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ALLOY COMPOSITIONS

Joseph V. Emmons, Shaker Heights, Ohio, assignor to The Cleveland Twist Drill Company, Cleveland, Ohio, a corporation of Ohio

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This application is a continuation in part of my co-pending applications Serial No. 741,532 filed August 27, 1934, and Serial No. 56,355 filed December 27, 1935.

In my prior Patent Nos. 1,937,334 and 1,998,953 there are disclosed alloy compositions of the class in which molybdenum and tungsten are principal alloying elements and in which molybdenum and tungsten bear to each other a certain defined proportional relationship. The present invention is in effect an extension of the teachings in these prior patents particularly with respect to variations in certain of the primary alloying constituents, whereby alloy compositions particularly suited for certain classes of work and rather distinct from the compositions disclosed in my said prior patents are produced.

It is among the objects of my invention therefore to provide alloy compositions of the same general character as those disclosed in my above-identified prior patent but which, due to variations in the amounts of certain of the alloying elements used, are better suited for certain purposes than the compositions defined in such prior patent. 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 setting forth in detail some approved combination 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.

My invention may be, as above indicated, stated in general terms as comprising the discovery that certain variations, from the composition or compositions disclosed in my aforementioned prior patent, result in alloys particularly useful for certain purposes; more specifically, the present invention relates particularly to variations in the amount of carbon and to the use of specified amounts of additional alloying elements such as cobalt and nickel.

In accordance with my present invention, an alloy may contain the following elements within the percentages given, viz:

	Per cent
Carbon	About 0. 10 to about 0. 45
Manganese	None to about 4. 00
Silicon	None to about 3. 00
Chromium	None to about 15. 00
Tungsten	About 0 .07 to about 6. 00
Vanadium	None to about 5. 00
Molybdenum	About 0. 60 to about 15. 00
Cobalt	None to about 16. 00
Nickel	None to about 10. 00

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in alloys of the character to which this invention relates.

A somewhat narrower range of percentages within which the several alloying elements may be present in compositions according to my invention is as follows:

	Per cent
Carbon	About 0. 25 to about 0. 40
Manganese	About 0. 05 to about 1. 00
Silicon	About 0. 20 to about 2. 25
Chromium	About 0. 20 to about 10. 00
Tungsten	About 0. 30 to about 4. 00
Vanadium	About 0. 20 to about 2. 50
Molybdenum	About 2. 00 to about 12. 00
Cobalt	None to about 10. 00
Nickel	None to about 6. 00

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in compositions of the character to which this invention relates.

A range of percentages within which the various alloying elements may be present in some of the alloys in accordance with the present invention and which have been found to possess particularly desirable properties is as follows:

	Per cent
Carbon	About 0. 25 to about 0. 45
Manganese	About 0. 05 to about 0. 50
Silicon	About 0. 05 to about 0. 45
Chromium	About 1 .00 to about 5. 00
Tungsten	About 0. 10 to about 4. 00
Vanadium	About 0. 60 to about 2. 50
Molybdenum	About 0. 60 to about 10. 00
Cobalt	None to 9. 00
Nickel	None to 4. 00

the remainder being substantially iron together with such other alloying elements and impurities

as are sometimes found in compositions of the character to which this invention relates.

In the following table are included several varieties or specific examples of alloy compositions falling within the foregoing ranges of percentages and arranged in the order of their carbon content:

Example	C	Mn	Si	Cr	W	V	Mo	Co	Ni
1	0.15	0.30*	0.30*	1.00	0.15	None	0.60	----	----
2	0.24	0.05	0.09	0.92	0.34	0.03	1.22	----	----
3	0.25	0.04	0.10	0.87	0.07	0.03	0.65	----	----
4	0.25	**	0.40	3.50	1.40	1.00	7.00	----	----
5	0.25	**	0.40	3.50	1.40	1.00	9.00	4.00	----
6	0.30	**	0.40	4.00	1.00	0.25	5.00	4.00	----
7	0.35	0.30*	0.30	1.00	0.15	None	0.60	----	----
8	0.35	**	0.30	1.00	0.30	None	1.20	----	----
9	0.35	**	0.40	3.00	1.25	2.20	6.00	----	----
10	0.37	0.12	0.30	3.37	1.01	0.73	5.52	----	----
11	0.37	0.11	0.70	9.53	0.83	0.20	4.03	4.27	----
12	0.40	0.30*	1.00	10.00	1.00	0.25	4.00	4.00	----
13	0.40	0.06	0.39	3.94	0.91	0.78	4.79	----	1.60
14	0.40	**	0.40	3.50	1.40	1.00	7.00	8.00	----
15	0.40	0.75	0.40	3.50	1.40	1.00	9.00	----	----
16	0.40	**	0.40	4.00	1.00	0.25	5.00	2.00	----
17	0.40	**	0.40	4.00	1.00	0.75	5.00	----	----
18	0.40	**	0.40	4.00	1.00	0.75	5.00	----	1.50
19	0.45	**	0.40	2.50	4.25	0.50	12.00	----	----
20	0.45	**	0.40	3.25	0.40	0.75	13.00	----	----

* Denotes below 0.30%.
** Denotes that the alloy was not analyzed for this element.

the remainder being substantially iron together with such other alloying elements and impurities as are sometimes found in compositions of the character to which this invention relates.

