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FORGED AND NITRIDED STEEL ROLL

Filed Sept. 26, 1962

2 Sheets-Sheet 1

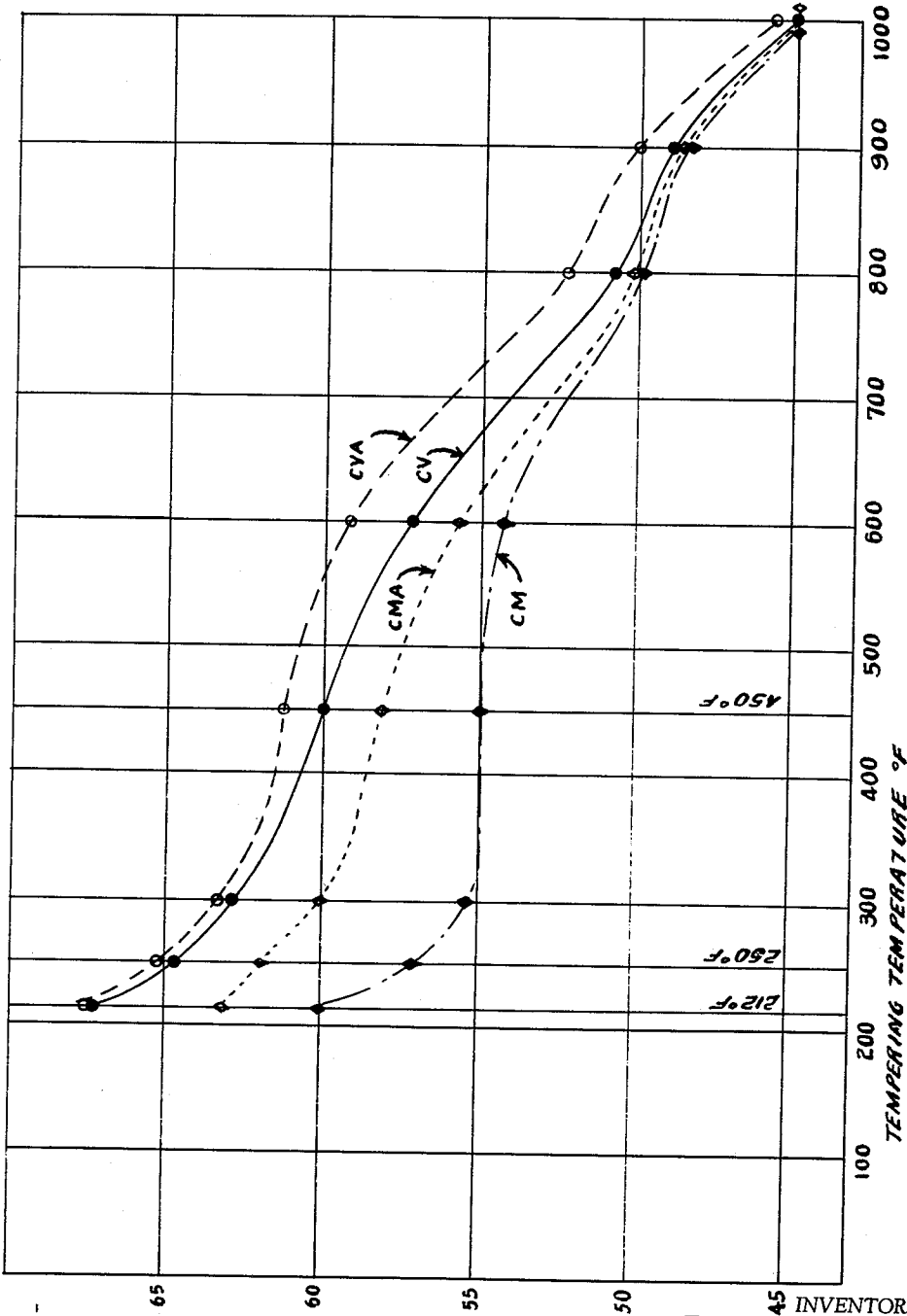


FIG. 1 -

HARDNESS - ROCKWELL 'C' AT ROOM TEMPERATURE

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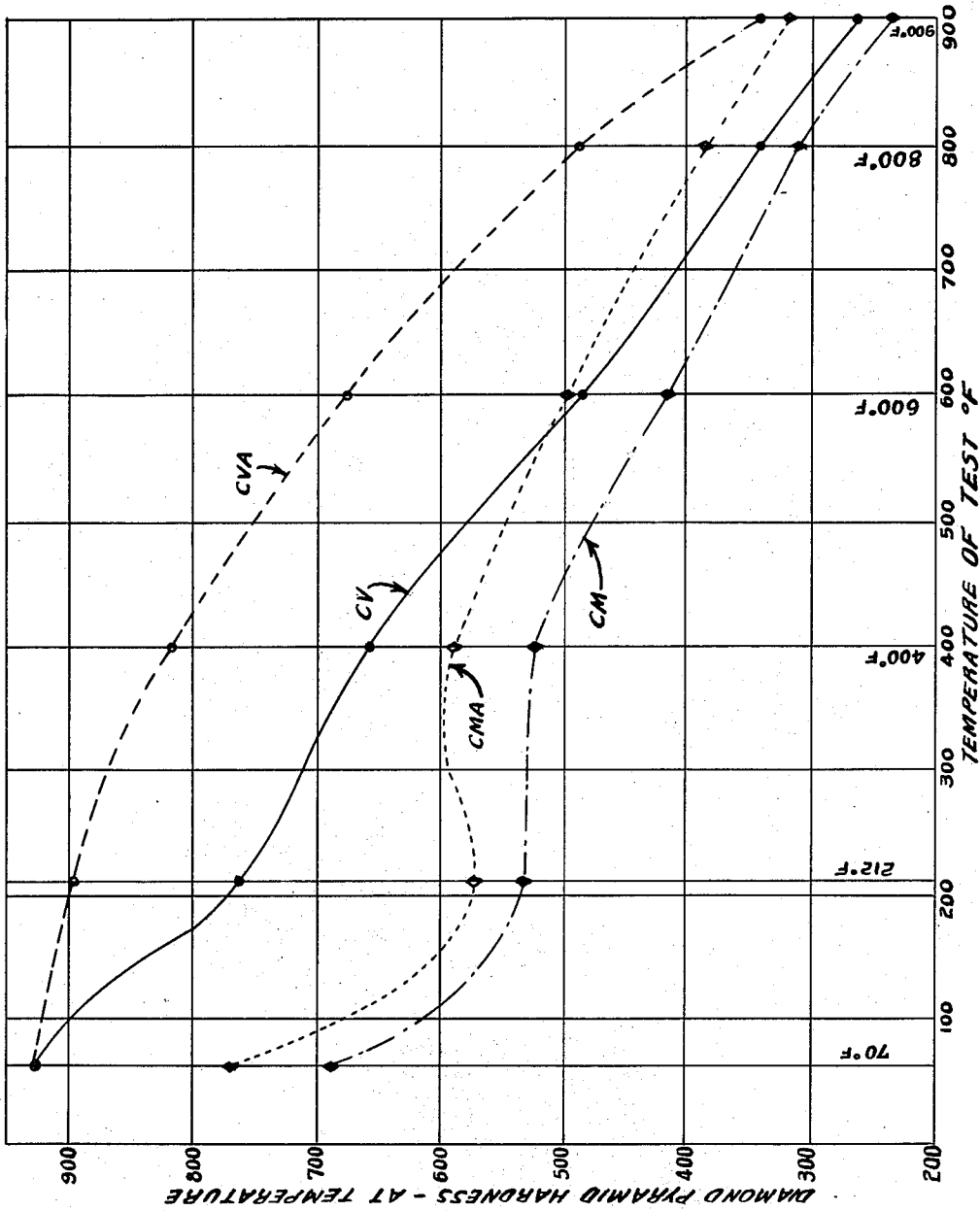


FIG. 2 -

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FORGED AND NITRIDED STEEL ROLL

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1 Claim. (Cl. 148-36)

This invention relates to alloy steel rolls for rolling mills and the like. More particularly it relates to an alloy steel for use in steel rolls having improved hardness characteristics.

