

Selection of Tool Steels for Stainless Steel Part Manufacturing



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In light of higher volumes and more demands on tools and dies forming stainless steel, the selection of the correct tool steel to perform production is critical. Some tool steels commonly used today are not able to cope with the wear and mechanical properties associated with long, demanding runs. The article looks at some factors that determine performance of a tool steel to assist in tool steel selection.

Introduction

Traditionally, the high carbon, high chromium cold work tool steels (DIN 1.2379) is the workhorse of the manufacturing industry. However, increased demands on tooling, in particular the stainless steel manufacturing industry, have revealed some shortcomings of the particular steel. In brief, the steel was originally developed to replace high speed steel during the second world war. Although not successful in high speed applications, it was found that the steel possessed good abrasion resistance - i.e. "resistance to wear by scratching" - and hence it became popular as a cold work tool steel. The predominant mode of wear found in manufacturing is abrasive wear through the abrasive action caused by foreign particles, oxides, dust, etc.

Ferritic and austenitic stainless steels work harden more rapidly compared to carbon steels of comparable hardness and thickness, and therefore require higher forming forces. Stainless also have a higher shear strength and consequently higher pressures are required in operations such as blanking, piercing and trimming. The thin oxide layer on its surface, which provides stainless steel with its anti-corrosion properties, also has the effect of increasing the friction between the tool and the workpiece¹. Consequently, significantly higher tool wear rates are experienced due to the introduction of an adhesive wear component, i.e. adherence of material. Materials of similar chemical composition has been known to increase adhesion by diffusion of elements and hence the use of high chrome tool steel tends to promote adhesive wear.

Effect of Alloying

The effect of alloying in tool steels are many fold. They allow for better mechanical properties, better response during heat treatment and form wear resistant carbides in the steel's structure. These carbides may range from fine and round to large and blocky in shape and size. The effect of the large carbides in steels is improved abrasive wear resistance but unfortunately these steels are more prone to cracking and chipping. These steels are typically 1.2379, 1.2080 and AISI D7 (see www.td.co.za - *Services* for a conversion chart). In order to "toughen up" 2379, it is often run at a lower hardness but as a consequence abrasive wear resistance and strength may suffer. On the other hand steels containing fine carbides (e.g. high speed steels), or less carbides, tend to be tougher at a comparable hardness. Unfortunately, these steels often do not show high abrasive wear resistance.

Tool steel manufacturing companies have realized that the microstructure of a steel plays a very important role in the steel performance, have made several improvements to accommodate the detrimental effect of undesirable carbide structures. This has been achieved by a more careful alloying mix, and tailor-made microstructures.

Lower Alloy Tool Steels

Lower alloy steels have the advantage of a chemical composition that is noticeably different from that of stainless steel (e.g. 5% Cr) and thereby the tendency to gall ("pick-up") is reduced. The steels show much improved resistance to edge chipping, improved adhesive wear resistance, however a lower abrasion resistance. These steels are typically 1.2363, 1.2510, AISI S7 and Uddeholm CALMAX. Low alloy steels should be used where toughness is a prime consideration, while total tool life is secondary.

Improved High Carbon Steels

With a careful balance of carbon and alloying content, it was found that the carbide structure in cold work steels could be changed from coarse blocky structures to finer, round structures. A further consequence of the change of carbide structure is better adhesive wear characteristics, and tools can be run harder without the risk of chipping, thereby also improving the abrasive wear characteristics. These steels, which include Bohler K340, Uddeholm SLEIPNER and DC53 (Hall and Pickles) show much improved toughness at comparable hardness over 1.2379. Where tool failure (cracking or breakage) or chipping is/could be the prime mode of failure, these steels should be selected. In many cases, they will not significantly outperform conventional high carbon, high chrome steels.

The new Bohler K360 has further improved its microstructure to offer both high adhesive and abrasive wear resistance, while maintaining toughness and chip resistance.

Powder Metallurgy Steels

The most significant improvement in mechanical properties of tool steel has been achieved through the process of powder metallurgy (PM). In this process, carbide and matrix powders are tailor made to the desired size and shape and then compressed and sintered into a fully dense billet. Even though PM steel compositions are often similar to conventional steels, the PM steels shown a far superior carbide distribution. Consequently a tool steel with unsurpassed mechanical properties is obtained. Table 1 shows a comparison of properties of steels at various hardness levels². It can be seen for example that a PM steel at 8 HRC points harder than 1.2379, show much improved properties. (Comprehensive comparisons are given at www.td.co.za - Services)

Table 1 : Comparison of tool steel properties at various hardness

Hardness	Steel	Toughness	Compression Strength	Fatigue Resistance
56	1.2379 AISI S7	B A+	D E	D D
60	1.2379 Vanadis 4*	C B	C A+	C B
62	1.2363 Vanadis 4* Vanadis 10*	A A+ A	C B B	B B B
64	ASP 30* 1.3343 Vanadis 10*	B C A	A A A	A B A
68 and over	ASP 60* Cemented Carbide	C E+	A+ A++	A+ ?

* - PM steels

A further advantage of PM steels is that more, hard carbides (e.g. vanadium carbides) can be introduced into the structure, thereby improving abrasive wear performance without risk of detrimental metallurgical consequences.

Typical PM steels include Bohler steels, the Vanadis, CPM, ASP and Cru-wear ranges. These steels uniquely combine properties of excellent toughness, high resistance to tool failure and good wear resistance. For example, the PM version of AISI M4 is heavily used by the CNC punch industry due to its high wear properties and its toughness.

Coatings

When using a thin flim, wear resistant surface coatings, only the steel mechanical properties are of interest as the coating takes care of wear. Thus a conventional tool steel which shows desired mechanical properties can be selected and coated. A further advantage of coating is that the high surface hardness resists abrasive wear while the dissimilar ceramic structure prevents adhesive wear. Ideally, the higher the compression strength (i.e. hardness), the better support for, and the performance of the coating. Thin film coatings such as TD, PVD and CVD can be used with virtually all types of steels, with coated PM steels embodying the ultimate in high performance tooling.

Other Factors

Several other factors may significantly affect the performance of a cold work tool steel. To name a few, these are actual hardness, lubrication, overall surface finish (not just smoothness) and localized damage. The TD Coating Centre often receives punches and dies used in highly demanding applications in which edge or surface damage is present. These will only serve as failure initiation points which will unnecessarily decrease the useful tool life.

In conclusion

Several new cold work and high speed steels are available to the stainless steel manufacturing community to solve manufacturing related problems. And new steels are being developed continuously.

The alloying elements and carbide structure has the biggest influence on the mechanical properties and thus should be judiciously selected. Ultimately, a tool steel that is suited to the manufacturing process should be selected, the manufacturing process should not be adjusted to suit the tool steel.

References

1. <http://www.metalfforming.com/magazine/1999/03/PVDCVD/PVDCVD.htm>
2. "Substrate Selection for tools used with Hard Film Coatings", T Arai et al, Metalforming, June 1998.