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FREE MACHINING STRUCTURAL ALLOY

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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 January 14, 1932; the present improvement forming a division of the aforesaid application, and relating particularly to the so-called "structural alloy" class described therein.

In said original 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 therein. The present invention relates to the second of the before mentioned groups—namely, "structural alloys", which may be defined as ferrous alloys containing less than .50% carbon, between 90% and 98% iron, with the balance non-ferrous elements ordinarily used in "structural alloy" steels.

Though such "structural alloy" steels find their principal use as heat treated parts in the construction of automobiles, machine tools, aircraft, ordnance, and many other machines and appliances, it is commonly known that some of these compositions are used for other than structural purposes, and my use of the term "structural alloy" is not intended to limit the scope of my invention in terms of use or application of the finished parts. Within the chemical boundaries adopted for this particular group, my invention provides free machining and non-galling properties, the novelty and value of which is independent of the ultimate use of the finished article.

In avoiding a low limit for carbon, I do so in conformity to the standard specifications for such "structural alloy" steels as S. A. E. 2512 and S. A. E. 3312 in which the carbon is specified ".17% max". The lower carbon types are frequently case hardened, and the higher carbon types are usually, though not necessarily, heat treated to utilize the alloy content to best advantage.

There are an almost limitless number of alloy steels within the scope of my "structural alloy" group but I find it convenient to assemble them into three principal sub-groups—namely, the "nickel group", the "chromium group" and the "manganese group". The "nickel group" contains nickel between 1% and 6%, either alone or accompanied by other alloying elements. A few representative nickel steels are:

		Percent
S. A. E. 2100	Carbon	As desired.
	Nickel	1.25 to 1.75.
S. A. E. 2512	Carbon	.17 maximum.
	Nickel	4.75 to 5.25.
S. A. E. 3200	Carbon	As desired.
	Nickel	1.50 to 2.00.
	Chromium	.90 to 1.25.
S. A. E. 4615	Carbon	.15.
	Nickel	1.50 to 2.00.
	Molybdenum	.20 to .30.

The above examples are illustrative only as nickel "structural alloy" steels can be compounded in many ways and even containing aluminum for nitriding purposes so that my nickel group may be defined as alloys containing less than .50% carbon, 1% to 6% nickel, with or without alloys of the group manganese-silicon-phosphorus-chromium-tungsten-vanadium - aluminum - molybdenum, etc. which last named group may total from .25% to 5.00%.

"Structural alloy" steels of the "chromium" sub-group may contain .25% to 4.00% chromium, with or without other alloying elements. For example

		Percent
S. A. E. 5100	Carbon	As desired.
	Chromium	.60 to 1.10.
S. A. E. 4100	Carbon	As desired.
	Chromium	.80 to 1.10.
	Molybdenum	.15 to .25.
S. A. E. 6100	Carbon	As desired.
	Chromium	.80 to 1.10.
	Vanadium	.18.
S. A. E. 7200	Carbon	As desired.
	Chromium	.50 to 1.00.
	Tungsten	1.50 to 2.00.
Valve steel (U. S. Pat. 1,707,364)	Carbon	As desired.
	Chromium	3.00.
	Silicon	2.00.
Nitriding steel	Carbon	As desired.
	Chromium	1.50.
	Aluminum	.75.

Thus the "chromium" sub-group may be modified in many ways within this definition: Carbon less than .50%, chromium .25% to 4.00%, alloys of the group manganese-silicon-phosphorus - nickel - tungsten - vanadium-aluminum-molybdenum totalling between .25% and 5%.

Manganese is of course present in practically all steels to the extent of about .20% to .50% but frequently it is added in larger percentages, be-

tween .50% and 3.00%, as an alloy to affect the properties of the steel, for example

		Percent
Special S. A. E. 1300	Carbon	As desired.
	Manganese	1.60 to 1.90
S. A. E. 9200	Carbon	As desired.
	Manganese	.60 to .90
	Silicon	1.80 to 2.20
Gun barrel steel	Carbon	.45 to .65
	Manganese	1.00 to 1.25
	Vanadium	.10 to .15

Manganese in excess of .50% may be added to any alloy steel to secure deeper and more rapid hardening so that such steels may be defined: Carbon less than .50%, manganese .50% to 3.00%, alloys of the group silicon-phosphorus-chromium-nickel-aluminum-vanadian - molybdenum-tungsten totalling between .25% and 3.00%.

The three sub-groups set forth do not necessarily comprehend all of the compositions that fall within my broad "structural alloy" group and they have been so classified not to limit the scope of my invention but to clarify its presentation.

