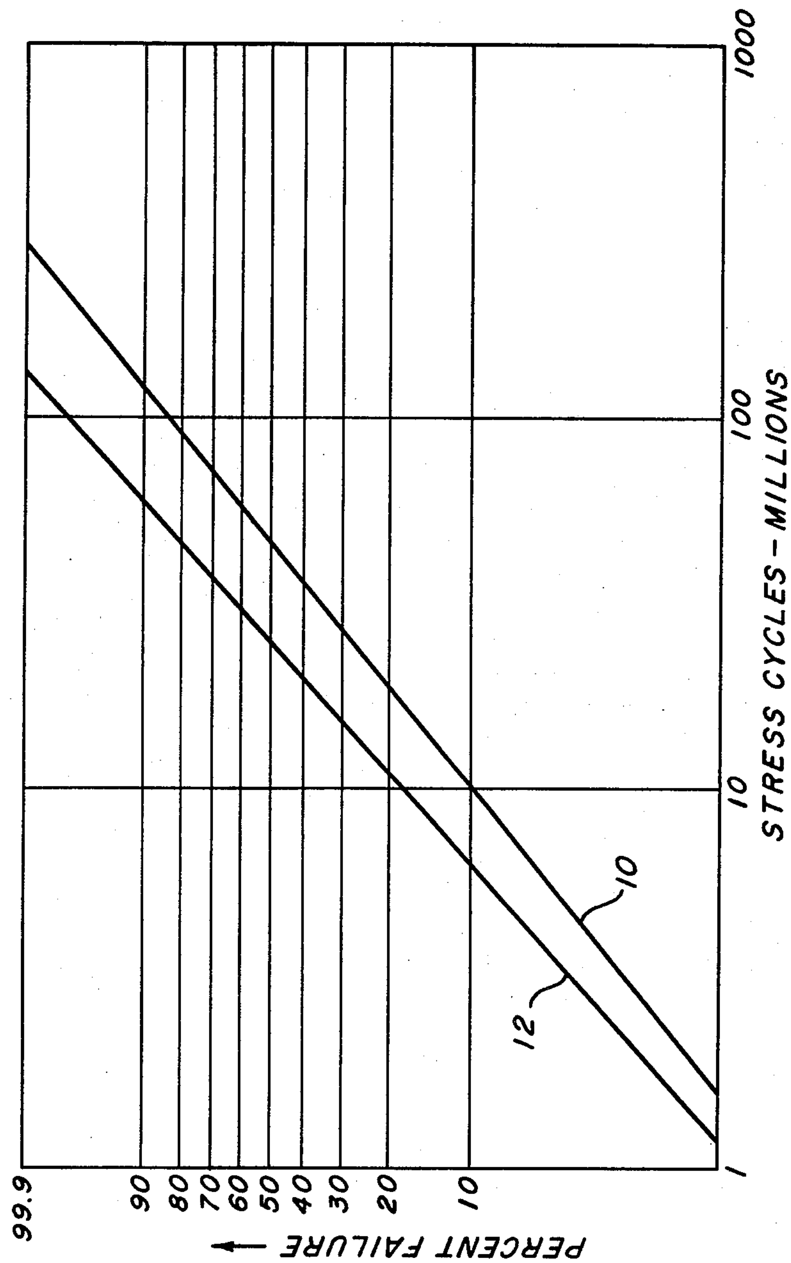
Nov. 28, 1972 C. P. WEIGEL 3,704,183

METHOD FOR PRODUCING A LOW-COST HYPEREUTECTOID BEARING STEEL

Filed May 26, 1971



INVENTOR.
CHARLES P. WEIGEL
By
Brown, Murray, Flick & Peckham
Attorneys

United States Patent Office

3,704,183
Patented Nov. 28, 1972

3,704,183

METHOD FOR PRODUCING A LOW-COST HYPEREUTECTOID BEARING STEEL

Charles P. Weigel, Canton, Ohio, assignor to The Timken Company, Canton, Ohio

Filed May 26, 1971, Ser. No. 146,911
Int. Cl. B22d *25/00;* C21d *7/14*
U.S. Cl. 148—126 2 Claims

ABSTRACT OF THE DISCLOSURE

Method for producing a low-cost hypereutectoid bearing steel having characteristics equal to or superior to higher priced steels of this type and containing as essential alloying additions .80–1.10% carbon, .50–1.00% manganese, .20–.60% chromium and .05–.25% molybdenum. A steel of this type, usually in the form of wire, rod, bar, forgings, rings or tubing, is annealed at a maximum temperature of 1400° F. for thirteen hours to produce an annealed microstructure comprising spheroidized carbides in a matrix of ferrite. After forming into bearing races or balls, the formed product is quenched from 1550° F. and thereafter tempered to produce a steel having a Rockwell C hardness of about 60 or greater and excellent fatigue strength.

