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Cutting Tool Materials

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Abstract: With the development of cutting and perfect with each passing day, the tool requirements are also getting higher and higher, the right choice for the material of cutting tool is the key to success, so as to become the urgent need of cutting tool materials. This article through to the tool of understanding, from the kinds, properties, processing the workpiece material is analyzed, that making tool materials should have the conditions. From the selection of cutter materials, heat treatment, machining, production tool are introduced in detail.

Key words: tool; heat treatment ; the workpiece material

1. Tool type

Cutting tools must possess certain mechanical properties in order to function adequately during the cutting operations. These properties include high hardness and the ability to retain it even at the elevated temperatures generated during cutting. They also include toughness, creep and abrasion resistance, and the ability to withstand high bearing pressures. In fact, cutting material differ in the degree to which they possess each of those mechanical properties. Therefore, a cutting material is selected to suit the cutting conditions, such as the workpiece material, cutting speed (production rate),coolants used, and so on. Following is a survey of the commonly used cutting tool materials[1].

Plain carbon steel. Plain carbon steel contains from 0.8 to 1.4 percent carbon and has no additives, and it is subjected to heat treatment to increase its hardness. Nevertheless, plain carbon steel is suitable only for making hand tools or when soft metals are machined at low cutting speeds, since it cannot retain its hardness at temperatures above 600 ℉(300 ℃)due to tempering action.

Alloy steel. The carbon content of alloy steel is similar to that of plain carbon steel. Nevertheless, it contains alloying elements(in limited amounts),as the name suggests. Tools made of alloy steel must also be heat-treated and used only when machining is carried out at low cutting speeds. Again, the temperature generated as a result of cutting, should not exceed 600℉(300℃)to avoid any tempering action.

High-speed steel. High-speed steel(HSS) is a kind of alloy steel that contains a reasonable percentage of alloying elements such as tungsten (18 percent),chromium(4 percent),molybdenum, vanadium, and cobalt. High speed steel is heat-treated by heating (at two stages),cooling by employing a stream of air, and then tempering it. Tools made of HSS can retain their hardness at elevated temperatures up to 1100 ℉(600℃). These tools are used when relatively high cutting speeds are required. Single point tools, twist drills, and milling cutters are generally made of HSS, except when those tools are required for high-production Machining.

Cast hard alloys. Cast hard alloys can be either ferrous or nonferrous and contain about 3 percent carbon, which in turn reacts with the metals to form very hard carbides. Those carbides retain their hardness even at a temperature of about 1650℉(900℃).Since such a material cannot be worked or machined, it is cast in ceramic molds to take the form of tips, which are mounted onto the holder either by brazing or mechanically.

Sintered cemented-carbide tips. Sintered cemented carbide was developed to eliminate the main disadvantage of the cast alloys, i.e., brittleness. Originally, the composition of that material involved about 82 percent very hard tungsten carbide particles and 18 percent cobalt as a binder. Sintered cemented carbides are always molded to shape by the powder metallurgy technique, i.e., pressing and sintering. Since it is impossible to manufacture the whole tool of cemented carbide because of the strength consideration, only tips are made of that material; these tips are brazed or mechanically fastened to steel shank, which have the required cutting angles.

Cemented carbides used to as Widia, taken from the German expression “wie Diamant”, meaning “diamondlike”. This is because they possess extremely high hardness, reaching about 90Rc,and they retain such a hardness even at temperatures of up to 1850℉ (1000℃). Recent developments involve employing combinations of tungsten, titanium, and tantalum carbides with cobalt or nickel alloy as binders. The result is characterized by its low coefficient of friction and high abrasion resistance. In fact, cemented-carbide-tip tools are recommended whenever the cutting speeds required or the feed rates are high and are therefore commonly used in mass production. Recently carbide tips have been coated with nitrates or oxides to increase their wear resistance and service life.

