Patented Apr. 23, 1935 1,998,956

UNITED STATES PATENT OFFICE

1,998,956

FERROUS ALLOY

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No Drawing. Original application December 22, 1934, Serial No. 758,754. Divided and this application March 11, 1935, Serial No. 10,391

13 Claims. (Cl. 75—1)

This application is a division of my co-pending application Serial No. 758,754, filed December 22, 1934.

This invention relates to ferrous alloys and more particularly to alloy steels in which tungsten is employed as a principal alloying constituent. More specifically, this invention relates to that type of ferrous alloys or alloy steels which is employed in the form of cutting tools and wear-resisting parts and which type is commonly referred to by those familiar with the art as an alloy tool steel.

As is well known to those familiar with the art, alloy tool steels have, in the past, been made with tungsten as the principal alloying constituent and the types commonly known as high speed steels are at present the standard commercial tool steels for high duty machining of metallic substances. The tungsten high speed steel most widely used commercially at the present time is essentially an alloy of carbon and iron with approximately 18% tungsten, 4% chromium and 1% vanadium. This standard type is commonly known as "18—4—1 high speed steel". In addition, such steel contains minor quantities of such alloying elements and impurities as manganese, silicon, copper, sulphur, phosphorus, arsenic, tin, etc. Such elements as cobalt, nickel, uranium and tantalum are sometimes added to secure certain changes in the properties of the steel.

In my previous U. S. Patent No. 1,937,334 is disclosed the fact that a very satisfactory steel capable of being satisfactorily used for the same purposes for which 18—4—1 high speed steel has been used may be secured, if to a steel in which molybdenum is the principal alloying ingredient, minor amounts of tungsten are added and if the amount of such tungsten is present in a defined proportional relationship to the amount of molybdenum present. It has been explained that the unexpectedly desirable results secured by the addition of minor amounts of tungsten to a molybdenum steel as taught in my above identified patent is due to a powerful auxiliary effect which such minor amount of tungsten has upon the molybdenum content of the alloy. The desirable results secured by the addition of such minor amounts of tungsten to a molybdenum steel are greater than any results which would be expected upon the theory of equivalency of tungsten and bolybdenum as taught in the prior art.

The present invention relates to the discovery that molybdenum, when added to a ferrous alloy composition, in which tungsten is the principal alloying element, and when thus added in amounts which bear a certain proportional relationship to the amount of tungsten present, has a powerful auxiliary effect upon such steel. Such results are considerably more pronounced than those usually achieved by the addition of molybdenum to high tungsten steels in accordance with the practices in the prior art.

It is a principal object of this invention, therefore, to provide a ferrows alloy composition, or more particularly, a tool steel of the type in which tungsten is a principal alloying constituent and to which there has also been added a minor amount of molybdenum for its powerful auxiliary effect, thus producing a steel which, when used for purposes of cutting tool, wear-resisting parts and the like, has performance characteristics equal to and in certain respects superior to those of comparable steels in the prior art.

It is a further object of my invention to provide a high speed tool steel of the high tungsten type having cutting or wear-resisting properties superior to the cutting or wear-resisting properties of the standard 18—4—1 tungsten high speed tool steel.

It is also an object of my invention to provide a high speed tool steel of the high tungsten type substantially equal in cutting or wear-resisting qualities to the standard 18—4—1 high speed tool steel but which contains a materially lesser amount of the expensive ingredient tungsten.

It is also an object of my invention to provide a high speed tool steel of the type in which tungsten is the alloying element having the dominating effect and which steel has a lower specific gravity than comparable steels of this type known to the prior art.

It is a further object of my invention to provide high speed tool steels which may attain a higher degree of secondary hardness after hardening and tempering than is usual with the standard 18—4—1 type of steel.

It is still another object of my invention to provide steels having high secondary hardness and also having high values of strength and of plasticity developed simultaneously by the same heat treatment so that said steels exhibit exceptional toughness.

