Patented July 30, 1935 2,009,715

UNITED STATES PATENT OFFICE

2,009,715

FREE MACHINING ALLOY TOOL STEEL

Frank R. Palmer, Reading, Pa., assignor to The Carpenter Steel Company, Reading, Pa., a corporation of New Jersey

No Drawing. Original application January 14, 1932, Serial No. 586,697. Divided and this application May 31, 1934, Serial No. 728,305

11 Claims. (Cl. 75—1)

This invention relates generally to ferrous products adapted for use in the manufacture of machined articles having relatively free machining quality imparted thereto by a selenium-tellurium content, as fully set forth in my copending application Ser No. 586,697 filed Jan. 14, 1932; the present improvement forming a division of the aforesaid application, and relating particularly to the so-called "tool steel" class described therein.

In said application I pointed out that the ferrous alloys referred to might conveniently be divided into four general classes designated as "straight carbon" steels, "structural alloy" steels, "tool" steels and "special" alloy steels as fully described in said application. The invention described herein applies to the third of the before mentioned groups—namely, "tool steels". Substantially straight carbon tool steels have been set forth in my copending divisional application Ser. No. 714,828 filed March 9, 1934, and the present division relates to alloy "tool steels" which may be defined as ferrous alloys containing not less than .50% carbon and between 70% and 98% iron with the balance non-ferrous elements ordinarily used in alloy tool steels.

My use of the term "tool steel" does not imply that the steel must be used for tools only since these alloys containing more than .50% carbon are extensively used for such structural purposes as springs, ball bearings, cams, magnets, racks, gears, etc. and are very extensively used in the component parts of small mechanisms such as fire-arm locks, sewing machines, adding machines, etc.

The variety of alloy "tool steels" is legion but I find it convenient to assemble them into three principal sub-groups—namely the "tungsten group" the "chromium group" and the "manganese group". The "tungsten group" contains tungsten between 1.00 and 22%—either alone or accompanied by other alloying elements. A few of these well-known types are noted below:

		Percent
SAE 7260	Carbon	.60
	Tungsten	1.50 to 2.00
	Chromium	.50 to 1.00
Tungsten tap steel	Carbon	1.20
	Tungsten	1.50
Tungsten finishing steel	Carbon	1.30
	Tungsten	3.50
High speed steel	Carbon	.70
	Tungsten	18.00
	Chromium	4.00
	Vanadium	1.00
Cobalt high speed steel	Carbon	.65 to .85
	Tungsten	12.5 to 21.00
	Chromium	3.5 to 4.5
	Vanadium	.75 to 2.00
	Cobalt	3.5 to 13.00
	Molybdenum	.80 maximum
Mushet self-hardening	Carbon	1.85 to 2.00
	Manganese	2.00 to 2.75
	Tungsten	8.75 to 9.25

There are many other tungsten tool steels well-known to the art containing between 1.00% and 22% of tungsten, together with such alloying elements as manganese, silicon, chromium, nickel, vanadium, cobalt, molybdenum, uranium, etc.

The "chromium group" may contain from .50% to 15% chromium as for example:

		Percent
SAE 5195	Carbon	.95
	Chromium	.90 to 1.10
SAE 52100	Carbon	1.00
	Chromium	1.20 to 1.50
SAE 6160	Carbon	.60
	Chromium	.80 to 1.10
	Vanadium	.18
SAE 3270	Carbon	.70
	Chromium	.90 to 1.25
	Nickel	1.50 to 2.00
SAE 4150	Carbon	.50
	Chromium	.80 to 1.10
	Molybdenum	.15 to .25
Chrome magnet steel	Carbon	1.00
	Chromium	3.50 to 4.00
High carbon, high chrome tool steel	Carbon	2.25
	Chromium	11.00 to 15.00

A variety of other chromium tool steels are known containing chromium between .50% and 15% together with other alloys of the group manganese, silicon, nickel, vanadium, tungsten, molybdenum, etc. The application of my invention to all ferrous alloys containing chromium between 4% and 60% is described in my Patent No. 1,846,140, which was copending with my original application Ser. No. 586,697 of which the present application is a division.

The "manganese group" is best known in the so-called non-shrinkable oil-hardening tool steels containing between 1% and 2% manganese—with or without other elements such as vanadium, chromium, tungsten, molybdenum, etc. Another well-known example is silicon-manganese steel (SAE 9250) containing manganese .60% to .90% and silicon 1.80% to 2.20%. The Mushet self-hardening steel previously described contains up to 2.75% manganese, and the old "smokeless barrel" steel contains about 1.25% manganese.