Ceramic tips. Ceramic tips consist basically of very fine alumina powder(Al_2O_3),which is molded by pressing and sintering. Ceramics have almost the same hardness as cemented carbides, but they can retain that hardness up to a temperature of 2200℉(1100℃)and have a very low coefficient of thermal conductivity. Such properties enable cutting to be performed at speeds that range from two to three times the cutting speed when carbide tips are employed. Ceramic tips are also characterized by their superior resistance to wear and to the formation of crater cavities, and they require no coolants. Nevertheless, their toughness and bending strength are low, which must be added to their sensitivity to creep loading and vibration. Therefore, ceramic tips are recommended only for finishing operation(small depth of cut)at extremely high cutting speed of up to 1800ft/min.(600m/min).Following are the three common types of ceramic tips:

1.Oxide tips, consisting mainly of aluminum oxide. They have a white color with some pink or yellow tint.

2.Cermet tips, including alumina and some metal such as titanium or molybdenum. They are dark gray in color.

3.Tips that consist of both oxides as well as carbides and they are black in color.

Ceramic tips should not be used for machining aluminum because of their affinity to oxygen.

Diamond. Diamond pieces are fixed to steel shanks and are used in precision cutting operations. They are recommended for machining aluminum, magnesium, titanium, bronze, rubber, and polymer. When machining metallic materials, a mirror finish can be obtained.

2.The work material

The term machinability is often applied to work materials to describe theirmachining properties; it can have several meanings depending on the cutting process under consideration. When it is stated that material A is more machinable than material B, this can mean that a lower tool-wear rate is obtained with material A, or a better surfrace finish can be achieved with material A, or that less power is required to machine material A. Clerly, with finishing processes, tool wear and surface finish are the most important considerations; with roughing operations, tool wear and power consumption are important[2].

It should be noted that any statement regarding machinability may only apply under the particular set of circumstances existing when the observation was made. For example, under a given set of conditions a better surface finish may be obtained with material A than material B; however, under another set of conditions, say with a different tool material, the situation may be reversed. Similar behavior can occur with the other criteria of machinability, tool-wear rate, and power consumption. To complicate the situation further, a certain group of material may be placed in one order of machinability on a tool-wear basis, but in a different order if surface-finish or power-consumption criteria are applied. Clearly, the term machinability can have little meaning except in a loose qualitative sense.

Even though the term is meaningful only in a loose qualitative sense, many attempts have been made to obtain a quantitative measure of machinability-a machinability index or number. A method for producing such an index, if the results were meaningful, would be most helpful, particularly to steel manufacturers who must check the machining properties of their work material and therefore would welcome a quick and reliable checking method. Many ingenious methods are of doubtful meaning, they can be used to measure the variation in some machining property of material having the same specification. It would be most difficult to prove that the results of these tests yield quantitative information on machining properties of practical interest, although experience has shown that these results to give some guide.

3.Heat treatment of steel

Heat treatment is a method by which the heat treater can change the physical properties of a metal. There are three main operation consists of heating the steel above its critical range and then quenching it, that is rapidly cooling in a suitable medium such as water, brine, oil, or some other liquid. Having been hardened, the metal must be given a tempering treatment which consists of reheating the hardened steel to a temperature below the critical range[3], thus producing the required physical properties.

The critical points or critical temperatures are the temperatures at which a certain change takes place in the physical condition of the steel. These points are very important because in order to properly harden a piece of steel, it must be heated to a temperature above the upper critical point. Having known the critical points for a certain steel, we can easily control the heat in the furface. Gas, oil and electric furnaces are the most commonly used for heat treating metals.

Annealing is the uniform heating of a metal above usual hardening temperatures, followed by very slow cooling. Annealing may be carried out either to soften a piece that is too hard to machine or to remachine a piece that has already been hardened. Annealing also relieves internal stresses produced by machining[4].