BACKGROUND OF THE INVENTION

As is known, AISI 52100 steel has been used extensively, and almost exclusively, for ball bearing applications. Such a steel contains as essential alloying additions, .98–1.10% carbon, .25–.45% manganese and 1.30–1.60% chromium. The relatively high amount of chromium is added to assist in hardenability; however this materially increases the cost of the product.

In the manufacture of bearings from AISI 52100 steel, tubular shapes, bars, forgings and rings (for forming bearing races) and wire or rod (for forming balls) are initially annealed at about 1450° F., maximum temperature, and furnace cooled at a controlled rate for twenty-two hours, followed by air cooling. In the heat treating process, spheroidized carbides are formed in a matrix of ferrite to produce a product having good machinability, cold heading and/or cold forming properties. After the machining, cold heading or forming operation, the balls and races are quenched in oil from about 1550° F. and then tempered to achieve a Rockwell C hardness of 60 or greater. Of course, the steel must also have good fatigue strength.

While various alloys with about .6 or .7% carbon have been proposed in the past as low-cost substitutes for AISI 52100 bearing steel, these generally result in greater difficulty in obtaining spheroidized annealed microstructures or fatigue strengths inferior to those of AISI 52100.

SUMMARY OF THE INVENTION

The present invention resides in the discovery that a high carbon bearing steel can be prepared which contain substantially less total alloy content than conventional bearing steels, without sacrificing the hardenability, fatigue strength and processing characteristics of higher alloy bearing steels. At the same time, the annealing time required to achieve adequate carbon diffusion to produce a spheroidized microstructure is materially reduced with the steel of the invention.

Specifically, it has been found that the carbon content

can be reduced somewhat in a high carbon steel, and that the chromium content can be reduced to as little as .20%, by increasing the manganese content and by adding suitable amounts of molybdenum. The steel of the invetnion contains as essential constituents, in addition to iron and carbon, manganese, molybdenum and chromium.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying single figure drawing comprising a plot showing the superior fatigue strength of the steel of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The bearing steel of the invention has the following "broad" and "preferred" compositions:

	Analysis, percent by weight	
	Broad	Preferred
Carbon	.80-1.10	.90
Manganese	.50-1.00	.50-.80
Sulfur	.005-.06	.008-.04
Silicon	.20-.35	.20-.35
Chromium	.20-.60	.25-.40
Molybdenum	.05-.25	.05-.10
Nickel	[1].35	[1].35
Iron	Balance	Balance

[1] Maximum.

Nickel and silicon are relatively unimportant in achieving the desired characteristics of the alloy and can be classified as residual amounts. .20–.35% silicon is that amount found in most alloy steels. Similarly, a certain amount of sulfur is found in every steel; however, it is desired to deliberately include .008–.04% sulfur to improve machinability and fatigue strength. As was mentioned above, carbon, manganese, chromium and molybdenum are the essential additions, the chromium and molybdenum acting to increase hardenability. In the "preferred" analysis given above, percent by weight of carbon is .90%; however it should be understood that this can vary plus or minus five points, in accordance with usual metallurgical practices.

The steel of the foregoing composition is melted, formed into tubing, forgings, rings, bars, rod, wire or other shapes, and then annealed at a maximum temperature of 1400° F. for thirteen hours in order to achieve a spheroidized microstructure comprising spheroidized carbides in a matrix of ferrite. In the annealing step, the steel is passed through eleven zones of a roller hearth furance at a constant speed, the time in each zone being about one-eleventh of the total time of thirteen hours. The temperatures of the respective zones are shown in the following Table I:

TABLE I.—ANNEALING TEMPERATURES IN ELEVEN ZONE ROLLER HEARTH FURNACE

Zone	1	2	3	4	5	6-11
Temperature, ° F	1,250	1,300	1,350	1,400	1,400	1,300

Thus, the product is heated to 1250° F., 1300° F. and 1350° F. each for about one hour and eleven minutes, followed by heating to 1400° F. for about two hours and twenty-two minutes, and finally cooled to 1300° F. for the remainder of the total of thirteen hours, followed by an air cool. The annealing time of thirteen hours at a maximum temperature of 1400° F. compares favorably with the required annealing time of twenty-two hours at a maximum temperature of 1450° F. for AISI 52100 steel. Furthermore, the shorter annealing time reduces the cost of the product and results in less scaling and less decarburization.

The annealed product is then cold headed or cold formed into balls and machined or formed into races which are thereafter heated to a temperature of 1550° F., followed by quenching in oil. In this condition, the product has a Rockwell C hardness of about 63–66. The final step in the process is to temper the product at 300° F. for about 1 to 2 hours to achieve a Rockwell C hardness of 60 or greater.

