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METHOD OF THERMOMECHANICALLY ANNEALING STEEL

Raymond A. Grange, Washington Township, Westmoreland County, Pa., assignor to United States Steel Corporation, a corporation of Delaware

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This invention relates to a method of thermomechanically annealing steel. More particularly, the invention relates to method of processing medium carbon alloy steels and high carbon steels which are initially in the hot worked condition before machining.

Medium carbon alloy steels and high carbon steels are often annealed after hot working and before machining, cold working or final heat treatment. The intermediate annealing step is practiced because in the hot rolled or normalized condition, such steels are too hard to machine or cold form satisfactorily. Moreover, the proeutectoid carbide network in very high carbon steels must be eliminated by suitable annealing prior to the final hardening heat treatment in order to avoid a brittle condition in the product. Carbon and low alloy hypereutectoid steels are commonly annealed merely by slow cooling after partial or complete austenitization. However, it is not usually satisfactory to perform this relatively simple annealing for hypereutectoid steels or for certain high alloy steels. For such compositions, a prolonged spheroidized annealing treatment is required. Because of the long duration of spheroidize annealing treatment, the process is costly and technologically undesirable since it increases the production time required. It has been discovered that a large time saving may be possible if the mechanical working is combined in a critical manner with thermal treatment.

The present invention involves a method of treating steels which involves drastic deformation (i.e. mechanical working) over a range of temperature beginning not more than 150° F. above and finishing slightly below the A_1 temperature, i.e. less than 50° F. below the A_1 temperature. The total reduction in cross section is in excess of 50% and if the deformation temperature is within the above specified range, the necessary reduction can be accomplished in a series of steps. Thus, mechanical working can be performed as the temperature falls progressively in this temperature range or by a cyclical series of heating-deformation-air cooling steps with the deformation temperature reduced in each step. It is not necessary to heat steel before each step longer than required for temperature uniformity. Thus, the thermomechanical annealing process may be carried out within minutes in contrast to the several-day period usually required for satisfactory spheroidization by a conventional thermal anneal. The thermomechanically annealed product, although somewhat harder than thermally spheroidized steel, is nonetheless sufficiently ductile to permit machining or cold forming and its microstructure is suitable for subsequent hardening by heat treating. Thermomechanical annealing in accordance with the invention also has advantages over thermal spheroidization in that it avoids formation of graphite which sometimes occurs particularly in very high carbon steels during thermal annealing. Certain alloy steels which are extremely difficult to thermally anneal can be softened sufficiently to permit working and cold forming in the above described thermomechanical annealing process.

During mechanical working, the proeutectoid carbide in the steel fragments or breaks up. This fragmentation will occur when mechanically worked at ambient temperature as well as at elevated temperature. However, gross cracking of the steel may be avoided by performing

the initial stages of mechanical working at a temperature above the A_1 temperature of the steel. Also, mechanical working greatly accelerates the coalescence of carbides into spheroids at elevated temperature. However, it is necessary to conduct the final deformation below the A_1 temperature to avoid a nonuniform microstructure in the product.

The thermomechanical process in accordance with the invention is particularly well suited for the treatment of high carbon steel of the type used for razor blades and cutlery. The following example of a steel of this type will aid in understanding the invention.

A strip of steel consisting essentially of 1.26% carbon, 0.36% manganese, 0.008% phosphorus, 0.025% sulfur, 0.18% silicon and 0.25% chromium was hot rolled to 0.32-inch thickness after first heating to 1450° F. This temperature was 125° F. above the steel's A_1 temperature. It was rolled using a series of six roll passes, each at a successively lower temperature, so as to finish at slightly below the A_1 temperature of the steel. The steps in the heating-rolling sequence are shown in the table.

	Heating		
	Temp., ° F.	Time, min.	Thickness, in.
Pass:			
1	1,450	1	0.23
2	1,425	1	0.20
3	1,400	1	0.16
4	1,375	1	0.12
5	1,350	1	0.095
6	1,325	1	0.07

Before each rolling pass was performed, the steel was heated in a lead bath of controlled temperature after which it was allowed to cool naturally to obtain the above cyclical sequence of reducing temperatures. The strip was air cooled after each pass and with allowance for air cooling time and the entire annealing treatment was performed in about 30 minutes. Upon completion of the thermomechanical annealing, the steel had a microstructure of uniformly dispersed spheroidal carbides in a ferrite matrix. The hardness was determined to be 285 DPH (diamond pyramid hardness) and the steel machined with comparative ease.

After the cyclical heat treatment, the steel was rolled at room temperature to strips 0.017-inch thick without difficulty, thus demonstrating its satisfactory cold formability. The microstructure also indicated improved formability by the absence of any vestige of carbide network or carbide lamellae. Moreover, the microstructure of the steel was satisfactory for subsequent hardening heat treatments since it contained the desired uniform dispersion of spheroidal carbides in a ferrite matrix.

It is apparent from the above that various changes and modifications may be made without departing from the invention. Thus, the above described thermomechanical technique is capable of annealing a wide variety of steel compositions. The processing saves a considerable amount of time over the conventional processing of high carbon steels and can be used to anneal certain alloy steels, especially those high in alloy content, which cannot be satisfactorily annealed by thermal treatment. Although the aforementioned example is described in connection with the flat rolling of strip, it is obvious that other methods of mechanical working could be employed. Similarly, a variety of suitable heating methods may be used other than the specific example described herein.

I claim:

1. A method of thermomechanically treating steels to provide a product having a spheroidized microstructure, good cold formability and satisfactory ductility, which is particularly suitable for hypereutectoid and alloy steels comprising drastically deforming said steel over a tem-

perature range beginning above the A_1 temperature but not more than 150° F. above the A_1 temperature and finishing at a temperature below the A_1 temperature but not more than 50° F. below the A_1 temperature of said steel to a total reduction in area of more than 50 percent.

2. A method according to claim 1 wherein said drastic deformation is performed as the temperature falls progressively through said range.

3. A method according to claim 1 wherein said drastic deformation is performed by a cyclical series of (a) heating, (b) deformation, and (c) air cooling steps with the deformation temperature lower in each succeeding step.

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L. DEWAYNE RUTLEDGE, Primary Examiner

W. W. STALLARD, Assistant Examiner