All of these "structural alloy" compositions can, if desired, be annealed softer than 250 Brinell hardness to render them commercially machinable, although it is not uncommon for them to be purchased from the steel maker already heat treated to some higher physical test. Although they are inherently machinable in such condition, 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 in carbon steels is abhorrent in alloy 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 "structural alloy" 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 parts.

I find that the machinability of "structural alloy" 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 "structural alloy" steels can be satisfactorily made with between .05% 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 "structural alloy" steels is as unpopular as the use of sulphur because of its embrittling effects 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% and I contemplate that commercially, the phosphorus will seldom be used in alloy steels in percentages higher than about .12%.

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

Free machining "nickel" steels

Carbon	.41	.41	.49	.48	.09
Manganese	.56	.53	.43	.23	.46
Silicon	.23	.23	.20	.22	.18
Phosphorus	.011	.011	.010	.013	.009
Sulphur	.018	.019	.020	.021	.019
Nickel	1.39	1.36	1.73	1.68	5.03
Chromium		.67	1.02	.98	
Selenium				1.75	.20
Tellurium	.06	.266	.067		

Free machining "chromium" steels

Carbon		.081	.40
Manganese		.33	.32
Silicon		3.27	.30
Phosphorus		.012	.005
Sulphur		.019	.015
Chromium		1.31	1.01
Nickel		.66	
Molybdenum			.18
Selenium			.257
Tellurium		.75	

Free machining "manganese" steel

Carbon	.50	.38	.48
Manganese	.78	.78	1.11
Silicon	2.02	.34	.25
Phosphorus	.015	.006	.043
Sulphur	.013	.016	.002
Chromium		1.00	
Selenium	.217	2.53	.09

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 "structural alloy" 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 alloy steel parts such as pump shafts, bushings, bolts and nuts, slides, etc. depends to a considerable extent upon freedom of action in service or in assembly and disassembly. Any anti-friction or non-galling qualities imparted to the alloy steel by the use of my invention contributes added value to the utility of the parts.

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 "structural alloy" steels in an electric induction furnace, the compounding of the base analysis proceeds as usual and a few minutes before pouring the heat of the ferro-selenium or ferro-tellurium are added and are quickly assimilated. The loss by volatilization may range from 10% for .10% metalloid addition with 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 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 "structural alloy" 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 copper in a chrome-nickel steel would not alter the fact that it was in need of improved machinability and that the addition of my selenium and/or tellurium elements provide such improvement. Hence such copper would be comprehended by my statement "balance substantially iron".

What I claim is:—

1. The combination of .03% to 2% metalloid of the group selenium-tellurium with an inherently machinable "structural alloy" base; said base comprising 90% to 98% iron, carbon in an amount less than .50%, and the balance alloying elements, and being capable of annealing softer than 150,000 pounds per square inch ultimate tensile strength with more than 3% elongation in two inches; 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 with an inherently machinable "structural alloy" base; said base comprising 90% to 98% iron, carbon in an amount less than .50%, and the balance alloying elements, and being capable of annealing softer than 250 Brinell hardness; the combination of said metalloid with said base imparting materially improved machinability to the resulting alloy.

3. An alloy containing nickel 1% to 6%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .03% to 2%, other alloying elements .25% to 5.00%, the total of nonferrous elements being between 2% and 9% and the balance being iron.

4. An alloy containing nickel 1% to 4.50%, chromium .25% to 1.75%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05% to .50%, balance substantially iron with iron not exceeding 98%.

5. An alloy containing nickel 1% to 4.50%, chromium .25% to 1.75%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05% to .50%, phosphorus .05% to .20%, balance substantially iron with iron not exceeding 98%.

6. An alloy containing chromium .25% to 4.00%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .03% to 2.00%, other alloying elements .25% to 5.00%, the total of nonferrous elements being between 2% and 9% and the balance being iron.

7. An alloy containing chromium .50% to 2.00%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05 to .50%, alloys of the group molybdenum-vanadium .10% to .50%, balance substantially iron with iron not exceeding 98%.

8. An alloy containing chromium .50% to 2.00%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05 to .50%, phosphorus .05% to .20%, alloys of the group molybdenum-vanadium .10% to .50% balance substantially iron with iron not exceeding 98%.

9. An alloy containing manganese .50% to 3.00%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .03% to 2.00%, other alloying elements .25% to 3.00%, balance iron with iron not exceeding 98%.

10. An alloy containing manganese .50% to 2.00%, silicon .50% to 2.50%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05% to .50%, balance substantially iron with iron not exceeding 98%.

11. An alloy containing manganese .50% to 2.00%, silicon .50% to 2.50%, carbon in an amount less than .50%, metalloid of the group selenium-tellurium .05% to .50%, phosphorus .05% to .20%, balance substantially iron with iron not exceeding 98%.

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