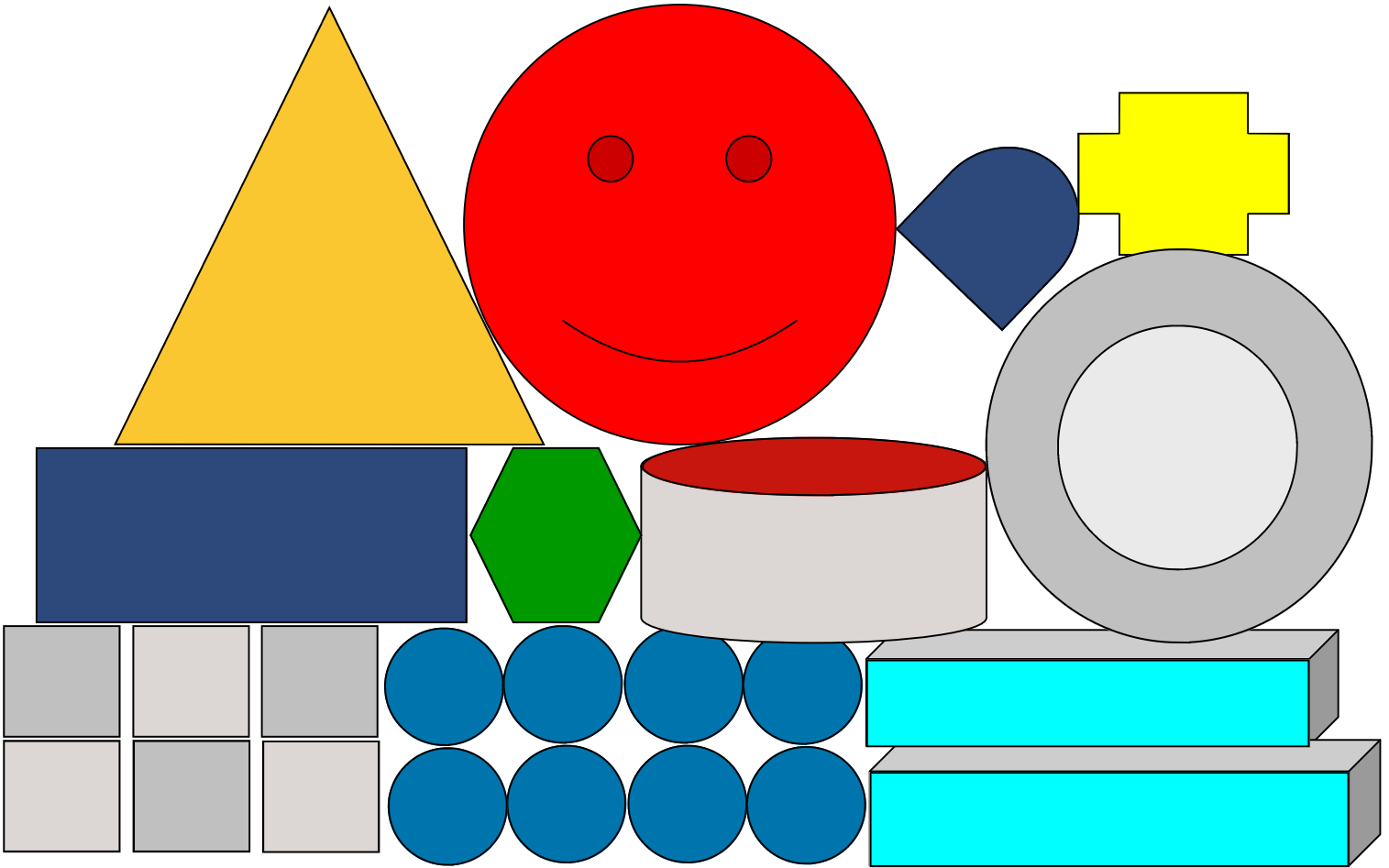


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A GATEWAY EDUCATIONAL ENLIGHTENMENT ARTICLE

Subject: HOW TO SELECT THE CORRECT TOOLING STEEL

Over the years I've received thousands of calls, letters and e-mails from desperate people all over the world wanting to know why one of their parts failed. I couldn't even hazard a guess of how many of them were simply that the wrong grade of metal was chosen to begin with, or the heat treat process was just innocently incorrect.

