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FERROUS ALLOY

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No Drawing. Original application February 21, 1939, Serial No. 257,686. Divided and this application March 30, 1939, Serial No. 264,983

1 Claim. (Cl. 75—123)

This invention relates to alloy steels and more particularly to alloy steels which are especially suitable for use in the manufacture of tools or dies, and the present application is a division of my co-pending application Serial No. 257,686, filed February 21, 1939.

At present there are a number of steels of this nature in use but as a rule, in order to make them conform to the general requirements of ready forgeability and machinability, they are not sufficiently hard to offer a high resistance to abrasion. With this in mind, an important object of the present invention resides in the provision of an improved alloy steel of this character which can be hardened to a Rockwell hardness in excess of C 60, whereby it offers a high resistance to abrasion, and yet can be readily forged and annealed so as to be commercially machinable.

A feature of the invention which contributes to the accomplishment of the recited object consists in the discovery that by the employment of vanadium in a predetermined ratio in steels of the type under discussion it is possible to employ a carbon content far in excess of that employed in steels of this type that are in use at the present time. Thus, it has been found that the element vanadium, because of its extremely high affinity for carbon, will form carbides in the alloy, large amounts of which will not go into solid solution at the normal hardening and forging temperatures. Even in the hardened state the improved steel will have a comparatively tough matrix in which are embedded extremely hard carbides.

In my Patent No. 2,105,115, granted January 11, 1938, the fact was disclosed that carbon contents up to 1.25% or 1.50% could be employed in molybdenum steels as long as there was also present a vanadium content in excess of two and one-half to one and below three and one-half to one of the carbon content. This was an important discovery, but to repeat, it did not offer the wear resistance which forms the subject matter of the present invention. What I have now discovered is that steels having carbon contents in excess of 1.25% and less than about 3.50% carbon may be prepared as long as the steel contains a vanadium content of approximately three times the amount of carbon present. Accordingly, in an alloy steel of the character under discussion having a carbon content in excess of about 1.25% and less than about 3.50% the vanadium content would range from about 3.00% to about 11.00%.

To repeat, steels containing about 2.50% carbon or more have not heretofore been regarded as commercially forgeable, and an important feature of the present invention resides in the discovery, and the attendant disclosure, that such steels may be rendered readily forgeable by incorporating in them approximately three times as much vanadium as carbon present. Steels so prepared have extremely high resistance to wear, can be hardened extremely hard, some of them even as high as Rockwell C 70, yet they can be annealed to a hardness of under 275 Brinell, at which hardness they are commercially machinable.

In establishing the premises of my invention several series of heats of steel were prepared, some of which will be described in the ensuing paragraphs.

Heat No. 1

A steel was made containing 1.95% carbon, 1.20% silicon, .35% manganese, and 5.12% vanadium, which, by quenching in water from 1750° F., produced a hardness of Rockwell C 69, and by quenching from temperatures as high as 2200° F. obtained a hardness as high as Rockwell C 67. This steel was also annealed to a hardness of 255 Brinell, at which hardness it could be readily machined. The steel was readily forgeable and forged with about the same ease as would a 1.00% carbon tool steel.

Heat No. 2

A heat of steel was prepared containing 3.05% carbon, 1.01% silicon, .32% manganese, and 9.60% vanadium, which it was possible to harden to approximately Rockwell C 70 from 1600° F. and to Rockwell C 67 from 2200° F. This steel was annealed to a hardness of 255 Brinell, at which hardness it could be readily machined. It likewise forged with the same ease as a carbon tool steel of about 1.00% carbon content.

Having made the discovery that when the vanadium-carbon ratio was approximately that as given that such a material could be readily forged and annealed and hardened to extremely high hardnesses, other alloys were then added to the base composition given, namely, a carbon content of from about 1.25% to about 3.50% and a vanadium content of from about 3.00% to about 11.00%.

Heat No. 3

A heat of steel was made containing 3.10% carbon and 8.60% vanadium, to which was added a tungsten content of 4.92%, and the material remained forgeable.

Heat No. 4

This heat of steel contained a carbon content of 2.94% and a vanadium content of 9.50%, to which was added 10.6% of tungsten. The material remained forgeable and was found to reside within the premises of the invention herein disclosed.

Two additional heats of steel were made containing 3.12% carbon and 10.10% vanadium, and 3.14% carbon and 10.10% vanadium, to which were respectively added 15.58% tungsten and 24.50% tungsten, but neither of these steels appeared to be commercially forgeable. It was therefore concluded that with the carbon on the higher side of the carbon range about 12.00% tungsten was the maximum that should be added in order to maintain the material commercially forgeable. In order to determine the upper limit of molybdenum, heats were prepared constantly increasing the amount of molybdenum present and it was found that the material was not commercially forgeable in the higher carbon range after the molybdenum content exceeded about 10.00%. Molybdenum and tungsten were added to determine the upper combined limit of both of these elements and it was found that as long as the combined amount of the two was under about 10.00% the material could be successfully forged, whereas if the combined amount exceeded this figure the material appeared to be no longer commercially forgeable.

