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CAST HIGH-SPEED STEEL TOOLS AND PROCESS OF MANUFACTURING THEM

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This application is a continuation-in-part of United States application Serial Number 751,871, filed July 30, 1958, now abandoned.

It has already been suggested to make tools from high-speed steel in the form of steel castings. There is only little information in the literature on the results obtained with such tools. The reports available on comparisons between tools consisting of high-speed steel castings and tools of hot-worked steels of the same type are inconsistent. It has been found, however, that roughing milling cutters consisting of a steel casting have the same performance as forged milling cutters. On the other hand it has been found that lathe tools made from non-worked high-speed steel have much shorter edge lives than those made from worked material.

In spite of numerous successful tests, the weld-surfacing of high-speed steel has not been used on an appreciable scale in the manufacture of new tools. This is due to the fact that the machining costs of weld-surfaced tools are in most cases too high compared to the costs of normal manufacture, and probably also to the difficulties encountered in controlling the oxide losses, the solidification conditions and the formation of pores during hard facing. The good experience obtained with layers of satisfactory quality, which have been properly deposited, is not readily applicable to high-speed steel cast in molds, particularly in high-precision molds, because the cooling conditions are entirely different.

On the other hand, it would be highly desirable for numerous reasons to make tools which consist of high-speed steel castings and have about the same performance as tools of hot-worked steels of the same type.

During the manufacture of the tool, processing and material costs can be saved which are particularly significant where high-grade materials which can be worked and machined only with difficulty are used.

Reference should also be made to the freedom in design afforded by the use of suitable molding processes. These enable, e.g., the provision of sufficient chip flow clearances on the casting, an improved design of the cutting edges so as to improve the cutting conditions, or the provision of the transition from the tooth to the body of the milling cutter in a form which is preferable to a flat surface. Besides, the manufacture of complicated profile milling cutters, which had previously to be assembled from a plurality of parts for reasons of manufacturing technology, can be reduced in cost by casting each tool in one piece.

The present invention relates to tools consisting of high-speed steel castings, which enable the advantages stated hereinbefore of a molding process to be achieved because they give reliably the same and in many cases a better performance than tools of hot-worked steels of the same type.

Thorough experiments have shown that the steel for tools consisting of high-speed steel castings should have a carbon content which is 0.1–0.4% above the upper allowable carbon content of a hot-worked steel of the same type. With forged high-speed steel having a certain composition, this upper allowable carbon content is determined by the number of carbides, which spontaneously

deteriorate the forgeability if they occur too frequently. The limiting composition ranges of forged high-speed steels, which include to the present knowledge all high-speed steels to be taken into consideration, are as follows:

	Percent
C	0.6–2.0
Si	<<1
Mn	<1
Cr	3–10
W	0.5–23
Mo	0–12
V	0.8
Co	0–23
N	0–0.5
B	0–3
Al	0–3
Ti	0–6
Nb	0–10
Ta	0–10

These figures are based on the assumption that any values of Ti, Nb, Ta and Zr in percent by weight must correspond to the following formula:

percent Ti/5 plus percent Nb/10 plus percent Ta/20 plus percent Zr/10 equals 1.2

The carbon content, however, does not only depend on the grade of steel but also on the intended use. In connection with the present application it may be said that tools consisting of high-speed steel castings mainly subjected to abrasive stresses should have a more highly increased carbon content whereas in tools subjected to considerable impact or bending stresses the carbon content should only slightly exceed the upper limit specified for forged tools of the same type. In many cases, it is desired to achieve a carbon content which is at the upper limit of the usual contents in hot-worked high-speed steel or up to 0.1% above this limit because this enables a higher toughness of the steel casting.

To avoid an inferior performance, these castings must be hardened at the same high hardening temperature as the hot-worked steel of the same type having a lower carbon content. In connection with the invention it is essential that the hardening should be preceded by annealing of the castings for one to eight hours at a temperature between 1050° and 1200° C. in order to avoid undesired overheating effects at the high hardening temperatures.

It is known to subject forged high-speed tools to a diffusion annealing.

It is not obvious, however, to subject cast high-speed steels to this treatment. Owing to the destruction of the carbides, forged high-speed steels have a structure entirely different from that of cast high-speed steels. After a precision casting process as described in the application a cast grain, which may not be excessively coarse, with a coherent ledeburite network is available. These known disadvantages of the as-cast state are eliminated according to the invention by the recommended diffusion annealing. It is surprising that this is possible because it is known that the microsegregation present in high-speed steel ingots cannot be equalized even by heating to 1200° C. for several hours so that a good high-speed steel structure cannot be obtained in this manner. Such segregation can only be removed by hot working.

Hence, the invention provides tools consisting of high-speed steel castings and having at least the same performance as tools of hot-worked steels of the same type, the castings consisting of a steel having a carbon content which is 0.1–0.4% over the upper allowable limit of the carbon content and in cases in which a particularly high toughness is desired is at the upper limit of the carbon content for the hot-worked steel of the same type or up to 0.1% above this limit. Generally then it can be stated for purposes of this invention that the steel castings may have a carbon content which is at the upper limit of the carbon content for the hot-worked steel of the same type to 0.4% above said limit.