It is known that steel rolling operations require the use of steel rolls which possess special hardness characteristics to withstand the temperatures and mechanical forces to which they are subjected in use. It is customary to treat such rolls by various conventional methods in order to impart a hardened outer surface that will resist the abrasive forces encountered, while maintaining the central portions of the roll soft so as to have the required toughness to resist mechanical shocks. As disclosed in U.S. Patent No. 2,619,439, the disclosure thereof which is incorporated herein by reference, steel work rolls are desirably surface hardened to at least 58 Rockwell C. Moreover, since the surface of many work rolls are heated above room temperature in service and since the room temperature hardness and the hot hardness of a roll material may differ greatly, it is necessary to provide roll materials having adequate hardness at operating temperatures.

It has now been discovered that the increased speeds in rolling mill production, and the heavier reductions made in rolling operations have resulted in roll temperatures sufficiently high to temper back the body hardness of the roll below useable levels, and sufficiently high to prevent the maintenance of adequate hardness and strength at the operating temperature. For example, a sample of the following standard roll steel Composition A was chosen.

Element:	Percent by weight
Carbon -----	0.89
Manganese -----	0.34
Phosphorus -----	0.009
Sulfur -----	0.006
Silicon -----	0.34
Nickel -----	0.17
Chromium -----	1.85
Vanadium -----	0.08
Molybdenum -----	0.22
Remainder iron and other elements in residual amounts to make 100.00%.	

This material was machined into 8 test specimens, each being three-quarters of an inch in diameter by two inches long, and having a tapped hole at one end for hardening. Each specimen was spray quenched and one of such specimens was tempered for 24 hours at each of the following temperatures: 212° F., 250° F., 300° F., 450° F., 600° F., 800° F., 900° F. and 1000° F. Suitable flats were then ground on one side of the cylindrical surface of each specimen, and a Rockwell hardness test made thereon at room temperature. The resulting values are plotted as points on the faired curve CV in FIG. 1. The points thus plotted correlate draw temperature in degrees Fahrenheit and Rockwell C hardness. The specimen which was tempered at 212° F., was then sampled to produce small specimens from near the cylindrical surface of the original specimen. These small specimens were polished to a micro finish and tested at elevated temperatures (212° F., 400° F., 600° F., 800° F., and 900° F.) for

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Diamond Pyramid Hardness, using an indenter load of .730 kg. The maximum temperature variation between specimens was 6° F., and the specimens were soaked for 30 minutes at each temperature prior to testing. The tests were made in vacuum, and the specimens were laid upon a lavite block to avoid contamination, while five impressions were made at each temperature with a Vickers-type sapphire indenter. The results of this hot hardness test were plotted as points on the faired curve CV in FIG. 2. The points thus plotted correlate the elevated temperature in degrees Fahrenheit and Diamond Pyramid Hardness. The 70° F. point on curve CV in FIG. 2 was obtained by calculation from the Rockwell C hardness before elevated temperature testing.

By following a similar procedure, samples of another standard roll steel Composition B were tested.

Element:	Percent by weight
Carbon -----	0.68
Manganese -----	0.79
Phosphorus -----	0.013
Sulfur -----	0.012
Silicon -----	0.24
Nickel -----	0.48
Chromium -----	1.63
Vanadium -----	0.07
Molybdenum -----	0.44
Remainder iron and impurities to make 100.00%.	

The results of these tests are plotted as points on the faired curves CM in FIGS. 1 and 2.

The effects of high temperatures at extended periods of duration on standard roll steels can be readily seen from these test results.