The type of steel which characterizes the present invention and is notable for its low carbon content has great usefulness in the field of steels in which strength and toughness are of greater importance than cutting quality.

Example Nos. 1, 2 and 3 are low alloy types of steel, the field of usefulness of which may be expected to lie in materials required to retain hardness and strength at high operating temperatures and also as a base material to which a carburized case may be applied. Example 2, when hardened at 2040° F. had a Rockwell hardness of C46 and when then tempered at 1050° F. had a hardness of C44. Example 3, when hardened at 2040° F. had a Rockwell hardness of C44 and when then tempered at 1050° F. had a hardness of C39.

Example Nos. 4, 5, 6 and 9 represent a type of steel useful in die work where the maximum amount of toughness is desirable together with a high resistance to deformation under severe loads and at elevated temperatures.

Example Nos. 7 and 8 are particularly suitable for structural parts required to have great strength at high operating temperatures.

Example Nos. 10 and 17 have shown great strength and hardness together with a high degree of plasticity which have made them particularly useful for hot work dies of the type used in forging, extruding and coining operations upon highly heated blanks. The most suitable hardening temperature range is from 2150° F. to 2250° F. The most suitable tempering temperature range is from 800° F. to 1200° F. A preferred heat treatment which has been satisfactory for many types of dies combines a hardening temperature of 2250° F. with a tempering temperature of 1050° F. which usually produces a Rockwell hardness from C57 to C60. It will be observed that the above mentioned hardening and tempering temperatures are materially higher than have been proposed for steels of comparable total alloy content in the prior art. The above mentioned Rockwell hardness is also higher than is customarily employed for hot work, extruding and coining dies and the use of such high hardness is only made possible by the exceptional plasticity exhibited by these examples at this high hardness. The performance of dies made from these steels has been better than that of the commercial steels of the prior art with which they have been compared. As a result of the above observations these steels were immediately commercialized and are now being sold to the trade.

Example Nos. 11 and 12. These steels have a high degree of strength and plasticity together with a high hardness which is well maintained at elevated operating temperatures. They also have a high resistance to corrosion and scaling. The range of hardening temperatures is 2100° F. to 2250° F. The range of tempering temperatures is 700° F. to 1200° F. A heat treatment at which favorable properties may be expected is hardening from 2220° F. and tempering at 1000° F. This results in a Rockwell hardness of about C59. When so hardened the microstructure shows very coarse austenitic grains but moderately fine martensitic needles. There are only traces of free carbides undissolved. In addition to usefulness for hot and cold dies these steels may be expected to be useful for cutting materials of low hardness such as wood.

Example Nos. 13 and 18 are notable in that they contain a material percentage of nickel. These steels have a high degree of strength and plasticity and retain a high hardness at tempering and operating temperatures in excess of 1100° F. Hot work dies such as coining dies made from these steels have shown an excellent performance in excess of that shown by steels of the prior art with which they have been compared. The range of hardening temperatures is 2150° F. to 2240° F., and the range of tempering temperatures is 1000° F. to 1200° F. When hardened at 2220° F. and tempered at 1050° F. a Rockwell hardness of about C61 is shown. It will be recognized that this Rockwell hardness is very high to have been retained by steels of this carbon content after such a tempering temperature.

Example Nos. 14 and 16 are characterized by having a moderately high alloy content together with substantial amounts of cobalt. These steels may be expected to have a broad range of both hardening and tempering temperatures in which their most desirable properties will be developed. Their resistance to tempering will be sufficiently great to enable them to be employed for hot die work.

Example Nos. 15, 19 and 20 are characterized by a high alloy content and may be expected to show such resistance to deformation at both high and low operating temperatures as to make them useful in dies for both hot and cold work.

The types of steel disclosed herein having a carbon content below 0.30 will, as above indicated, probably find a field of usefulness, principally in the structural steels, in which strength is a more important characteristic than cutting quality. The valuable possibility is also recognized of carburizing this type of steel so that it may have a strong and tough core together with a hard wear-resisting case.

As previously indicated, compositions of the general class disclosed herein are similar to the

general class disclosed in my prior patents such as Nos. 1,937,334 and 1,998,953 with respect to the tungsten and molybdenum content, i. e., the amount of tungsten in the compositions may be broadly stated as comprising about 2% to about 40% of the amount of molybdenum present. A somewhat narrower range of proportional relationships between tungsten and molybdenum contemplates the use of tungsten in amounts from 10% to 30% of the amount of molybdenum present. The broad range from 2% to 40%, above referred to, may be conveniently divided into the following groups, viz.:—2% to 16%, 16% to 25% and 25% to 40%.

