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HEAT-TREATED ZIRCONIUM STEEL AND PROCESS OF MAKING SAME.

No Drawing.

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To all whom it may concern:

Be it known that we, FREDERICK M. BECKET and ALEXANDER L. FEILD, citizens of the United States of America, residing at 565 Park Ave., and 52 East 41st Street, respectively, New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Heat-Treated Zirconium Steel and Processes of Making Same, of which the following is a specification.

This invention relates to the art of steel manufacture and comprises a process for heat-treating steel containing zirconium whereby is obtained a product possessing mechanical properties of a superior order of merit. The invention comprises also, as a novel product, a heat-treated steel, similar in composition to an ordinary carbon steel except for the presence therein of a small percentage of zirconium, (with or without small percentages of certain other alloying elements as hereinafter more fully described) yet which possesses properties hitherto obtainable only in the so-called alloy steels containing in customary amount (that is to say, the sum of the alloying elements usually upward of one per cent) one or more of the well known alloying elements such as chromium, nickel, vanadium, and molybdenum. These results are attained, in accordance with the present invention, by the heat-treatment of a steel having a zirconium content, said zirconium being incorporated in the molten steel bath during the process of manufacture. Optimum treating conditions in so far as now known are hereinafter set forth.

As is well known, it is possible by the heat-treatment of steels of the grades known as forging, tool, or spring steels to obtain products possessing a wide range of properties. Generally speaking, the higher the temperature employed to draw or temper a given quenched steel, the greater is the extent to which the initial properties of the quenched steel are altered in the direction of increased ductility and toughness, decreased hardness, and lowered tensile strength. In the manufacture of heat-treated forgings and rolled products a tempering or drawing temperature is commonly employed which results in such balancing of the various mechanical properties as appears, from practical experience and the-

oretical considerations, to be most desirable and advantageous from the standpoint of serviceability or engineering design, or both. In the automobile and air-craft industries, in particular, the properties obtainable by the employment of the various commercial alloy steels in the heat-treated state have been especially desirable, due among other things, to the obvious advantages of decreased weight and the ability of such steels to withstand severe service conditions.

We have found it possible, in accordance with the present invention, so to improve the properties of an ordinary carbon steel by the incorporation therein of a small percentage of zirconium followed by suitable heat-treatment that the resulting heat-treated product has properties much more nearly comparable to those of the more expensive heat-treated alloy steels to which reference has already been made.

The effect of zirconium, employed under conditions as specified below, is exhibited in a tendency to maintain the ductility of the steels, as indicated by per cent reduction of area, even when these are tempered under conditions to secure great hardness coupled with high strength.

The improvement brought about by zirconium is most marked when the zirconium treated steel is drawn (tempered) in the lower range of drawing temperatures, 350°—450° C. The desired effect is brought about in marked degree by the presence in the steel, for instance, of about 0.15 per cent zirconium in the case of a steel of about 0.70 per cent carbon content. As a preferred range of zirconium content we would specify from 0.04 to 0.40 per cent zirconium, although we do not consider the present invention to be restricted to any particular range of contained zirconium.

There exist a multiplicity of methods, familiar to those skilled in the art, by which the zirconium may be incorporated in the molten steel. It is preferably added to the steel (for example in the furnace or ladle), in the form of an alloy with silicon, or in the form of an alloy or aggregate containing zirconium and silicon. But our invention is not limited to the use of zirconium in conjunction with silicon, or to its introduction in the form of an alloy.

The table which follows contains under columns I and II the results of tests con-

ducted on two steels tapped from the same electric furnace heat. The steels analyzed 0.70 per cent carbon, 0.62 per cent manganese, 0.026 per cent phosphorus, and 0.03 per cent sulphur. They were identical in composition and manner of treatment except that the steel described under column I contained 0.15% zirconium, incorporated in the molten steel in the form of an alloy of iron, silicon and zirconium, (ferrosilicon-zirconium). Columns I and II contain the results obtained by drawing, at five different temperatures, the steels previously quenched in water from 825° C. The zirconium-treated and the untreated steels were, for each temperature of draw, heat-treated simultaneously and with every precaution to secure uniformity of practice to the end that the test data might be strictly comparable.