The resulting product has a density of 0.283 pound per cubic inch, a specific gravity of 7.83, a modulus of elasticity of 29×10^6 pounds per square inch and a modulus of rigidity of 12×10^6 pounds per square inch. In addition, the product has excellent fatigue strength, comparable to that of the higher alloy AISI 52100 bearing steel and much better than AISI 5160 which is sometimes used as a low-cost substitute for bearing steels. This is shown in the accompanying drawing wherein curve **10** is that for the steel of the invention; whereas curve **12** is that obtained from fatigue tests conducted on AISI 5160 steel. The steel of the invention has an L_{10} fatigue life (i.e., a probability of 10% failures, or 90% survival) after about 10 million stress cycles; whereas AISI 5160 steel has an L_{10} fatigue life after only 6.5 million stress cycles. Note that the improvement in fatigue life persists at 50% survival. Thus, the steel of the invention has an L_{50} fatigue life of 45 million stress cycles as compared with 25 million stress cycles for AISI 5160.

Typical hardenability of the steel of the invention, determined with the Jominy hardenability test, is shown in the following Table II:

TABLE II.—TYPICAL HARDENABILITY (NORMALIZE 1,650° F., ANNEAL, QUENCH 1,550° F.)

"J" distance from quenched end in) 1/16 inch	1	2	3	4	5	6	7	8	10	12
Rockwell C hardness at corresponding point	65	65	65	61	47	43	43	43	43	41

NOTE.—Minimum hardness on 0.5 inch section heated to 1,525° F.±10° for 20 minutes and oil quenched, 63.0 Rockwell C.

This compares favorably with the more expensive, conventional bearing steels.

The effect of the austenitizing temperature on the steel of the invention is shown in Table III:

TABLE III.—HEAT TREATED PROPERTIES EFFECT OF AUSTENITIZING TEMPERATURE

Austenitizing temperature (° F.)	As-quenched hardness (Rockwell C)	Hardness after 300° temper
1,450	66.0	63.5
1,475	66.6	63.5
1,500	65.0	64.0
1,525	66.0	63.5
1,550	66.0	63.5
1,575	65.0	63.0
1,600	65.0	63.5

Note that the austenitizing temperature has very little effect on the as-quenched hardness. Finally, the effect of the tempering temperature on the steel of the invention is shown in Table IV:

TABLE IV.—EFFECT OF TEMPERING TEMPERATURE (1,550° F. QUENCH)

Tempering temperature (° F.) [1]	Hardness Rockwell C after—	
	One-hour temper	Two-hour temper
200	65.0	65.0
300	64.0	63.5
400	60.5	60.0
400	58.5	58.0
600	55.5	55.5
700	52.5	52.0
800	49.0	49.0
900	45.0	45.0
1,000	40.0	39.0
1,100	36.0	35.0
1,200	32.0	30.0
1,300	26.0	24.0

[1] As-quenched hardness; 65.0 Rockwell C.

Note that in order to achieve the desired Rockwell C hardness of 60, tempering temperatures up to 400° F. may be employed. The tempering time is not particularly critical.

Although the invention has been shown in connection with certain specific examples, it will be readily apparent to those skilled in the art that various changes in composition and method steps can be made to suit requirements without departing from the spirit and scope of the invention.

I claim as my invention:

1. In the method for forming a bearing element from an alloy steel consisting essentially of .80–1.10% carbon, .50–1.00% manganese, .20–.60% chromium and .05–.25% molybdenum, the steps of: melting said alloy steel and forming it into a desired shape, annealing said alloy steel at a maximum temperature of 1400° F. for thirteen hours to produce a spheroidized microstructure comprising spheroidized carbides in a matrix of ferrite, thereafter heating said article to a temperature of about 1550° F. and quenching, and finally tempering said article at a temperature of about 300° F. to achieve a Rockwell C hardness of about at least 60.

2. The method of claim **1** wherein said steel is annealed starting at a temperature of 1250° F. which increases during said thirteen hour annealing time to 1400° F. and thereafter decreases to a low of 1300° F. during said annealing time.

References Cited

UNITED STATES PATENTS

2,105,048	1/1938	Lauenstein	148—3
2,195,402	4/1940	Baird	148—3
2,352,408	6/1944	Reece	148—3
2,370,179	2/1945	McCarroll	148—142
2,399,730	5/1946	Gagnebin	148—3
2,824,820	2/1958	Lena	148—142
3,087,842	4/1963	Borras	148—3
3,463,677	8/1969	Nakamura	148—142

HYLAND BIZOT, Primary Examiner

U.S. Cl. X.R.

148—3; 75—126