Attention is directed to the fact that certain of the examples included in the foregoing description of my invention may be readily nitrided.

Throughout the foregoing description several tables have been given indicating the ranges of percentages within which the various alloying elements may be present in an alloy composition according to the present invention. The specific examples which have been given indicate in general terms the proportional relationship within such broad ranges which should be maintained between the several alloying elements for best results. The tables giving the broad ranges of composition should, therefore, be construed as indicating merely the limits within which the various alloying elements may be present but not as indicating any proportional relationship between such elements.

As is well known to those familiar with the art, any specification for a particular alloy composition must permit of certain variations due to the fact that in making up the composition, 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 alloy compositions to given specifications.

It should be noted that where the term "none" is used to denote the absence of silicon, manganese, chromium, and vanadium, or where an alloy composition is indicated as being "free" from any one or more of these elements, the construction to be placed upon these terms is a commercial absence of the elements in question. Silicon, manganese, chromium, and vanadium may be considered as commercially absent if they are present in amounts less than 0.05%.

It is understood that in the compositions specified herein, minor amounts of other alloying elements such as titanium, tantalum, columbium, uranium, boron, zirconium, copper, aluminum, etc., as well as minor amounts of impurities such as sulphur, phosphorous, arsenic, tin, etc., may be included and when the phrase "the remainder being substantially all iron" is used, it is intended to include minor amounts of such elements which, for example, may find their way into the composition by being present in the raw materials such as scrap used in making up the composition.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made as regards the materials employed, provided the ingredients stated by any of the following claims or the equivalent of such stated ingredients be employed.

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

1. A ferrous alloy composition notable for its low carbon content and the fact that when hardened at the maximum hardening temperature specified, the resultant microstructure shows no more than traces of undissolved carbides making the composition particularly suitable for the manufacture of dies and other articles in which great strength and plasticity are required, comprising:

	Per cent
Carbon	From about 0.10 to about 0.45
Manganese	From an effective amt. to about 4.00
Silicon	From an effective amt. to about 3.00
Chromium	From an effective amt. to about 15.00
Vanadium	From an effective amt. to about 5.00
Molybdenum	From about 0.60 to about 15.00

Tungsten from about 10% to about 30% of the amount of molybdenum present, and the remainder being substantially all iron.

2. A ferrous alloy composition as defined by claim 1 comprising:

	Per cent
Carbon	From about 0.25 to about 0.40
Manganese	From about 0.05 to about 1.00
Silicon	From about 0.20 to about 2.25
Chromium	From about 0.20 to about 10.00
Molybdenum	From about 2.00 to about 12.00
Vanadium	From about 0.20 to about 2.50

Tungsten from about 10% to about 30% of the amount of molybdenum present, and the remainder being substantially all iron.

3. A ferrous alloy composition as defined by claim 1 comprising:

	Per cent
Carbon	From about 0.25 to about 0.45
Manganese	From about 0.05 to about 0.50
Silicon	From about 0.05 to about 0.45
Chromium	From about 1.00 to about 5.00
Molybdenum	From about 0.60 to about 10.00
Vanadium	From about 0.60 to about 2.50

Tungsten from about 10% to about 30% of the amount of molybdenum present, and the remainder being substantially all iron.

4. A ferrous alloy composition as defined by claim 1 comprising:

	Per cent
Carbon	From about 0.25 to about 0.45
Manganese	From about 0.05 to about 0.50
Silicon	From about 0.05 to about 0.45
Chromium	From about 1.00 to about 5.00
Molybdenum	From about 0.60 to about 10.00
Vanadium	From about 0.60 to about 2.50

Tungsten from about 16% to about 25% of the amount of molybdenum present, and the remainder being substantially all iron.

5. A ferrous alloy composition as defined by claim 1 comprising:

	Per cent
Carbon	About 0.37
Manganese	Not substantially in excess of 0.30
Silicon	About 0.30
Chromium	About 3.37
Molybdenum	About 5.52
Vanadium	About 0.73
Tungsten	About 1.01

and the remainder being substantially all iron.

6. A ferrous alloy composition as defined by claim 1, comprising:

	Per cent
Carbon	About 0.24
Manganese	About 0.05
Silicon	About 0.09
Chromium	About 0.92
Tungsten	About 0.34
Vanadium	About 0.03
Molybdenum	About 1.22

and the remainder being substantially all iron.

7. A ferrous alloy composition as defined by claim 1, comprising:

	Per cent
Carbon	About 0.40
Manganese	About 0.75
Silicon	About 0.40
Chromium	About 3.50
Tungsten	About 1.40
Vanadium	About 1.00
Molybdenum	About 9.00

and the remainder being substantially all iron.

JOSEPH V. EMMONS.