Quite often it's because of a bad habit phenomenon that I call the 'grandfather act'. The grandfather act is very often the favorite manor of engineering methods to chose a metal grade. Example: what often happens is an engineer is tasked to design a new part, or improve a previous design. No one wants to make a bad choice, and often there isn't time to spend in researching their assigned project. So they seek out a previous, 'grandfather act' design, and use that grade of steel. The problem with that act, is it's highly unlikely that previous failures, poor or even good performance was ever recorded. It may seem expedient at the moment, because it is easier to invoke the 'grandfather act' because 'just maybe' the steel choice might still work. It's a common assumption that if someone chose a grade 5 years ago, or 50 years ago, they knew what they were doing, so just trust them. But that is just an assumption! While they're at it, they will likely also check to see what grand dad called out for the hardness, and they assume that 'might' work for them also.

Engineers typically get some training in how tensile and yield strengths should affect a metal, but most parts that fail, or produce short life is because the application itself has been poorly interpreted. And that is not always easy without good observations, and smart judgment, plus an education of what forces are present.

And, that's where this article leads us to focus on: **HOW CAN WE CHOSE THE CORRECT TOOL STEEL OR METAL TO FILL AN APPLICATION?**

That doesn't mean we make it easier to chose the correct grade of steel. All we can do is challenge you to stop and evaluate the application.

To do it right, first we must evaluate each individual part's interaction to all the other parts in an application. To do it correctly, here is a series of questions that might help steer toward the best results.

1. What operation will the tool or part be performing? Cutting, shearing, punching, forming, or any, and all mechanical operations?
2. What type and grade of material is going to be worked on? And, what is their chemistry?

WHAT DO ALL THE ELEMENTS IN STEELS BASICALLY DO?

THE ELEMENTS	THE POSITIVE EFFECTS
Carbon	.06 to .35% Allows shallow case hardening .35 to .60% Allows easier case hardening .60 to .80% increases hardenability .80% an up increases wear, but not always hardness
Manganese	Increases deeper hardening ability
Silicon	Adds strength and toughness
Chromium	Adds wear resistance and toughness
Nickel	Adds toughness and may enhance wear
Tungsten	Adds wear resistance
Vanadium	Refines grain structure
Molybdenum	Adds heat resistance and hardenability
Cobalt	Imparts heat resistance
Columbium	Adds wear resistance
Sulfur, Lead, Phosphorus, Calcium	Imparts better machinability. These elements are dirt and do not homogenize with the base elements.

Continued on page 7



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3. How thick is the material that is being worked on? Are there fragile cross sections?

4. How hard, soft, brittle or spongy is that material?

5. How many parts will the tool you need be expected or likely to be used to produce or experience?

6. If used for prototype proofing, how many parts will be needed?

7. What chemistry is present in the parts, and what is the percentage of the content?

8. In some cases even the atmosphere, temperature or physical area in the environment needs consideration.

In addition, what you are trying to determine should include an evaluation of:

A. How much wear is involved? Answering this little question will involve knowing the materials and/or conditions being worked on. But, you also need to recognize when materials or other factors would cause abrasion. For instance, paper may sound like a relatively harmless material to work on, compared to a bar of steel, but paper, like other materials may be full of abrasive minerals.

B. A steel bar might also contain some nasty elements as well. So, if your part design may be cutting, shearing, bending of other metals and materials, you need to know the elements in those metals or materials. If for instance you are cutting a metal with high amounts of Chromium, galling can become a major issue. (**Galling** is another type of wear, plus adhesion, often of similar elements between sliding or rubbing surfaces. Microscopically gall often occurs when uneven surfaces pick up minute amounts of material and it will build up on the surface where compression of the touching surfaces occurs. Similar elements, such as Chromium may gall easier than some other elements, but gall can occur between other elements. Careful element choices is the first line of defense, but breaking in and careful maintenance is essential.)

C. Is there heat, hot materials, or friction above 300⁰F involved, plus for how long is that heat present? Any heat above 300⁰F can cause change to hardness in heat treated metals and that effects the metal's properties.

D. Is there any heavy impact or shock resistance issues? Some times people will draw the hardness out of a hardened metal to increase impact and shock resistance only to lose or destroy wear resistance.

E. Is there any compression involved? Compression is any force exerted on another material. (Compression and shock are two very different forces.) It can be intermittent or repeated for some duration. Fatigue can enter in and the tool can fail prematurely. Again drawing the hardness down can ruin the original properties of a metal. Shock is easy to evaluate, compression can be more difficult to grasp.