The three sub-groups set forth do not necessarily comprehend all of the compositions that fall within my present "tool steel" group, and they have been so classified not to limit the scope of my invention but to clarify my presentation. For example, my invention provides greatly improved machinability in cast iron containing about 3.50% carbon. Such a product would never ordinarily be called an alloy tool steel, yet since it falls within the analysis limit of my arbitrary alloy "tool steel" group I include it within the scope of this division.

All of these "tool steel" compositions can be

annealed (usually softer than 250 Brinell hardness) to render them commercially machinable. However, it is very desirable that the machinability be improved if possible and without too much detriment to the ultimate use of the alloys. Sulphur which has heretofore been largely used as a free machining element is abhorrent in tool steels because of the large quantity of non-metallic inclusions that result from its use. I have discovered that selenium and/or tellurium can be used in percentages ranging from .03% to 2.00% to improve the machinability of alloy "tool steels" with a minimum of non-metallic inclusions, without interfering with the ability of these steels to harden and, in many cases, without substantial detriment to their use as finished tools and structural parts. My disparagement of sulphur in "tool steels" pertains of course to the ultimate utility of the finished article as I freely recognize that, from a purely machining standpoint, sulphur fulfills its normal free-machining function, and abnormally high sulphur in "tool steel" compositions could even be supplemented by selenium and/or tellurium with added machining advantage.

I find that the machinability of alloy "tool steels" shows slight but noticeable improvement with percentages of selenium and/or tellurium as low as .05% and that the machinability increases progressively as the content of these metalloids is increased up to about .25%. Further additions up to 2% give further progressive improvement but at a slower rate so that I contemplate practically all free machining alloy "tool steels" can be satisfactorily made with between .5% and .25% selenium and/or tellurium. However it is to be understood that percentages between .25% and 2.00% achieve the purposes of my invention and are objectionable only because of the cost of the larger addition—the higher percentage of loss in making these large additions—and the general deterioration in the cleanness of the alloy by increasing the amount of non-metallic matter.

Quite small percentages of selenium and/or tellurium can also be used to supplement small percentages of sulphur, the effect on machinability apparently being cumulative. For example many specifications limit sulphur to less than .04% or .05% but when supplemented by as little as .03% selenium and/or tellurium, the total percentage of free-machining metalloid may be as much as .07 to .08 which is sufficient to react favorably on the machining properties of the alloy. Thus my invention is commercially usable with selenium and/or tellurium even as low as .03%.

The use of phosphorus in alloy "tool steels" is as unpopular as the use of sulphur because of its embrittling effect on the finished parts. However I have demonstrated that my selenium and/or tellurium addition, when supplemented by phosphorus yields even further improved machinability and this additional improvement is available in all cases where the embrittling effect of phosphorus does not interfere with the application of the alloy.

Phosphorus has a noticeable effect at .05% which increases progressively with further additions. Excessive brittleness is produced with phosphorus as high as .50% but I contemplate that commercially, the phosphorus will seldom be used in "tool steels" in percentages higher than about .12%.

Examples of the application of my invention to the three sub-groups of alloy "tool steels," herein before described are given below:

Free machining tungsten "tool steel"

Carbon	.66
Manganese	.35
Silicon	.28
Phosphorus	.017
Sulphur	.011
Tungsten	18.72
Chromium	3.46
Vanadium	1.06
Selenium	.147

Free machining chromium "tool steels"

Carbon	.98
Manganese	.38
Silicon	.28
Phosphorus	.006
Sulphur	.014
Chromium	1.49
Selenium	.27

Carbon	.59
Manganese	.43
Silicon	.30
Phosphorus	.010
Sulphur	.020
Chromium	1.02
Nickel	1.73
Tellurium	.067

Free machining manganese "tool steel"

Carbon	.50
Manganese	.78
Silicon	2.02
Phosphorus	.015
Sulphur	.013
Selenium	.217

Machining tests made on the above examples confirm all of the other extensive experiments I have made in demonstrating the free machining effect of selenium and/or tellurium permitting of faster cutting speeds with a cleaner finish on the machined articles. I observe in these free machining "tool steels" the same anti-friction and non-galling qualities that have been characteristic of the presence of selenium and tellurium throughout my experiments. It is well-known to the art that the usefulness of many "tool steel" parts such as drawing dies and mandrels, cams, etc. are limited by the tendency of the tools to "pick up" from the materials being fabricated. Any anti-friction or non-galling qualities imparted to the "tool steel" by the use of my invention contribute added value in the utility of the tools.

Because of the poisonous nature of the fumes of tellurium emitted during the addition of this element to the molten steel bath I prefer to use selenium whenever possible. The exact quantitative equivalence of selenium and tellurium is not to be understood as I have frequently observed that tellurium is somewhat more potent for my purpose than selenium apart from other possible differences.