Other objects of my invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, said invention, then consists of the means hereinafter fully described and particularly pointed out in the claims.

The following description sets forth in detail some approved combinations of ingredients embodying my invention, such disclosed means constituting however, but a few of the various forms in which the principle of the invention may be used.

The present invention relates, as previously indicated, to the discovery that certain minor amounts of molybdenum, as hereinafter more fully defined, when added to a ferrous alloy composition of the type in which tungsten is a principal alloying ingredient, have a powerful auxiliary alloying effect thereon, considerably greater than any effect of molybdenum previously observed in such alloy compositions.

More specifically, this invention comprises the discovery that in the class of alloy tool steels in which tungsten is the dominating alloying element, there is a definite relationship between tungsten and molybdenum which, if properly observed, produces unexpectedly favorable results.

This relationship is made effective by adding to such steels auxiliary molybdenum in amounts from about 12% to about 28% of the amount of tungsten present. Such additions have been found to greatly and unexpectedly increase the cutting and wearing quality of tools made from the steel.

The above given range of from about 12% to 28% for the ratio between the tungsten and molybdenum may be conveniently divided into the following narrower ranges, viz:—

Molybdenum from about 12% to about 15% of the tungsten present;

Molybdenum from above 15% to about 25% of the tungsten present;

Molybdenum from above 25% to about 28% of the tungsten present.

The previously defined range for the ratio between the two elements may be further divided in the following manner, viz:—

Molybdenum from about 12% to about 20% of the amount of tungsten present; and

Molybdenum from above 20% to about 28% of the amount of tungsten present.

In the ensuing description wherein will be found a disclosure of a large number of alloys, in which the above defined proportional relationship between tungsten and molybdenum is maintained, it will be noted that there are certain groups of compositions which may be conveniently classified in the above defined manner.

The broad limits of composition within which this invention resides are as follows:

Carbon	about 0.15% to about 1.60%
Silicon	a trace to about 3.00%
Chromium	about 3.25% to about 6.00%
Tungsten	about 8.00% to about 20.00%
Vanadium	none to about 6.00%
Molybdenum	about 0.96% to about 5.60%
Cobalt	none to about 16.00%

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in this type of alloy composition.

A somewhat narrower range of compositions is as follows:

Carbon	about 0.65% to about 0.90%
Silicon	about 0.20% to about 2.20%
Chromium	about 3.37% to about 4.98%
Tungsten	about 10.32% to about 19.00%
Vanadium	about 0.45% to about 3.09%
Molybdenum	about 1.24% to about 5.32%
Cobalt	none to about 14.00%

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in this type of alloy composition.

A still narrower range of composition is as follows:

Carbon	about 0.65% to about 0.85%
Silicon	about 0.27% to about 1.00%
Chromium	about 3.42% to about 4.73%
Tungsten	about 11.04% to about 16.50%
Vanadium	about 0.68% to about 2.46%
Molybdenum	about 1.32% to about 4.62%
Cobalt	none to about 12.00%

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in this type of alloy composition.

Specific examples of alloy compositions made in accordance with this invention and falling within the above defined ranges of compositions, as well as within the above-mentioned proportional relationship between tungsten and molybdenum are as follows:

Example No.	C	Cr	W	Mo		Si	Va	Co
				Ratio $\frac{Mo}{W}$	Actual			
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	0.80	4.00	19.00	12.1	2.30	0.40	0.60	4.00
2	0.67	3.92	11.68	12.5	1.46	1.11	0.45	----------
3	0.72	4.05	13.05	13.6	1.78	1.27	0.72	----------
4	0.63	3.90	11.68	14.1	1.65	1.16	1.01	----------
5	0.66	3.93	12.00	14.1	1.69	2.20	0.68	----------
6	0.76	3.78	12.06	14.3	1.73	0.38	1.80	----------
7	0.70	4.98	11.96	14.6	1.75	1.30	0.67	----------
8	0.65	3.76	12.15	14.7	1.79	1.21	1.54	----------
9	0.73	4.00	11.04	14.7	1.62	1.19	0.68	----------
10	0.80	3.37	11.89	15.0	1.78	1.06	2.46	----------
11	1.03	3.66	11.75	15.0	1.76	1.48	3.62	----------
12	0.90	3.61	12.11	15.1	1.83	1.36	3.09	----------
13	0.65	3.92	11.05	15.1	1.67	0.47	0.76	----------
14	0.83	4.73	15.61	15.2	2.37	0.27	2.04	----------
15	0.69	3.71	11.72	15.4	1.80	1.25	None	----------
16	1.57	3.42	11.76	16.8	1.98	0.50	5.56	----------
17	0.74	4.05	9.86	17.4	1.72	1.43	0.72	----------
18	0.77	4.09	12.33	17.4	2.14	1.31	0.79	----------
19	0.76	3.92	10.54	18.7	1.97	1.23	0.83	----------
20	0.77	3.75	14.00	20.0	2.80	0.40	1.50	8.00
21	0.78	4.00	11.00	22.7	2.50	0.20	2.50	12.00
22	0.70	3.90	10.32	24.1	2.49	1.20	0.07	----------
23	0.70	3.93	12.41	25.0	3.10	1.32	0.76	----------
24	0.85	3.50	16.50	27.3	4.50	0.50	0.75	----------
25	0.79	4.00	8.50	28.0	2.38	0.20	3.00	16.00

Attention is directed to the fact that in the foregoing table the various compositions are arranged in the order of the proportional relationship therein between molybdenum and tungsten.

In the following table I include certain data in regard to the heat treatment and some of the physical properties of certain of the examples of the specific alloy compositions included in the previous table:—

Example number	Best hardening range °F.	Tempering range for maximum secondary hardness °F.	Maximum secondary hardness observed Rockwell C scale	Maximum torsional strength observed in inch-pounds [1]	Plasticity at maximum strength in degree of twist [1]	Specific gravity in annealed condition	Hardness in annealed condition Rockwell B scale
2	2270–2340	990–1140	66.0	476	126	8.32	
3	2310–2340	1040–1140	66.3	457	34	8.39	100–101
4	2270–2350	About 1040				8.36	
5	2270–2340	940–1090	65.3	442	50	8.29	102–104
6	2290–2340	940–1140	66.1	484	102	8.38	94–99
7	2270–2340	940–1140	65.2	431	38	8.36	99–100
8	2270–2340	840–1040	65.4	449	96	8.32	99–100
9	2270–2310	990–1140	66.5	429	29	8.29	99–100
10	2290–2340	1040–1140	67.7	454	45	8.28	97–99
11	2270–2330	940–1090	66.4	435	96	8.21	
12	2270–2330	940–1140	66.9	446	56	8.24	97–100
13	2310–2340	990–1140	65.7	429	48	8.40	97–88
14	2240–2310	940–1090	66.6	449	45	8.57	96–101
15	2240–2310	940–1040	65.4	418	47	8.35	101–102
16	2250–2310	940–1190	67.8	452	58	8.15	99–100
17	2270–2330	1040–1140				8.25	99–101
18	2240–2310	940–1040	64.4	429	67	8.33	99–100
19	2240–2310	940–1090	64.5	446	94	8.25	98
22	2240–2270	940–1040	62.4			8.28	100–104
23	2240–2340	940–1040	66.2	453	62	8.39	100–102

[1] For a description of the method of determing these properties refer to "Proceedings American Society for Testing Materials" vol. 31 Part II (1931), Page 47.

Certain maximum values, such as hardness, given in the foregoing table, are those which have been observed; however, it is possible that higher values may be attainable by different heat treatments.

While the above values, indicating the best hardening and tempering ranges, are the results of actual observations, it is recognized that they are a matter of opinion only and for specific purposes, desirable heat treatment might be found outside these values.

It will be observed that the specific gravities of the examples listed in the above table are materially lower than those of the 18—4—1 type of high speed steel, the specific gravity of which is generally in excess of 8.60.