It's also necessary to have some knowledge of what effects heat treating has on metals. We can't cover this area very far in this article, but here is a glimmer of why this is important. Years ago W1 or its simple non-tool steel grade, C1095 was used to make chisels. It had fair impact resistance and a high hardness, case hardened skin on a softer core. The core was soft because there was not enough of the elements needed to promote thorough hardening. But the high carbon on the outside of the metal developed hardness from the quick water quenching used to create hardening. Used as a chisel the repeated striking of the hammer often caused the hard outer structure to peen over. After a bit of use the pieces of the peened over edges would often break off, in flying pieces, and could injure workers if it flew at them.

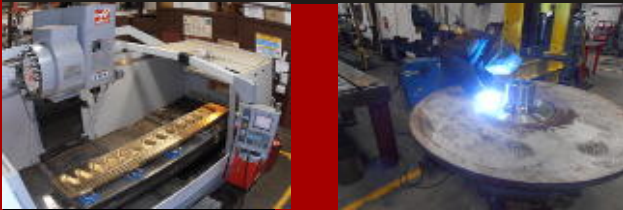
So thinking about and understanding that heat treatment of some grades could cause other dramatic and associated issues is quite important. Plus, metal grades have improved from granddad's era. I remember when it was basically just oil and

Continued on page 9



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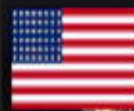
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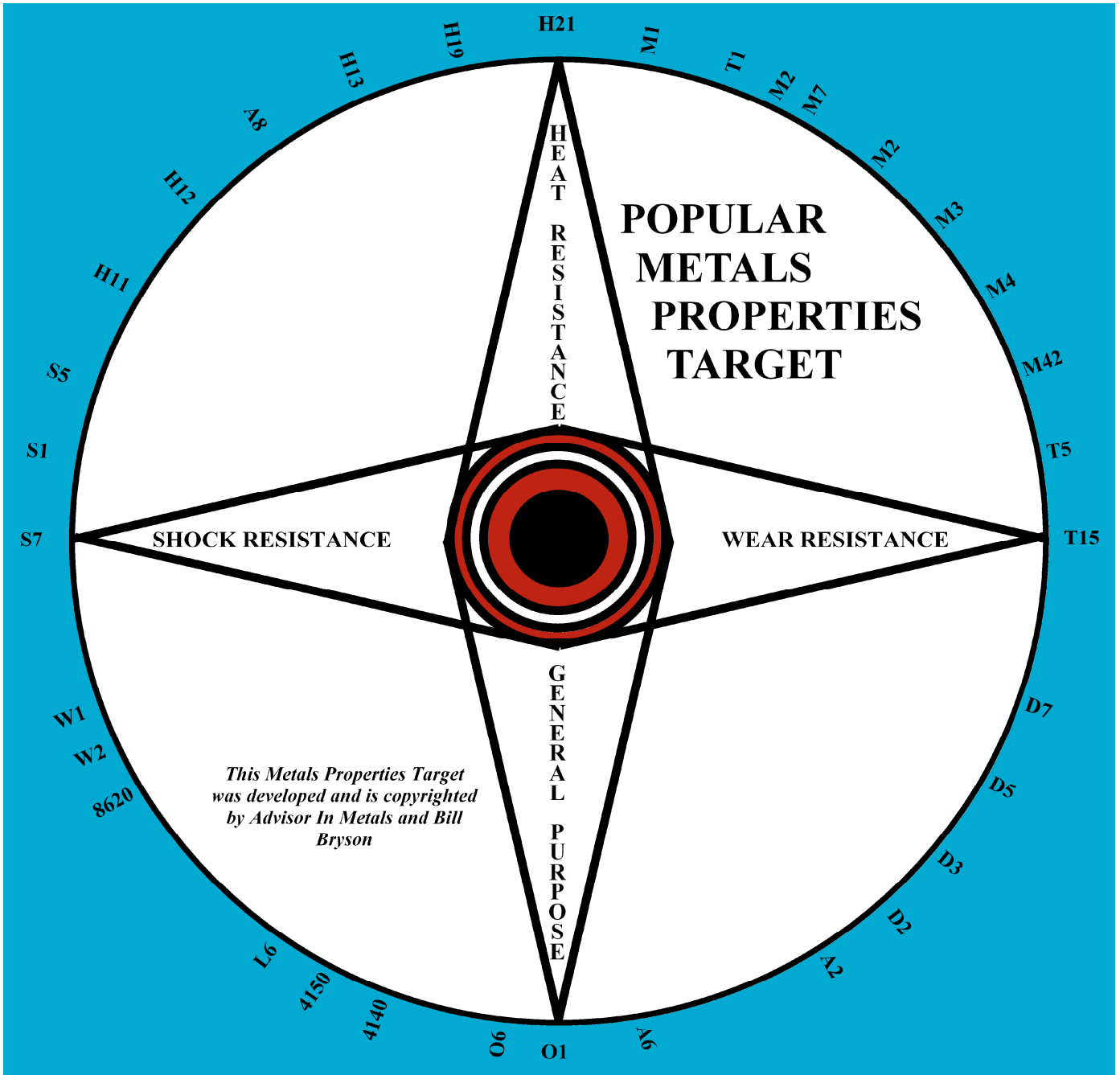
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water hardening steels. Water hardening steels are still needed primarily for spring applications. That hard exterior and softer, memory core are a perfect combination for springs. Oil hard steels are still used a lot, but air hards offer safer, cleaner, less distortion with reduced grinding.