Low carbon steels do not become hard when subjected to such a heat treatment because of the small amount of carbon contained. If it is necessary to obtain a hard surface on a part made of such steel, surface hardening operation must be carried out. One of the methods of surface hardening is cyaniding, which is done by keeping operation must be carried out. One of the methods of surface on a part made of such steel, surface hardening operation must be carried out. One of the methods of surface hardening is cyaniding, which is done by keeping the work in a molten bath of sodium cyanide from 5 to 30 minutes, depending on the size of the work and the depth of penetration required. Having been subjected to such a treatment, the work is then quenched in water or oil, and a very hard case 0.01 to 0.05 inch thick is formed. This process is also called case hardening.

Nitriding is also one of the case hardening methods. This process consists of keeping the steel in hot ammonia gas for some hours. Nitrogen, formed in this condition from ammonia, penetrates into the surface of the metal, thus forming a very hard case.

Another method of case hardening is carburization. The work is placed into a metal box containing carburizing material(that is, material with high carbon content);the box is closed and placed into a furnace for some hours at the temperature of 926 degrees centigrade. The depth to which the carbon penetrates depend upon the length of time the piece is kept in the furnace. Having been quenched in some liquid queching medium, the work has a hand case and a soft core.

carburizing, nitriding and cyaniding

1.Carburizing

(1)definition Carburizing is a method of introducing carbon into solid iron base alloys such as low carbon steel in order to produce a hard case(surface).

Carburizing increases the carbon content of the steel surface by a process of absorption and diffusion.

(2)process Low carbon steel(about 0.20% carbon or lower)is heated at

870 °to 920 ℃ in contact with gaseous solid or liquid carbon containing substances for several hours.

The high carbon steel surface(thus obtained)is hardened by quenching above the A_1 temperature.

(3)Characteristics

1)Case depth is about 0.05 inch(1.27mm).

2)Hardness after heat treatment is HRC65.

3)Carburizing causes negligible change in dimensions.

4)Distortion may occur during heat treatment.

(4)Typical Used In the case hardening of

1)Gears 2)Camshafts 3)Bearings

(5)Methods There are three general methods of carburizing, depending upon the form of the carburizing medium, namely

1)Pack Carburizing employing solid carburizing medium.

2)Gas Carburizing employing suitable hydrocarbon gases.

3)Liquid Carburizing employing fused baths of carburizing salts.

2. Nitriding

(1)Definition Nitriding accompanies the introduction of nitrogen into the surface of certain types of steels (e.g., containing Al and Cr)by heating it and holding it at a suitable temperature in contact with partially dissociated ammonia or other suitable medium.

This process produces a hard case without quenching or any further heat treatment.

(2)Characteristics

Case depth is about 0.38mm.

Extreme hardness (Vickers 1100)

Growth of 0.25-0.50mm occurs during nitriding.

Case has improved corrosion resistance.

(3)Typical Uses

1) Valve seats 2) Guides

3) Gears 4) Gauges

5) Bushings 6) Ball races

7) Aircraft engine parts 8) Aero engine cylinders

9) Aero crankshafts, air screw shafts 10) Grank pins and journals

3.Cyaniding

(1)Definition

In cyaniding carbon and nitrogen are introduced into the surface of steel by heating it to a suitable temperature and holding it in contact with molten cyanide to form a thin skin or case which is subsequently quench hardened.

(2)Characteristics

1)Case depth is about 0.25mm.

2)Hardness is about HRC65.

3)Negligible dimension change is caused by cyaniding.

4)Distortion may occur during heat treatment.

(3)Typical Uses

1)Screws 2)Nuts and bolts 3)Small gears

(4)Metals usually hardened by cyaniding

Plain carbon or alloy steels containing about 0.20% carbon.

(5)Cyaniding process

Low carbon steel is heated between 800 °and 870 ℃ in a molten sodium cyanide bath for a period of between 30 min and 3 hours, depending upon the depth required.

4 Conclusion

In the course of nearly three decades of development, the tool material technology has greatly changed the request of high-speed cutting tool performance, new materials and new technology emerging, tool performance continues to increase, high-speed cutting should be reasonable to use the tool toreduce production costs and increase productivity.

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