Particular attention is called to Examples No. 8 and 14. These steels showed outstanding cutting quality when used as drills, their drilling performance definitely exceeding that of the drills made of 18—4—1 high speed steel with which they were compared.

Particular attention is also called to the high secondary hardness developed by Examples Nos. 3, 6, 9, 10, 11, 12, 14, 16, 23. Hardnesses in excess of Rockwell C 66 are regarded as being above those ordinarily developed in the 18—4—1 type of high speed steel.

Attention is also called to the high tempering range which is recorded for Example 16. The values of 940 to 1190 indicate a broad range and a high order of red hardness.

The abnormally high plasticity values shown by Examples 2, 6, 8, 11 and 19 are caused by the peculiarity that the maximum strength of the steel is developed at a tempering temperature so low that it falls within the range of high plasticity.

The high silicon contents of many of the above examples are found to produce a very sound, thoroughly deoxidized steel. High silicon also reduces the specific gravity of the steel quite appreciably, thus reducing the weight of steel required to make a tool or other article of manufacture.

From the foregoing description, it will be apparent that my invention relates not to the substitution of molybdenum for tungsten in high speed tool steels as has been suggested in certain instances in the prior art, but instead to the production of a new type of tungsten steel in which a specific minor amount of molybdenum is used for its powerful auxiliary effect in increasing the cutting and wearing qualities of such steel. By the addition of the auxiliary quantities of molybdenum in the above defined specific ratio to the amount of tungsten present, I have been able to produce a high speed steel of the tungsten type having cutting properties better than those of the molybdenum-free tungsten steels of the prior art and also better than certain other molybdenum containing tungsten steels of the prior art which lie outside the above specified range of ratios of molybdenum to tungsten and with which comparisons have been made.

A wide variety of heat treatments may be employed in connection with the above mentioned steels, including among others hardening, tempering, carburizing, and nitriding, for the purpose of developing specific useful properties in articles made from such steels. It should be noted that the tempering and nitriding operations may, if desired, be carried out simultaneously.

If desired, steels of the above compositions may be deposited as weld metal for the purpose of producing localized cutting or wear-resisting portions of an article of manufacture.

Steels of some of the above compositions, due to their great strength and toughness, are suitable for use as supporting and auxiliary wearing parts in composite tools, employing primary cutting edges or wearing surfaces formed on elements of hard non-ferrous metallic compositions.

Exceptional hardness is obtainable by appropriate heat treatment of certain of the above-mentioned compositions. This makes possible tools particularly suitable for machining materials of greater hardness than those at present considered machinable by steels of the 18—4—1 high speed steel type.

Steels made in accordance with this invention may be produced with extreme hardness and a low degree of toughness. Such steel may be uti-

lized in composite tools by supporting them with stronger or tougher steels of the same or other compositions.

Certain compositions made in accordance with this invention have a grain structure, as cast, so fine as to make practical the production of some types of tools, cast to substantially their finished shape, which do not require hot work for grain refinement to fit them for use.

The resistance of certain compositions made in accordance with this invention to grain growth at temperatures approaching the melting point, makes possible the production therefrom of certain articles of manufacture by various processes requiring a high degree of plastic flow, such as die forging, pressing and extruding.

As is well known to those familiar with the art, any specification for a particular alloying composition must permit of certain variations due to the fact that in making up the steel it is extremely difficult, if not impossible, to commercially produce a composition exactly like a given specification. It is to be understood, therefore, that throughout the description and claims where I have used figures to denote definite amounts and ranges, such amounts and ranges are to be construed to include the range of variations usually permissible in making up steel to given specifications.

It is understood that in the composition specified therein, minor amounts of other alloying elements and impurities such as manganese, nickel, titanium, tantalum, uranium, copper, aluminum, sulphur, phosphorus, arsenic, tin, etc., may be included and when the phrase "the balance being substantially all iron" is used, it is intended to include minor amounts of such elements.