It is therefore an object of this invention to improve the resistance to tempering of standard roll steels.

It is another object of this invention to provide a roll steel alloy having increased hot hardness.

It is another object of this invention to provide a novel roll steel composition having increased tempering and hot hardness characteristics without nitriding.

It is another object of this invention to provide a novel roll steel composition susceptible to nitriding and having the aforementioned tempering and hot hardness characteristics.

The above objects have been accomplished by the discovery that the incorporation of adequate amounts of aluminum as an alloying element in roll steels having carbon concentrations not less than about 0.60 percent by weight. Preferably, the aluminum content will be in the range of from about 0.50 to about 1.50 percent by weight, while the preferred carbon concentration will be in the range of from about 0.60 to about 1.25 percent by weight. A preferred composition having a range of alloying elements is as follows.

Element:	Percent by weight
Carbon -----	0.60-1.25
Manganese -----	0.10-1.25
Phosphorus -----	0.005-0.050
Sulfur -----	0.005-0.050
Silicon -----	0.10-1.10
Nickel -----	Under 3.50
Chromium -----	1.40-2.50
Molybdenum -----	Under 1.25
Vanadium -----	Under 0.35
Aluminum -----	0.50-1.50
Remainder iron and other elements in residual amounts to make 100.00%.	

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Example 1

A 5 inch test ingot was poured having the following composition.

Element:	Percent by weight
Carbon -----	0.77
Manganese -----	0.31
Phosphorus -----	0.010
Sulfur -----	0.008
Silicon -----	0.32
Nickel -----	0.10
Chromium -----	1.92
Vanadium -----	0.08
Molybdenum -----	0.23
Aluminum -----	0.85
Remainder iron and other elements in residual amounts to make 100.00%.	

The ingot was forged under the hammer to a two and one-half inch octagon using standard roll practice. The ingot forged well, showing no difference from normal roll material, and no pulls or forging defects appeared. The ingot was then prepared and tested in accordance with both of the procedures hereinbefore described, and under which the conventional composition rolls were tested. The results of these tests are plotted as points on the faired curves CVA in FIGS. 1 and 2.

Example 2

A 5 inch test ingot was poured having the following composition.

Element:	Percent by weight
Carbon -----	0.64
Manganese -----	0.79
Phosphorus -----	0.010
Sulfur -----	0.013
Silicon -----	0.30
Nickel -----	0.23
Chromium -----	1.59
Vanadium -----	0.07
Molybdenum -----	0.45
Aluminum -----	0.95
Remainder iron and other elements in residual amounts to make 100.00%.	

The ingot was forged under the hammer to a two and one-half inch octagon using standard roll practice. The ingot forged well, showing no difference from normal roll material, and no pulls or forging defects appeared. The ingot was then prepared and tested in accordance with both of the procedures hereinbefore described under which the conventional composition rolls were tested. The results of these tests are plotted as points on the faired curves CMA in FIGS. 1 and 2.

The curves plotted on FIGS. 1 and 2 clearly indicate that the roll compositions of Examples 1 and 2 result in rolls having a greater hardness and greater resistance to tempering at elevated temperatures, than the corresponding standard compositions A and B.

These results suggest that the aluminum containing high carbon alloy compositions of this invention will have greater resistance to wear, denting and scuffing in roll service, and will probably hold a ground finish longer in the mill between grinds than the standard grade alloys in hot rolling applications.

Furthermore, it has been discovered that while rolls formed from the novel compositions of this invention have inherent elevated temperature properties showing improvement over conventional roll steel with normal heat treatment, and without surface hardening by nitriding, rolls so formed can be nitrided, and as so treated show further improvements over conventional nitrided roll steel alloys.

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Example 3

One of the test specimens of the composition of Example 1 was nitrided by the Floe process in the following stages:

First stage: 975° F. to 1000° F. for 9 hours with 20-25% dissociation

Second stage: 1025 to 1050° F. for 40 hours with 75-80% dissociation

The following comparative test results were determined:

Depth of Case and Hardness	Core Hardness As Received	Core Hardness After Nitriding
15 N Rockwell 92, Rockwell C 65, Depth .021 inch.	Rockwell C 49....	Rockwell C 44.