To manufacture the tools according to the invention, the castings having the aforestated carbon limits are subjected to a diffusion annealing at 1050–1200° C. for one to eight hours before they are hardened. Hardening is effected at the same temperature which is used for tools made from hot-worked steels of the same type having a normal carbon content. The tools are suitably preheated to 850° C., then heated in a salt bath furnace, quenched in oil and tempered twice at 540–580° C. for periods of one hour each.

The measures recommended according to the invention can be applied to advantage to all previously known types of high-speed steel and result in many cases, particularly in high-speed steels containing cobalt, to surprising increases in performance by as much as 50%.

Example 1

From a high-speed steel which, if used in the hotworked condition should have the following composition tungsten 12%, chromium 4%, vanadium 4%, cobalt 5%, carbon 1.25–1.4%, cast tools were made which had the following composition: tungsten 12%, chromium 4%, vanadium 4%, cobalt 5%, carbon 1.65%.

Diffusion annealing: 1 hour at 1100° C.
Preheating: 850° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1230–1260° C.
Tempering: Two tempering treatments of one hour each at 570° C.

Tools of the foregoing composition cast by the precision investment process of the invention had a milled length of 2400 m. on the average. This is a surprisingly high improvement as against the performance shown by tools made of forged steel with an average milled length of 1700 m.

Example 2

From a high-speed steel which, if used in the hotworked condition should have the following composition: tungsten 18%, chromium 4.3%, vanadium 1.6%, molybdenum 1%, cobalt 5% and carbon 0.75–0.83%, cast tools having the following composition were made—tungsten 18%, chromium 4.3%, vanadium 1.6%, molybdenum 1%, cobalt 5%; carbon: 1% for hob cutters, 0.9% for chasers, 1.0% for threading dies, 0.95% for keyway cutters.

Diffusion annealing: 1–8 hours at 1050–1200° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1250–1280° C.
Tempering: Two tempering treatments of about one hour each at 550–580° C.

Hob cutters are mushroom-shaped tools which are used for machining parts of the substructure for railroads. In spite of the fact that these conditions of use appear to be highly unfavorable for cast tools, the edge life of the cast tools after a suitable heat treatment has proven better than that of the conventional tools of similar, forged steel.

The life of the cast chasers and threading dies is also longer than that of tools of forged high speed steel.

Keyway cutters are subject to impact and bending. In comparison trials, the edge life of cast keyway milling cutters was up to twice the edge life of tools of wrought high speed steel.

Example 3

From a high-speed steel which, if used in the hotworked condition should have the following composition: tungsten 9.5%, chromium 4.3%, molybdenum 5.2%, vanadium 3.5%, cobalt 10.5%, carbon 1.2–1.3%, cast tools having the following composition were made—tungsten 9.5%, chromium 4.3%, molybdenum 5.2%, vanadium 3.5%, cobalt 10.5%, carbon: 1.3% for groove cutters, 1.55% for barrel fine borer tips.

Diffusion annealing: 1–8 hours at 1050–1200° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1180–1210° C.
Tempering: Two tempering treatments of about 1 hour each at 560–590° C.

The edge life of the tools mentioned first, the groove cutters from one regrinding to the next was the same as that of grooved cutters of forged material.

The life of the cast tips of the barrel borers was twice to three times the life of forged tools made from similar material.

Example 4

From a high-speed steel which, if used in the hotworked condition should have the following composition: tungsten 18.5%, chromium 4.3%, vanadium 1%, carbon 0.70–0.78%, cast high-speed milling cutters having the following composition were made—tungsten 18.5%, chromium 4.3%, vanadium 1%, carbon 0.78%.

Diffusion annealing: 1–8 hours at 1050–1200° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1240–1270° C.
Tempering: Two tempering treatments of about one hour each at 550–580° C.

On trial, the cast milling cutters had wearing properties at least equivalent to the previously used tools made from hot-formed steel.

Example 5

From a high-speed steel which, if used in the hotworked condition should have the following composition: tungsten 6.5%, molybdenum 5%, chromium 4.3%, vanadium, 2%, carbon 0.78–0.86%, cast tools having the following composition were made—tungsten 6.5%, molybdenum 5%, chromium 4.3%, vanadium 2%, carbon: 0.86% for profile milling cutters, 0.90% for guideway milling cutters.

Diffusion annealing: 1–8 hours at 1050–1200° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1190–1220° C.
Tempering: Two tempering treatments of about one hour each at 540–570° C.

The expensive profile milling cutters, having an intricate shape, had in several cases an edge life corresponding to 1.8 times the milling distance of the tools otherwise used before regrinding was necessary. This is of special importance when only a few regrindings of the tools are permissible in order to ensure constant dimensions.

An even greater improvement in edge life was achieved with the guideway milling cutters.

