are many high speed steels. The most popular are M-2, M-4, T-1, and T-15. The "M" series tool steels have an elevated content of molybdenum, whereas the "T" series has more tungsten. Low availability and high cost, especially for the "T" series, have reduced the use of these materials on a more widespread basis. D-2 tool steel has become more of a standard by which to benchmark a start point. Its primary use in industry, aside from slitting tools, has been forming, punching, and shearing dies in the tool and die industry. D-2 is still very popular and provides an adequate amount of service between sharpening, where downtime to change slitters is not a huge factor, and where a declining curve in cut quality is acceptable. Of course, there are many other types of tool and alloy steels that are being used in the cutting tool industry today, but for brevity, I have only mentioned the more popular ones.

Table I offers a comparison of the composition of seven types of high speed and cold forming steel tools. **Figure 1** provides a comparison of wear resistance of five

strength as 52100. The cost of the material along with manufacturing costs were higher, but the improved cut quality as well as additional blade and band life easily paid for any cost difference. At the same time many other tool steels began to emerge on the market.

In the sheet metal area, high speed steel began to be popular. High speed steel, by definition, is a tool steel that will maintain its hardness level at elevated temperatures. Its primary use in industry is for cutting tools in the machining industry. Drills and taps, end mills, and similar products are used to cut steel and produce an extremely high temperature at the cut point. This particular feature provides no advantage in slitting or cutting. The temperatures produced do not get to the point where there

types of these tools.

As the paper industry began to use machines that were larger, faster, and more productive, customers began to demand a brighter sheet, with little to no dust or edge cracks. At that time the knife industry began to look toward the powdered metal industry for answers. Making a good decision can become confusing in this area because simply using a powdered metal is only a start point.

One has to realize that there could be as many powdered metals as there are rolled steels. The advantage to using a powdered metal, very basically, is that during the manufacturing of the steel, it is first made into a very fine powder, about the consistency of pencil lead. In historic steelmaking processes, it is simply poured. This powder is dried and all inert gases are removed. From there it is heated and, with the use of pressure, formed into a billet. It is similar to the manufacturing of carbide or industrial diamonds. This gives the end user a product virtually free of grain. It also eliminates the problem of having a hard or soft spot in the slitter. Each carbide that is formed during the heat treating process will be of equal size and shape, thereby making the slitter more uniform within itself as well as each other. This technology now has to be married to the proper type of powdered metal.

As stated earlier, basically any metal can be powder. The cutting tool industry experimented with primarily two different types: CPM-10V™ (AISI A-11) and ASP-23™ (AISI M-3:2). Both materials are trade names of the companies that have developed them. Although each has proven to be a dramatic improvement over the standard rolled tool steels used in the past, the extremely high cost of the material as well as the fact that it is very difficult to machine and grind have made these tools expensive to manufacture and, ultimately, purchase. Because of its higher vanadium content and superior abrasion resistance, the AISI A-11 material has primarily taken over the slitter market in the powdered metal slitter area.

It would not be logical to have a superior top slitter without a bottom slitter of equal integrity. Tungsten carbide has emerged as the most widely used choice for this tool. Here again, to simply state that the band is made from tungsten carbide would be like saying that all paper is the same grade. The proper grade is needed to marry high wear resistance along with enough elasticity so it will not fracture during use. This is achieved by using more or less of the bonding agent in the manufacturing process. Cobalt is the bonding agent, and the percentage of content will dictate the amount of wear resistance versus impact strength the carbide will have. Today approximately 12% is the normal cobalt content in carbide bottom slitters used in the paper slitting industry.

This is a very good example of something that can be too hard for its application. A few years ago, zirconia and

alumina ceramic made an appearance on the bottom slitter market. Ceramic is only second in line to diamond in hardness, and the industry rallied to get this technology into practice. The end result was that because of the ceramic's extreme hardness levels, it was very brittle. Considering the difference between a laboratory setting and a mill setting, there was rarely a case where the ceramic bottom band wore out. They were almost always destroyed due to chipping before all of the life could be exploited.

HEAT TREATING

The type of material chosen is still not the entire answer to making the proper cutting tool choice. Heat treating techniques are also very important. Historically, heat treating was performed in an atmospherically controlled furnace that, because of the presence of some unwanted gases, could create uneven heat. In conjunction with the grain structure of the poured material, this could cause hard and soft spots in the parts being heat treated. Vacuum heat treating is used more today. It eliminates this problem by removing any of the unwanted contaminants from the heat treating environment, producing a more even heat. Unfortunately, because of the restraints of the size of the equipment, some larger knives cannot be treated in this fashion, and alternative methods are still being used. The method of heat treating also includes proper fixturing to ensure the knife maintains its shape when brought to the extreme high temperature required for the needed hardness.

Once brought up to heat, the knives now need to be quenched at the proper speed to get the actual hardness level. This will bring the hardness level quite higher than the requirement, but it must be done in such a way as to transform as much austenite (a nonmagnetic solid solution of carbon or iron carbide) into martensite (a very hard, brittle, solid solution of iron and carbon) as possible. Next, the parts are once again heated, though to a cooler temperature, and slowly brought back down to ambient. This drawing process will bring the hardness level to the exact requirement for the tools application while still allowing for the maximum transformation of the austenite into martensite. If this drawing process is repeated two or three times, it helps the stability of the material and also contributes to a greater austenite/martensite transformation.