Other forms may be employed embodying the features of my invention instead of the one here explained, change being made in the composition, provided the elements in the amounts stated by any of the following claims or the equivalent of such stated elements be employed.

I therefore particularly point out and distinctly claim as my invention:—

1. A ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 8.00% to about 20.00%; molybdenum from twelve and one-half per cent to twenty-eight per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

2. A ferrous alloy comprising; carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 10.32% to about 19.00%; molybdenum from twelve and one-half per cent to twenty-eight per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

3. A ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 11.04% to about 16.50%; molybdenum from twelve and one-half per cent to twenty-eight per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

4. A ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 8.00% to about 20.00%; molybdenum from twelve and one-half per cent to fifteen per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

5. A ferrous alloy comprising: carbon from about 0.65% to about 0.90%; chromium from about 3.37% to about 4.98%; tungsten from about 10.32% to about 19.00%; molybdenum from twelve and one-half per cent to fifteen per cent of the amount of tungsten present; silicon from about 0.20% to about 2.20%; vanadium from about 0.45% to about 3.09%; cobalt from a substantial amount to about 14.00%; and the remainder being substantially all iron.

6. A ferrous alloy comprising: carbon from about 0.65% to about 0.85%; chromium from about 3.42% to about 4.73%; tungsten from about 11.04% to about 16.50%; molybdenum from twelve and one-half per cent to fifteen per cent of the amount of tungsten present; silicon from about 0.27% to about 1.00%; vanadium from about 0.68% to about 2.46%; cobalt from a substantial amount to about 12.00%; and the remainder being substantially all iron.

7. A ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 8.00% to about 20.00%; molybdenum from fifteen per cent to twenty per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

8. A ferrous alloy comprising: carbon from about 0.65% to about 0.90%; chromium from about 3.37% to about 4.98%; tungsten from about 10.32% to about 19.00%; molybdenum from fifteen per cent to twenty per cent of the amount of tungsten present; silicon from about 0.20% to about 2.20%; vanadium from about 0.45% to about 3.09%; cobalt from a substantial amount to about 14.00%; and the remainder being substantially all iron.

9. A ferrous alloy comprising: carbon from about 0.65% to about 0.85%; chromium from about 3.42% to about 4.73%; tungsten from about 11.04% to about 16.50%; molybdenum from fifteen per cent to twenty per cent of the amount of tungsten present; silicon from about 0.27% to about 1.00%; vanadium from about 0.68% to about 2.46%; cobalt from a substantial amount to about 12.00%; and the remainder being substantially all iron.

10. A ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 8.00% to about 20.00%; molybdenum from twenty per cent to twenty-eight per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

11. A ferrous alloy comprising: carbon from about 0.65% to about 0.90%; chromium from

about 3.37% to about 4.98%; tungsten from about 10.32% to about 19.00%; molybdenum from twenty per cent to twenty-eight per cent of the amount of tungsten present; silicon from about 0.20% to about 2.20%; vanadium from about 0.45% to about 3.09%; cobalt from a substantial amount to about 14.00%; and the remainder being substantially all iron.

12. A ferrous alloy comprising: carbon from about 0.65% to about 0.85%; chromium from about 3.42% to about 4.73%; tungsten from about 11.04% to about 16.50%; molybdenum from twenty per cent to twenty-eight per cent of the amount of tungsten present; silicon from about 0.27% to about 1.00%; vanadium from about 0.68% to about 2.46%; cobalt from a substantial amount to about 12.00%; and the remainder being substantially all iron.

13. A tool formed of a ferrous alloy comprising: carbon from about 0.15% to about 1.60%; chromium from about 3.25% to about 6.00%; tungsten from about 8.00% to about 20.00%; molybdenum from twelve and one-half per cent to twenty-eight per cent of the amount of tungsten present; silicon from a substantial amount to about 3.00%; vanadium from a substantial amount to about 6.00%; cobalt from a substantial amount to about 16.00%; and the remainder being substantially all iron.

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