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ALLOY STEEL

Ralph P. De Vries, Menands, N. Y., assignor to Allegheny Ludlum Steel Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

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My invention relates to alloy steels which substantially maintain their hardness when repeatedly heated to temperatures of the order of 1200° to 1600° F., and air cooled. It also relates to steels which are characterized by high hardness and high strength at elevated temperatures.

One of the objects of my invention is to provide an alloy steel which, while adapted for general use, is particularly suited for those applications where resistance to scaling combined with high strength and hardness at elevated temperatures are required characteristics, and where such strength and hardness are not substantially affected by repeated heating and cooling. Such steels are especially adapted for use in poppet valves of internal combustion engines, hot work dies and similar articles which may be either forged or cast.

The essential alloying elements in my steel and the approximate percentage ranges, by weight, within which they must be used to accomplish the foregoing objects are about as follows:

	Per cent
C	.50 to 1.25
Cr	20.00 to 26.00
Mn	2.00 to 6.00
N	.10 to .50
Fe	Balance

In addition to the foregoing, other elements may, of course, be incorporated in such small

quantities as will not substantially impair the characteristic properties of the alloy. For example, silicon, a usual ingredient in steel, may be present up to about 0.75%. Additions of cobalt do not in any way affect that outstanding characteristic of my alloy which is its ability substantially to maintain its hardness upon repeated heating to and air cooling from temperatures of the order of 1200° to 1600° F. But cobalt in quantities of from about 0.25% to about 2.50% does increase, in degree, the maintainable hardness, and is therefore useful for hot die purposes and also for poppet valve applications. Phosphorus and sulphur may be present in the usual small quantities, and the content thereof may even be raised to as high as about 0.15%, in which case the phosphorus increases the hardness obtainable. Where phosphorus is present in more than the usual maximum of about 0.04%, small quantities of selenium, up to about 0.20%, may be added to improve the machineability of the alloy.

In the table below, I have set forth for comparative purposes a number of alloy steels each containing carbon, chromium and manganese within the limits of my invention above set forth, together with their hardness in the as forged condition, their hardness when air cooled from temperatures of the order of 12000° F. to 1600° F., and their hardness after reheating and air cooling from temperatures of this order.

Melt No.	Analysis							Cone Rockwell hardness						
	C	Cr	Mn	N	Co	P	Se	As forged	Air cooled from—			After reheating and air cooling from—		
									1200° F.	1400° F.	1600° F.	1200° F.	1400° F.	1600° F.
S-31	.60	23.68	5.02	.16				40/41	38	39	35	38	36	38
S-32	.64	23.48	5.19	.26				34/35	43	42	38	42	42	40
S-47	.61	23.34	4.52	.26	.74			40/41	42	42	43	40	40	43
S-52	.60	21.85	4.78	.24				43/44	40	40	40	38	39	40
S-54	.60	23.94	5.36	.24				34	33	37	37	34	35	34
S-55	.59	25.75	5.12	.24				34	30	29	30	30	30	29
S-58	.63	25.63	6.16	.24				35	32	32	33	32	32	33
S-59	.64	23.34	5.70					29	22	22	25	24	24	26
S-62	.55	22.98	4.09	.24				41	38	43	41	42	37	40
S-63	.52	24.51	3.18	.25				38	35	33	34	27	23	27
S-65	.53	25.07	3.12	.26				36	31	22	27	21	19	22
S-72	.55	23.37	4.15	.24	.36			38	39	40	41	34	35	37
S-75	.52	22.67	4.46	.24		.136	.06	38	33	40	39	39	38	39
S-77	.84	23.26	4.96	.33				48	46	48	48	43	42	49
S-78	.91	24.02	3.16	.34				37	44	46	37	42	39	48
S-79	.85	25.17	2.63	.36				43	43	45	44	43	36	46
S-97	.69	24.05	5.22					24	24	23	24	23	21	24
S-98	.73	22.18	4.72					40	32	33	35	25	27	32
S-99	.80	23.26	4.50					37	30	32	33	27	24	32
S-100	.77	25.00	2.82					20	18	18	18	18	18	18
S-101	.81	25.34	5.16					27	25	23	23	22	22	23