The next area we need to look at in choosing a proper material for our project, can be:

Availability

There are 100s of metal choices and grades of metals in the marketplace. But you or your company do not want to use them all. In no way should a company ever consider needing to use all the different grades of material listed in the target, so please remember every grade of steel and most metals were designed to fit one particular application. If you need tool steels, focus in on using just three or four basic tool steels.

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Heat Treatment

You may have an in-house heat treating furnace, but there are several steels that require temperatures above 2100°F. They also may have very critical soak times that are literally measured in seconds, or the grain structure goes punk. Remember it's the grain structure that makes a metal great. It's not the hardness! All the elements in a steel have a distinct purpose and function. They can be made usable with good heat treating, or made completely ruined.

Suggestion for most companies:

Adopt a few grades of steel as your base so that you can be very specific in the heat treatment recipe that you want performed for each grade. That recipe shouldn't be varied without a lot of thought and understanding.

1. You need one tool steel for decent wear resistance. Perhaps A2.
2. Then another steel for shock applications like S7. Some use another steel grade for general purpose applications, but S7 can fill the majority of all general purpose applications and it may cost less per pound than other general purpose grades. Plus S7 has the best shock resistance of all other grades of tool steels.
3. If you have hot work applications then S7 might serve that as well. S7 can handle hot work up to 1000°F for intermittent high temp usage. H13 is a good grade for higher, longer hot work applications.
4. One more grade may be needed for higher wear resistance like D2.

Grade	Charpy ft/lbs	Quench Medium
A2	17	Air
A6	28	Air
A8	42	Air
D2	8	Air
D3	6	Oil
D5	6	Oil
H11	85	Air
H12	96	Air
H13	68	Water
H19	43	Air
H21	34	Air
L6	72	Oil
M1	12	Oil
M2	10	Oil
M3	7	Oil
M42	10	Oil
M7	11	Oil
O1	33	Oil
O6	33	Oil
S1	185	Oil/H ₂ O
S5	170	Oil/H ₂ O
S7	235	Air
T1	9	Oil
T15	4	Oil
T5	5	Oil
W1	80	Water
W2	77	Water
4140	65	Oil
4150	65	Oil
8620	75	Oil

Each of the above grades (A2, S7, H13 and D2, up to a certain mass size) are primarily air hardening. **Air hardening grades are safer and cleaner to heat treat than oil or water quench steels. That mean less decarb, less scale formation, less grinding, less distortion, and lower quench cracking danger.**

Most applications will not need High Speed steels, so just one, two or three steels are often enough for any company's in-house applications. The goal of the AIM target is to give you more information to make sound logical decisions on what your application needs are. There are some areas where you might have an application where you need wear, impact and hot work resistance. You will need to focus on the most valuable asset to the least to make a logical choice.

The rest of the tool steels on the market are designed for other specialty applications, and can also be carryovers from previous decades of usage. So why are they still in use, you might ask? It's because all the engineering drawings and documentation from decades back are very costly in man-hours to go back, review, re-engineer and revise. And swapping steel grades without thorough examination could be as dangerous as the grades presently called for.