TABLE

	0.70% carbon 0.15% zirconium	0.70% carbon without zirconium	S. A. E. 3450. (Nickel- chromium)
	I	II	III
Drawing temperature.....	375° C.	375° C.	
Per cent elongation.....	8.3	5.2	
Per cent reduction of area.....	23.3	6.6	
Yield point, lbs. sq. in.....	185,952	128,125	
Ultimate strength, lbs. sq. in.....	227,203	197,800	
Izod number, ft.-lbs.....	7.5	7.5	
Brinell hardness.....	414	433	
Drawing temperature.....	412° C.	412° C.	427° C.
Per cent elongation.....	12.7	7.5	12.5
Per cent reduction of area.....	45.8	22.9	51.0
Yield point, lbs. sq. in.....	172,620	180,180	175,000
Ultimate strength, lbs. sq. in.....	198,828	207,144	200,000
Izod number, ft.-lbs.....	14.8	10.5	
Brinell hardness.....	407	418	
Drawing temperature.....	440° C.	440° C.	440° C.
Per cent elongation.....	13.0	8.5	13.0
Per cent reduction of area.....	48.0	30.0	51.0
Yield point, lbs. sq. in.....	160,100	171,935	171,000
Ultimate strength, lbs. sq. in.....	183,700	197,512	195,000
Izod number, ft.-lbs.....	14.7	13.1	
Brinell hardness.....	388	387	
Drawing temperature.....	540° C.	540° C.	540° C.
Per cent elongation.....	18.0	14.7	17.0
Per cent reduction of area.....	48.2	39.4	55.0
Yield point, lbs. sq. in.....	122,220	128,890	138,500
Ultimate strength, lbs. sq. in.....	140,704	147,007	156,000
Izod number, ft.-lbs.....	29.0	35.5	
Brinell number.....	288	298	
Drawing temperature.....	600° C.	600° C.	600° C.
Per cent elongation.....	21.2	19.6	19.0
Per cent reduction of area.....	54.7	51.2	58.5
Yield point, lbs. sq. in.....	105,632	110,164	118,000
Ultimate strength, lbs. sq. in.....	125,085	127,683	137,000
Izod number, ft.-lbs.....	35.6	42.6	
Brinell number.....	233	238	

The Izod numbers given under columns I and II were obtained by tests conducted with a 120 ft.-lb. Izod machine, using a test-piece of 10 by 10 mm. cross-section, a 2-mm. 45° notch with 0.01 inch radius at the bottom, and a striking distance of 0.866 inches. The notch was cut after the test pieces were heat-treated.

It will be apparent to those familiar with this art that the properties of the zirconium-treated steel, as given in column I, closely approach those of certain alloy steels. For convenience of comparison we have given in

column III the values (so far as available) for a nickel-chromium steel used for such heat-treated parts as require exceptionally high physical properties and must be capable of resisting severe dynamic stresses in service. The steel in question (known as S. A. E. steel 3450) contains carbon 0.45-0.55; nickel 2.75-3.75; and chromium 0.60-0.95. The values in the table were read from curves in S. A. E. handbook, Vol. I, page D-65.

The Izod numbers for the steel of column III are not available. It is, however, certainly true that the zirconium-treated steel above described has a value for notch-toughness (Izod number) which falls not far below that of a nickel-vanadium or chrome-vanadium steel tempered to produce approximately the same ultimate strength and ductility.

We have also conducted comparative experiments on heat-treated carbon steels containing both more and less than 0.70 per cent of carbon, with and without a zirconium content, and have found beneficial effects due to zirconium similar to those above described. We conclude therefore that our discovery is applicable broadly to the heat-treatment of carbon steels containing zirconium.