By comparison of melts S-31, S-32 and S-77, it will be noted that the chromium and manganese contents are as nearly alike as can be melted, but that the nitrogen content in these specimens is 0.16%, 0.26% and 0.33%, respectively. Each of these steels, when heated and cooled from 1200° F., 1400° F. and 1600° F., and again heated and cooled from these temperatures, maintains a hardness in the neighborhood of 35 to 45 Cone Rockwell. Specimen S-31 containing the lowest quantity of nitrogen maintains the lowest hardness. Specimen S-32, although less hard than specimen S-31 in the "as forged" condition, becomes harder upon heating and cooling, and maintains a higher hardness upon reheating and cooling, than specimen S-31, while S-77 which contains .33% of nitrogen together with slightly higher carbon than the other two specimens, maintains the highest hardness. Specimens S-59, S-97, S-98, S-99, S-100 and S-101 contain no nitrogen. It will be noted that some of these specimens have a hardness in the "as forged" condition which is comparable to that of the three specimens above discussed. This hardness is not maintained when the steel is reheated and cooled from the test temperatures, thus showing that the "as forged" hardness is only incidental and has no relation to the property of maintainable hardness. Specimen S-98, for example, having a forged hardness of 40 drops to a hardness of 25 when reheated and air cooled from 1200° F., and specimen S-99 having a forged hardness of 37 drops to a hardness of 24 when reheated to 1400° F. and air cooled.

That the ranges of chromium and manganese within which my results are attained are quite critical will be apparent from a consideration of the above table. For example, specimens S-55 and S-58 with both chromium and manganese near the maximum claimed limits show that the maintained hardness is rather low with carbon in the lower portion of its range. On the other hand, specimens S-31, S-77, S-78 and S-79 show that the maintained hardness increases with a decrease in the chromium, an increase in the carbon, a decrease in the manganese or by a combination of these modifications. Specimen S-79 with chromium near the upper limit, manganese near the lower limit and carbon and nitrogen in about the middle of their respective ranges maintains its hardness quite consistently upon heating and cooling.

It has often been found that steels which have a relatively high hardness when tested at room temperatures do not have relatively high strength or hardness when tested at elevated temperatures. The steel of my invention which has a high maintainable hardness in the temperature range of 1200° to 1600° F., has however, both high hardness and high strength at heat, the strength at a temperature of 1500° F. running consistently from 25000 to 35000 pounds per square inch. Such high strengths are usually

found only in steels where high melting point and expensive elements such as molybdenum, tungsten or tantalum are used in fairly large proportions or where, in addition to the chromium, at least 10% to 20% of iron is replaced by nickel or manganese so that the alloy content approximates about 50% of the total composition. In my steel, however, the alloy content does not exceed from about one-fourth to one-third of the total weight of the steel.

My preferred quantities of chromium and manganese fall in about the middle of the ranges of these elements above specified, with carbon at least ten to fifteen points above the minimum, and nitrogen around 0.25% or more. Within these preferred ranges the alloy maintains hardness even when cooled slowly from high temperatures.

From the foregoing tests, it also seems preferable when chromium is present in the extreme upper portion of its range, that both carbon and nitrogen should also be well above the minimums specified, and the manganese should be in the lower portion of its range.

Steels which show a good order of maintainable hardness in the ranges of 1200° to 1600° F., are sometimes worthless for commercial purposes because of lack of ductility at room temperature. This is not the case with my alloy. Specimen S-77, for example, which hardens to 48 Cone Rockwell, has a bend of 5° with great strength when tested at room temperature.

What I claim is:

1. An alloy steel characterized by the substantial maintenance of hardness upon repeated heating to temperatures of the order of 1200° to 1600° F. and air cooling; said steel containing a plurality of ingredients of which the following, in the proportions stated are the only elements necessary to attain said characteristic, carbon from 0.50% to 1.25%, chromium from 20% to 26%, manganese from 2% to 6%, nitrogen from 0.10% to 0.50%, and the balance iron.

2. An alloy steel characterized by the substantial maintenance of hardness upon repeated heating to temperatures of the order of 1200° to 1600° F. and air cooling; said steel containing a plurality of ingredients of which the following, in the proportions stated, are the only elements necessary to attain said characteristic, carbon from 0.60% to 1.25%, chromium from 21.5% to 24.5%, manganese from 2.5% to 4.5%, nitrogen from 0.25% to 0.50%, and the balance iron.

3. An alloy steel characterized by the substantial maintenance of hardness upon repeated heating to temperatures of the order of 1200° to 1600° F. and air cooling; said steel containing a plurality of ingredients of which the following, in the proportions stated, are the only elements necessary to attain said characteristic, carbon from 0.60% to 1.25%, chromium from 24% to 26%, manganese from 2% to 4%, nitrogen from 0.25% to 0.50%, and the balance iron.

RALPH P. DE VRIES.