Any conversation regarding heat treating would not be complete without also discussing cryogenics. This is a process in which the part is slowly brought down to an extremely cold temperature, sometimes as cold as -320°F. It is soaked there for a period of time based upon the amount of cross section of the part, slowly brought up to a heated temperature, and finally slowly brought back to

ambient. During the heat treating process, the austenite/martensite transformation is never complete, and the cryo process is supposed to further complete this transformation. Whether this process actually works to the degree where it provides an actual value from a wear resistance point of view is still debatable. It does produce, however, a more stable part, thereby making the slitter flatter, with a more uniform shape, giving the end user a better slitter from a geometric standpoint.

With all of the changes made in paper formulation and all of the "higher bar" quality standards being demanded, the reasons for better knife materials and processes can all be summed up in two words: "closed nip." Slit quality is totally dependent on a closed nip at the cut point. When the blades or bands begin to get even slightly dull, a radius is formed, and a very slight open nip begins to develop. This open nip is what causes the fibers to be pulled or the edges to be cracked, resulting in complaints or rejected product.

The key is to start with a knife material that has superior wear characteristics so that a closed nip can be maintained for a longer period of time. If this is coupled with superior grinding techniques, such as superfinishing, an absolute closed nip is the result. Setting depths can be reduced, causing less drag on the sheet and fewer fiber pulls. The side load force can be reduced to prolong the life of the slitters from metal to metal wear. All these things promote a closed nip and high quality cuts.

Of course, these same high quality cuts can be produced using lesser grades of material or something other than carbide. The problem is that it will only be for an abbreviated period of time. As the cutting edges of the blades and bands begin to wear, the nip begins to open and the cut deteriorates.

KEY ELEMENTS

Even with superior materials, heat treating, and grinding processes being used, poor quality cuts will definitely not disappear. These are only the steps required to ensure top quality cutting. If the slitter section or knife box section is in poor condition as a result of holders, bearings, alignment, or other items, there is no material made that will help.

Operator education is also key. If employees are given the best tools to use without the knowledge of how and why, they too will not produce the dividends needed. It is not as simple as spending some money on better cutting tools. Problems do not diminish as a result of investing in a product if no one knows how to properly utilize it. Not only will there be no signs of improvement, but more problems could occur. Quality of parts, condition of the equipment, and education of the operators are all of

equal value to the end result.

In the case of sheeter knives, going to improved materials can make a definite impact. Once again, depending on the condition of the machine and the capacity of the person setting the knife, it will improve not only the cut quality but also the longevity of the knife in the machine. There are some mills that work on a very strict preventive maintenance schedule that are running five rolls up on a cut size sheeter and changing every 20 weeks. It took more than five years to gradually get to that point, and they are still experimenting, trying to get to 25 weeks. In most of the cut size syncro systems, the A-11 powdered metal on both the fly as well as the bed knives have become the most widely used. There are two reasons for this. First, the system used to attach the knife to the knife box is like a wedge in shape. When it is wedged into place, there is a chance that the angle of the knife will not be the same as the wedge. Although this should not happen, after awhile parts begin to wear and could gall the soft face of the knife and render it worthless on any setting in the future. This does not happen very often.

The second reason is more prevalent. When the fly knife is being set to match the bed knife, there are a series of bolts that make contact on the back of the fly to slightly move it to the same shape as the bed knife. The ends of these bolts will actually make dimples into the soft carrier material of the knife that the carbide is attached to. This will make no impact on the setting the first time it is used; however, the bolts will have a tendency to walk back into those dimples on any subsequent settings, causing much difficulty.

Although some mills have gone to carbide inlay knives in the lower beds, the solid powdered metal A-11 has been the most widely used. In fixed bottom knife configurations, carbide bed knives have become very popular with the A-11 powdered metal fly knife. The reason is that there is only one bed knife, and the A-11 fly will give at least some forgiveness, if by chance the two knives should click. If they were both carbide, there would be a very good chance that one or both knives would be destroyed. Considering the cost of the carbide knives, it is very good insurance. The fly knives, because they are solid hardened A-11 powdered metal, can also be adjusted without fear of putting dimples into the soft carrier and creating problems on future settings.

Once again, it needs to be stressed that improved material will not necessarily mean better results. If the top tapes following the cutoff are set too low, they will tear the sheet at the cutoff and cause fluffing. If the knife box is out of alignment, the bearings are worn, or if there is too much play in the drive gear, there will be an impact on the quality of the sheet as well as how often the

knives will need to be changed. Although the knives (slitters versus cut-off) vary in shape, the action is still quite similar.

What we absolutely need to have is a closed nip at the cut point. Any slightly open nip, whether from normal wear, honing from the sharpening process, or honing during use, will create the pulling and pounding associated with having dull knives in the machine.

These issues explain why it is so important to have the exact specifications not only on the setup process in the plant, but also the tolerancing of the knives themselves, as well as the material type that best suits the machine and material being cut. If all of these issues are addressed on a consistent basis, many of the problems now being seen in the converting area will no longer exist. It is very similar to what has been done on the manufacturing side of the mill for years. A complete list of items can be checked on a down day, and slitting now needs to be included in that list.

SUMMARY

Slitting and sheeting have and will continue to change dramatically. Materials used to manufacture knives need to keep up with the demands of a sheet with increased fillers as well as higher quality standards of the end user. Accurate tolerancing, heat treating techniques, good machine maintenance, and operator education are all of equal value to achieve a closed nip at the cut point, which is an absolute requirement for sheeting and slitting. **TJ**

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