Example 4

One of the test specimens of the composition of Example 2 was nitrided by the same process utilized in Example 3, and the following comparative test results were determined:

Depth of Case and Hardness	Core Hardness As Received	Core Hardness After Nitriding
15 N Rockwell 93, Rockwell C 67, Depth .023 inch.	Rockwell C 43....	Rockwell C 43.

For comparison with the test results of Examples 3 and 4, a specimen of standard Nitralloy nitriding steel was given the same nitriding treatment utilized in Examples 3 and 4. The test results on this specimen were as follows:

Depth of Case and Hardness	Core Hardness After Nitriding
15 N Rockwell 93, Rockwell C 67, Depth .023 inch....	Rockwell C 35.

Therefore, it is seen that while the case hardness of the nitrided compositions of Examples 3 and 4 closely approaches that of conventional nitriding steels, the core hardness of specimens of said compositions is appreciably higher. This indicates advantages in service where high surface loads are applied. Such loads cause failures in conventional nitriding steels because of the inability of the core to support the high loads. The higher core hardness of the nitrided compositions of this invention would have greater resistance to the stresses causing such failures.

Brittleness in roll steels, also a problem with conventional nitrided cases of high hardness levels is improved by utilizing the compositions of this invention. The edge of a sample of conventional nitrided steel cracked and spalled when struck sharply with a hammer. The specimens of Examples 3 and 4 show appreciable deformation when struck with a hammer without cracking or spalling.

Similarly, a Brinell hardness test using a 500 kg. load on the case of a conventional nitrided steel produced circumferential cracks in the impression. The specimens of Examples 3 and 4 showed no cracks in the impression when subjected to the same test. This indicates that the improved nitrided compositions of this invention have greater toughness and resistance to cracking and chipping when subjected to heavy loads than conventional nitriding steels. Even though other nitrided steels such as for example SAE 4140 and 4340 also show improved toughness when subjected to hammer blows or Brinell testing, these grades are approximately 15 N Rockwell 87 or 53 to 55 Rockwell C after nitriding. The improved roll compositions of this invention provide improved toughness in nitrided grades at much higher case hardness levels.

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While the preferred embodiment of the steel composition of this invention has been described in some detail, it will be obvious to one skilled in the art that various modifications may be made therein without departing from the invention claimed hereinafter. For example, a free machining variety of the novel steel composition of this invention may be readily prepared by increasing the sulfur level, to an amount in the range of about 0.05 to about 0.33 percent by weight of the composition, and where necessary a vacuum deoxidized grade of the composition may be obtained by utilizing an extremely low silicon content, i.e., an amount in the range of about 0.01 to about 0.10 percent by weight of the composition. Moreover, it will readily be apparent that while the steel composition of this invention has been disclosed with an end product use as roll steel, other standard steel products would be correspondingly improved by virtue of the characteristics of this composition, all without departing from the scope of the following claim.

Having thus described my invention, I claim:

A forged and nitrided steel rolling-mill roll characterized by improved hot hardness characteristics and im-

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proved resistance to cracking and spalling, and consisting essentially of (parts being expressed in percent by weight of composition before nitriding):

	Carbon -----	0.60-1.25
5	Manganese -----	0.10-1.25
	Phosphorus -----	0.005-0.050
	Sulfur -----	0.005-0.050
	Silicon -----	0.10-1.25
	Nickel -----	Under 3.50
10	Chromium -----	1.40-2.50
	Molybdenum -----	Under 1.25
	Vanadium -----	Under 0.35
	Aluminum -----	0.50-1.50
15	Remainder iron and other elements in residual amounts.	

References Cited in the file of this patent

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	2,619,439	Rennick -----	Nov. 25, 1952
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