The most notable improvement brought about by zirconium occurs, as can be seen, in that range of drawing temperatures associated with the formation of troostite in the finished product, 350°-450° C.

An advantageous manner of practicing the invention is to draw (temper) the steel in a furnace, for example of the electric muffle type, in such manner that the heat-treated parts are brought up to the temperature of the furnace by radiation from the walls, and thereafter allowed to remain at this temperature for an appreciable period, say 15 minutes for a standard test piece; then remove and allow to cool in air. Such treatment has given decidedly better results both in the zirconium-treated and the untreated (control) steel than a 15-minute draw in a lead bath at corresponding temperatures. Evidently the rate of heating during the draw, or the time of draw, or both, have an important effect upon the transformations occurring in the steel. Just what is the exact optimum procedure, however, is a question which must be determined for each kind and grade of steel by means of a simple series of tests of the character usually applied for this purpose.

The structural changes occurring in quenched steels during the tempering process are not yet fully understood. In the present state of knowledge relating to this subject it is difficult to account for the effect of small percentages of zirconium upon heat-treated carbon steels. We are inclined

to believe, however, without thereby limiting our invention, that the explanation eventually will be found to lie in the influence of zirconium in promoting transformation of martensite into troostite over a lower or narrower range of temperature than is possible in steel not containing zirconium, and probably before the appearance of an appreciable amount of sorbite.

There are a large number of chemical elements which if present in steels in sufficient quantity, either singly or in combination, give rise to compositions which are technically known as alloy steels. It will be understood that steels as produced industrially are rarely if ever entirely free from all these elements. Certain of the alloying elements, for example silicon and manganese, are normal constituents of carbon steels as now made, but the quantities present in such carbon steels are insufficient to produce the characteristic alloy steels of these elements. Most or all of the other alloying elements are at times present in small quantities in steels which are nevertheless universally designated as carbon steels. In many cases such elements are introduced fortuitously, it being impracticable to exclude them completely from the raw materials, including steel scrap, which make up the furnace charge.

We regard as within the scope of our invention all heat-treated steels containing zirconium and containing other alloying elements in less than their normal alloying proportions when such steels are characterized by substantially higher ductility than is characteristic of zirconium-free steels of comparable composition, strength, and hardness; and we make no exception to the foregoing when the alloying element or elements (other than zirconium) are intentionally added to produce a special effect.

We claim:

1. A heat-treated carbon steel containing zirconium and characterized by substantially higher ductility as indicated by per cent reduction of area than is characteristic

of zirconium-free steels of comparable strength and hardness.

2. A heat-treated carbon steel containing 0.04 to 0.40 per cent zirconium and characterized by substantially higher ductility as indicated by per cent reduction of area than is characteristic of zirconium-free steels of comparable strength and hardness.

3. Heat-treated steel containing zirconium in association with an alloying element or elements, the latter in less than normal alloying proportion.

4. Heat-treated steel containing 0.04 to 0.40 per cent zirconium in association with an alloying element or elements, the latter in less than normal alloying proportion.

5. The herein described process comprising introducing zirconium into a carbon steel, and heat-treating the product, whereby it acquires a substantially higher ductility as indicated by per cent reduction of area than is characteristic of zirconium-free carbon steels of comparable strength and hardness.

6. The herein described process comprising introducing 0.04 to 0.40 per cent zirconium into a carbon steel, and heat-treating the product, whereby it acquires a substantially higher ductility as indicated by per cent reduction of area than is characteristic of zirconium-free carbon steels of comparable strength and hardness.

7. The herein described process comprising introducing into a steel zirconium and an alloying element or elements, the latter in less than normal alloying proportion, and heat-treating the product.

8. The herein described process comprising introducing into a steel 0.04 to 0.40 per cent zirconium and an alloying element or elements, the latter in less than normal alloying proportion, and heat-treating the product.

In testimony whereof, we affix our signatures.

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