Ingots were made of the base composition already described containing both tungsten and chromium, and also containing tungsten, molybdenum and chromium. With the chromium content as high as 5.00% and with the carbon content approximately 2.00% it was found that either tungsten or molybdenum, or both, could be added to a total percentage of approximately 12.00% and the material would still be commercially forgeable. It was found, however, that an ingot of 3.25% carbon, 8.90% vanadium, 10.79% tungsten, and 4.12% chromium formed with considerable difficulty, which would indicate that in the presence of about 10.00% of tungsten or molybdenum, or a total of both, that a chromium content higher than 5.00% could not be added and still obtain a commercially forgeable material. All of these compositions naturally contain varying amounts of silicon, generally less than 1.50%, and a manganese content generally less than .75%, and additionally they also contain the customary small amounts of impurities of sulphur and phosphorus.

The purpose of adding other alloying ingredients to the base composition was to alter the physical properties of the alloy so that the material would have red hardness or would retain its hardness up to temperatures of approximately 1100° F. Hardened material made of the base composition decreased slightly in hardness with an increase in tempering temperature, but the material containing tungsten and molybdenum, or both, with a chromium content of from 3.00% to 5.00% did not materially decrease in hardness when the quenched specimens were tempered as high as 1100° F.

Ingots were made similar to those to which tungsten, molybdenum and chromium were added, but with a lesser vanadium content; that is, with the vanadium content below 2.00%, and none of the ingots so made could be successfully forged, which is indicative of the fact that it is the presence of the carbon-vanadium ratio that permits the material to be forgeable.

The following table will additionally serve to give information concerning a number of compositions which were prepared and is indicative of the manner in which the material forged:

Heat	C	Si	Mn	W	Mo	Cr	Va	Remarks
1136	3.05	1.01	.32				9.60	Readily forgeable.
1137	1.95	1.20	.35				5.12	Do.
1138	3.10	.82		4.92			8.60	Forgeable.
1139	2.94	.72	.37	10.64			9.50	Do.
1140	2.10	1.31	.31	4.72			5.30	Readily forgeable.
1141	2.09	1.41	.29	10.47			5.12	Do.
1144	3.12	.72		15.58			10.10	Not forgeable.
1145	3.14	.90	.35	24.50			10.10	Do.
1147	2.00	.96	.37	16.02			5.05	Readily forgeable.
1148	1.99	.89	.38	23.87			5.05	Not forgeable.
1150	1.99	.99	.40	10.47		4.66	6.00	Forgeable.
1161	2.06	.83	.27	5.20	3.93	4.93	6.30	Do.
1162	2.06		.29	5.20	3.93	4.93	6.30	Do.
1165	1.92	1.07	.38	5.01	3.94	4.04	6.70	Do.
1166	1.94	.40	.29	4.75	4.02	4.12	8.10	Do.

The following table shows the Brinell hardness that was obtained after annealing some of these materials at a temperature of 1650° F.:

Heat number	Brinell hardness after annealing
1136	255
1137	255
1139	286
1140	269
1141	286
1147	277
1150	262
1161	277
1166	248
1165	269

It was discovered that material either of the base composition or with tungsten, molybdenum and chromium added in the percentages described hardened with an extremely fine grain. The following table gives two typical examples of the grain size obtained, hardening from different temperatures, the grain size based upon the standard Shepherd fracture test, where the finest grain is rated as 10 and the coarsest at 1:

HEAT 1136

Quenching temperature, ° F.	Fracture grain size
1600	9
1750	9¼
1800	9
2000	9
2200	8½

HEAT 1137

1600	10
1750	10
1800	10
2000	10
2200	9¼

HEAT 1141

1600	9¼
1800	10
2000	10
2200	9

The following table shows the hardness obtained expressed in the Rockwell C scale on a few of the heats when quenched from different quenching temperatures:

Heat number	Degrees Fahrenheit				
	1600	1800	2000	2200	2300
1136	70	67	68	67	------
1137	68	68	68	66	------
1139	70	70	70	70	69
1140	70	69	68	67	------
1141	71	70	70	68	67

Material made from heat 1161 after quenching from 2350° F. retained a hardness of 68 Rockwell C after tempering for one hour at 1050° F., definite proof of the red hardness of some of the compositions to which tungsten or molybdenum, or both, and chromium were added.

Material made from heat 1136 within the range of the basic composition when quenched from 1600° F. and tempered at 1050° F. for 1½ hours showed a hardness of 47 Rockwell C and when quenched from 2200° F. and tempered at 1050° F. for 1½ hours showed a hardness of 57 Rockwell C, which indicates that while the material had some red hard properties there was a noticeable drop in hardness when it was tempered at 1050° F. It was also found that material of the basic composition shows a resistance to abrasion of as much as 10 to 1 over that of carbon tool steel containing 1.00% carbon and hardened to a Rockwell hardness of C 67.

Having thus described the invention, what I claim as new and desire to secure by Letters Patent of the United States is:

An improved forgeable and machinable alloy steel, said steel containing from about 1.25% to about 3.50% carbon and from about 3.00% to not more than 10% vanadium; the ratio of the vanadium to the carbon being in excess of about 2 to 1 and less than about 4 to 1, with the remainder of the alloy substantially all iron.

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CERTIFICATE OF CORRECTION.

Patent No. 2,174,282. September 26, 1939.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 14, for "10.6%" read 10.64%; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of November, A. D. 1939.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.

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