In the manufacture of my improved steel I have used elemental selenium and tellurium both in powder and stick form but I find it more desirable to first make an alloy of iron containing about 50% iron and 50% of the metalloid, and use this for additions to the molten bath. The 50% iron-metalloid alloy is heavy and is better

assimilated by the bath with less loss by volatilization. In the manufacture of alloy "tool steels" in an electric induction furnace, the compounding of the base analysis proceeds as usual and a few minutes before pouring the heat the ferro-selenium or ferro-tellurium is added and is quickly assimilated. The loss by volatilization may range from 10% for a .10% metalloid addition to correspondingly higher losses for larger additions. In the electric arc furnace, the metalloid is best added to the flowing stream during tapping and the losses will be somewhat greater than in the induction furnace. In making open hearth alloy "tool steels" the metalloid is best added during the tapping operation but the losses may range 50% and higher due to the more oxidized condition of the metal. I regard tellurium as dangerous to use in the melting shop without proper protection for the workmen.

I have tested the machinability and noted the anti-friction qualities of alloy "tool steels" both in the cast and rolled condition and find that my invention applies equally well to castings and rolled, forged or drawn products.

In the sub-joined claims, the term "balance substantially iron" is used with the understanding that the ferrous balance may contain appreciable percentages of extraneous elements of such nature and proportion that they do not alter the properties of the alloy for the purpose of my invention. For example, the presence of uranium in a high speed steel would not alter the fact that it was high speed tool steel—that it was in need of improved machinability and that the addition of my selenium and/or tellurium elements provide improved machinability. Hence such uranium would be comprehended by my statement "balance substantially iron".

Since none of the "tool steels" to which my present invention relates are austenitic in nature, the term non-austenitic is used in the claims to more accurately define the invention.

What I claim is:—

1. The combination of .03% to 2% metalloid of the group selenium-tellurium with an inherently machinable non-austenitic base; said base comprising iron 70% to 98%, and carbon .50% to 4.00% and the balance alloying elements; and the combination of said metalloid with said base imparting materially improved machinability to the resulting alloy.

2. The combination of .03% to 2% metalloid of the group selenium-tellurium and .05% to .50% phosphorus with an inherently machinable, non-austenitic base; said base comprising iron 70% to 98%, carbon .50% to 4.00% and the balance alloying elements; and the combination of said phosphorus and metalloid with said base imparting materially improved machinability to the resulting alloy.

3. A non-austenitic alloy "tool steel" containing iron 70% to 98%, tungsten 1% to 22%, carbon .50% to 2.50%, metalloid of the group selenium-tellurium .03% to 2.00%, the balance being alloying elements.

4. An alloy steel containing tungsten 10% to 20%, chromium 2% to 6%, vanadium .50% to 3%, carbon .50% to 1.00%, metalloid of the group selenium-tellurium .03% to .50%; said alloying elements totalling not more than 28%, and the balance being substantially iron.

5. An alloy steel containing tungsten 10% to 20%, chromium 2% to 6%, vanadium .50% to 3%, carbon .50% to 1.00%, metalloid of the group selenium-tellurium .03% to .50%, phosphorus .05% to .20%; said alloying elements totalling not more than 28% and the balance being substantially iron.

6. A non-austenitic alloy "tool steel" containing chromium .50% to 4%, carbon .50% to 2.50%, metalloid of the group selenium-tellurium .03% to 2.00%, other alloying elements .25% to 4.00%, balance substantially iron, with iron not exceeding 98%.

7. An alloy "tool steel" containing chromium .50% to 2%, carbon .80% to 1.25%, metalloid of the group selenium-tellurium .03% to .50%, balance substantially iron, with iron not exceeding 98%.

8. An alloy "tool steel" containing chromium .50% to 2%, carbon .80% to 1.25%, phosphorus .05% to .20%, metalloid of the group selenum-tellurium .03% to .50%, balance substantially iron, with iron not exceeding 98%.

9. A non-austenitic alloy "tool steel" containing manganese .50% to 3.00%, carbon .50% to 2.50%, metalloid of the group selenium-tellurium .03% to 2.00%, other alloying elements .25% to 3.00%, balance substantially iron, with iron not exceeding 98%.

10. An alloy "tool steel" containing manganese 1.25% to 2.00%, carbon .50% to 1.25%, metalloid of the group selenium-tellurium .03% to .50%, balance substantially iron, with iron not exceeding 98%.

11. An alloy "tool steel" containing manganese 1.25% to 2.00%, carbon .50% to 1.25%, phosphorus .05% to .20%, metalloid of the group selenium-tellurium .03% to .50%, balance substantially iron, with iron not exceeding 98%.

FRANK R. PALMER.