Example 6

From a high-speed steel which, if used in the hotworked condition should have the following composition: tungsten 6.5%, molybdenum 5%, chromium 4.3%, vanadium 2%, cobalt 5% and carbon 0.79–0.86%, cast rough cutters for woodworking were made with the following composition—tungsten 6.5%, molybdenum 5%, chromium 4.3%, vanadium 2%, cobalt 5%, carbon 0.85%.

Diffusion annealing: 1–8 hours at 1050–1200° C.
Hardening: Quenching in oil after heating in a salt bath furnace at 1200–1230° C.
Tempering: Two tempering treatments of about one hour each at 550–580° C.

Rough cutters for woodworking operate at very high rotary and cutting speeds. If the tool encounters hard portions in the wood, such as knots, there is a great danger of brittle failure. Under these adverse conditions, cast tools subjected to the heat treatment of the invention have been just as suitable as tools made from wrought high-speed steel.

What is claimed is:

1. A process for the production of cast high-speed steel tools having a carbon content which is at the permissible upper limit of carbon of the hot-worked steel of the same composition to 0.4% above said limit comprising annealing the cast tools from 1–8 hours at 1050° C. to 1200° C. before hardening.

2. The product of the process of claim 1.

3. A process for the production of cast high-speed steel tools having a carbon content which is about 0.1 to 0.4% above the permissible upper limit of carbon of the hot-worked steel of the same composition, comprising annealing the cast tool from 1–8 hours at 1050° C. to 1200° C. before hardening.

4. A process for the production of cast high-speed steel tools having a carbon content which is at the permissible upper limit of carbon of the hot-worked steel of the same composition, to 0.1% above said limit comprising annealing the cast tool from 1–8 hours at 1050° C. to 1200° C. before hardening.

5. A process for the production of cast high-speed steel tools as set forth in claim 1 in which two tempering treatments of about one hour each are carried out at a temperature between 540° C. and 580° C. after the hardening treatment.

6. A process for the production of cast high-speed steel tools as set forth in claim 1 in which the tools are preheated to about 850° C. before the hardening treatment and two tempering treatments of about one hour each are carried out at a temperature between 540° C. and 580° C. after the hardening treatment.

7. A process for the production of cast high-speed steel tools consisting essentially of 12% tungsten, 4% chromium, 4% vanadium, 5% cobalt, 1.65% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one hour at 1100° C. preheated at 850° C., hardened by quenching in oil after heating in a salt bath furnace at 1230°–1260° C. and subjected after the hardening to two tempering treatments for one hour each at 570° C.

8. A process for the production of cast high-speed steel tools consisting essentially of 18% tungsten, 4.3% chromium, 1.6% vanadium, 1% molybdenum, 5% cobalt and 0.95–1.0% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050°–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1250–1280° C. and subjected after the hardening to two tempering treatments for one hour each at 550–580° C.

9. A process for the production of cast high-speed steel tools consisting essentially of 18% tungsten, 4.3% chromium, 1.6% vanadium, 1% molybdenum, 5% cobalt, 0.90% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1250–1280° C. and subjected after the hardening to two tempering treatments for one hour each at 550–580° C.

10. A process for the production of cast high-speed steel tools consisting essentially of 9.5% tungsten, 4.3% chromium, 5.2% molybdenum, 3.5% vanadium, 10.5% cobalt and 1.55% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1180–1210° C. and subjected after the hardening to two tempering treatments for one hour each at 560–590° C.

11. A process for the production of cast high-speed steel tools consisting essentially of 9.5% tungsten, 4.3% chromium, 5.2% molybdenum, 3.5% vanadium, 10.5% cobalt and 1.3% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1180–1210° C. and subjected after the hardening to two tempering treatments for one hour each at 560–590° C.

12. A process for the production of cast high-speed steel tools consisting essentially of 18.5% tungsten, 4.3% chromium, 1% vanadium, 0.78% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1240–1270° C., and subjected after the hardening to two tempering treatments for one hour each at 550–580° C.

13. A process for the production of cast high-speed steel tools consisting essentially of 6.5% tungsten, 5% molybdenum, 4.3% chromium, 2% vanadium, 0.86–0.90% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1190–1220° C., and subjected after the hardening to two tempering treatments for one hour each at 540–570° C.

14. A process for the production of cast high-speed steel tools consisting essentially of 6.5% tungsten, 5% molybdenum, 4.3% chromium, 2% vanadium and 0.85% carbon, the balance essentially of iron in which the cast tools are diffusion annealed for one to eight hours at 1050–1200° C., hardened by quenching in oil after heating in a salt bath furnace at 1200–1230° C., and subjected after the hardening to two tempering treatments for one hour each at 550–580° C.

15. A process for the production of high-speed steel tools which have been cast into molds by the precision investment casting process, said steel consisting essentially of at least about 1.4% carbon, substantially 12% tungsten, 4% chromium, 4% vanadium, 5% cobalt, the balance essentially iron, comprising preheating said tool as cast to 850° C., then subjecting the tool to diffusion annealing for 1 to 8 hours at 1050° C. to 1200° C. and then tempering for 1 hour at 570° C.

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