Let's look at Quality before we close. There are lots of good metals still being made in America, and there are lots of other grades being imported. The one area of real importance is many of the imports do not always follow the AISI standards to the letter. American mills typically aim to hit the middle of all the

Continued on page 15



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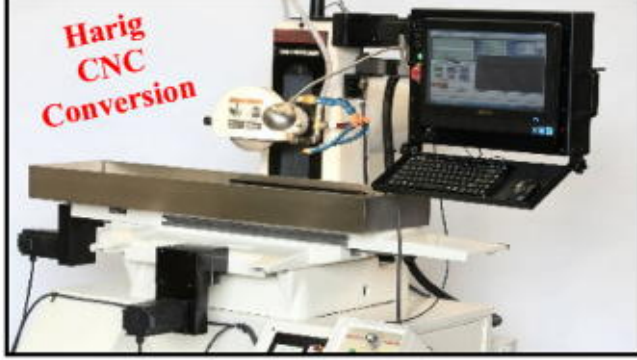
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chemistry ranges. Imported metals that offer AISI grades are still within the proper range but historically tend to be very close to the bottom. That will often impact the heat treating time and temperatures, and may have or may not have an adverse effect on the grain structure. Obtaining great grain structure, not necessarily hardness can be of monumental importance to tool life. But the differences will show up clearly if mixed mill metals are heat treated in the furnace at the same, or different times. It will often show up in hardness, but even more noticeable in structure. That typically will effect wear, impact and other performance issues. So try to avoid mixing lots of steel.

Bottom line: If you are purchasing a tool steel from a domestic mill, it may or may not have superior qualities. That difference also makes a difference in the heat treating processes being performed. Often import grades require 25^o to 35^oF hotter offset temperatures in order to bring the structure to hardness. Think about this: Let's look deeper by considering a D2 heat treatment. D2 requires a soak at 1850^oF. If the temperature range is below 1827^oF, or above 1888^oF for any length of time, the grain structure will be affected. Thus, a mixed load of domestic or imported D2 in the same furnace we will find some degeneration occurring. Yes, they may exhibit an acceptable hardness reading, but hardness should never be the ruling dictate. Does it matter with other grades you might be asking? Yes, perhaps not as harshly but yes, wear and shock resistance can be exhibited.

For this reason, it is strongly recommend establishing a documented heat treatment guideline that is used to communicate the acceptable heat treatment, tempering and in some cases revitalizing recipes to be used whether a purchase or in-house heat treat service.

Many years ago, I got a call from a company that had a 16 cavity H13 injection mold that cracked. This mold cost them a bit over \$700,000 and this was the 2nd failure in 9 months. After reviewing the heat treatment, and the operating demands, I simply set them with a recipe, and part

of that recipe was called on every 3-4 months, or if they had a 3 day weekend, to pull the mold, clean it, then put it back in the tempering furnace and rerun the tempering 25 degrees lower than the original tempering temperature for a minimum of 9 hours. They ran the mold for 7 more years and the mold never broke again. Unfortunately the company went out of business. But the problem was nothing more than stress from repeated compression pressures that caused the problem.

So how do you develop the right steel to do each job application? Analyze the task, and be careful to look at all the facets, and facts! Look deeply at every task a steel is requested to perform. Then look at all the materials your steel has to work on. If you are convinced wear is a factor, don't stop your thinking there. Never assume there is only one detrimental cause of failure, fatigue or stress. **PRESS ON AND RECORD YOUR OBSERVATIONS!** Your grand kids might appreciate it!

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"This time you put the children into their coats, and I'll go honk the horn."

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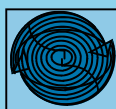
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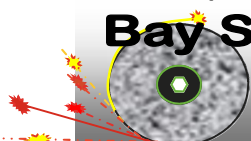
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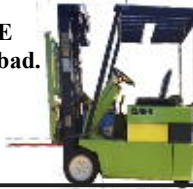
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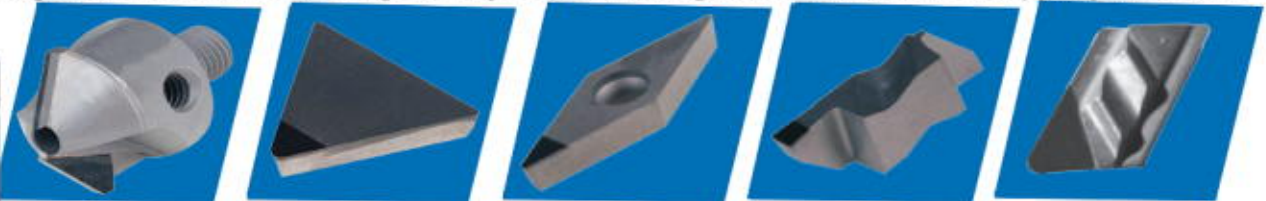
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