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STEEL, AND METHOD OF IMPROVING THE CREEP STRENGTH THEREOF

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This invention is specifically concerned with improving the creep strength of molybdenum containing low and medium alloy ferritic steel of the type designed for elevated temperature service. The present application is a continuation in part of a copending application bearing Serial No. 254,128, which was filed February 1, 1939.

The exact analyses of steels with which this invention is concerned need not be specifically advanced, since they are well known. However, those unfamiliar with such steels may refer to pages 975 through 982 of "The making, shaping and treating of steel," fifth edition, published by the Carnegie-Illinois Steel Corporation. It is to be understood that the present invention is not concerned with the high alloy steels such as those in the austenitic stainless series.

The present invention is based on the discovery that when a molybdenum containing low and medium alloy ferritic steel of the type designed for elevated temperature service is heated to above its omega solubility temperature and then cooled at a rate preventing visible omega precipitation, its creep strength can be adjusted to an optimum value by reheating the steel to a temperature below its omega solubility temperature and above the service operating temperature of the steel, and holding the steel at this second-named temperature for a time producing a faintly visible but indistinct omega precipitation, the steel then being cooled to prevent further omega precipitation.

The omega phase results from the molybdenum content of the steel and is believed to be an iron-carbon-molybdenum or an iron-molybdenum compound. It represents the steel's third phase, its other phases being the ferrite and cementite. It has the characteristic of being completely soluble in austenite, but soluble in ferrite only to a limited degree. This solubility in ferrite appears to decrease with decrease of temperature. The omega phase diffuses and agglomerates very slowly in ferrite—much more slowly than does iron carbide. This diffusion may occur as a result of the migration of individual atoms, rather than by movement of whole molecules of the compound.

The omega solubility temperature for all the steels has not yet been ascertained, but it is known that it is exceeded when any of the steels are heated to fully austenitic condition. While air cooling generally provides a sufficiently fast cooling rate to prevent visible omega precipitation, microscopic examinations will definitely determine whether the rate chosen is sufficiently fast. The reheating temperature must be above the temperature at which the steel is to operate when it is is placed in service, but it must not be so high that omega precipitation cannot occur. The holding time of the temperature chosen depends on the temperature and on the exact composition of the steel, since these determine the omega diffusing rate, but in practical work the steel can be heated progressively longer time periods, cooled and microscopically examined, to determine what time period results in precipitation of the omega phase to an extent that is faintly visible but cannot be said to be a distinct precipitation. It is difficult to describe exactly the appearance of the precipitate providing the maximum creep strength, but creep strength tests may be used to determine the holding time providing the optimum creep strength.

As a specific example of the invention, a carbon-molybdenum steel of the type described, and which contained up to .20% carbon and about .50% molybdenum, was heated to 1650° F. when it became entirely austenitic. Air cooling served to prevent visible omega precipitation and the steel was then subsequently reheated to about 1300° F., which is below the lower critical temperature of the steel but is above the temperature at which this steel operates in service. The holding time necessary at 1300° F. was five hours, this producing an omega precipitation that was just barely detectable by microscopic examination. Creep strength tests showed that this five-hour period produced the optimum creep strength.

The creep strength of this steel after normalizing alone, or after normalizing and drawing in the conventional manner, was definitely inferior to the creep strength obtained by holding the temperature of the steel at 1300° F. for five hours. Microscopic examination failed to reveal any trace of the omega precipitate after normalizing, or after drawing at 1200° F. in the conventional manner, or, in fact, even when the steel was held at 1200° F. for five hours. Prolongation of the 1300° F. holding period beyond the five hours produced quite a pronounced precipitate and an incidental lowering in the creep strength. It appears that there is an optimum omega particle size necessary if maximum creep resistance is to be obtained and that the time and temperature of the treatment must be correlated to produce this end.

The precipitate produced by this treatment proved to be stable at operating temperatures as high as 1100° F., at which temperatures a speci-

men of the carbon-molybdenum steel, subjected to the described heat treatment, maintained a linear creep rate for 14,000 hours, at which time the test was stopped. Microscopic examination failed to reveal any change in the particle size of the omega precipitate.

It was formerly common to normalize steels of the type to which this invention relates, and to subsequently temper or draw the steel at temperatures higher than the service operating temperature of the steel. This was done, however, solely to adjust the physical properties of the steel and with no thought of increasing its creep strength, due to the lack of any appreciation of the principles of the present invention. These prior art treatments could only accidentally result in a precipitate of the character produced in the case of the present invention. As a matter of fact, in no instance of this tempering or drawing, whether performed for the purpose of adjusting the mechanical properties, or to stabilize the iron carbide, were those skilled in the art cognizant of the fact that such reheating involved the precipitation of a third phase. In most instances, these prior art treatments resulted in a decrease in the creep strength of the steel, whereas it has been shown the adjustment of the temperature and holding time taught by the present invention provides the steel with its maximum creep strength.

In its broader form, this invention is applicable to any steel of the type described which has a composition resulting in a slowly diffusing third phase that is soluble in austenite and which is substantially insoluble in ferrite. This phase is possible in the case of such steels which contain tungsten, columbium, titanium, etc., with, of course, the carbon usual to its type. However, the invention is most applicable to molybdenum containing steels of the type in question, since the greatest creep strength is then obtained.

I claim:

1. A method of improving the creep strength of molybdenum containing low and medium alloy ferritic steel of the type designed for elevated temperature service, said method comprising heating said steel above its omega solubility temperature, cooling said steel at a rate preventing visible omega precipitation, reheating said steel to a temperature below said solubility temperature and above the service operating temperature of said steel, holding said steel at the second-named temperature for a time producing a faintly visible but indistinct omega precipitation and then cooling said steel.

2. A method of improving the creep strength of molybdenum containing low and medium alloy ferritic steel of the type designed for elevated temperature service and containing up to .20% carbon, from .40% to 2.00% molybdenum and being otherwise of a composition suitable for said type; said method comprising heating said steel to completely dissolve its phase resulting from its molybdenum content, cooling said steel at a rate preventing visible precipitation of said phase, reheating said steel to a temperature effecting precipitation of said phase and which is higher than the service operating temperature of said steel, holding said steel at the second-named temperature to obtain a faintly visible but indistinct precipitation of said phase and then cooling said steel.

3. A method of improving the creep strength of molybdenum containing low and medium alloy ferritic steel of the type designed for elevated temperature service and containing up to .20% carbon, from .40% to 2.00% molybdenum and being otherwise of a composition suitable for said type; said method comprising heating said steel to completely dissolve its phase resulting from its molybdenum content, cooling said steel at a rate preventing visible precipitation of said phase, reheating said steel to a temperature effecting precipitation of said phase and which is higher than the service operating temperature of said steel, holding said steel at the second-named temperature for a time effecting precipitation of said phase to a degree providing the optimum creep strength at said service operating temperature and then cooling said steel.

4. A molybdenum containing low and medium alloy ferritic steel having a composition typical of the type designed for elevated temperature service and characterized by a structure including a faintly visible but not clearly distinct precipitation of the phase resulting from its molybdenum content.

5. A low and medium alloy steel of the type designed for elevated temperature service and including an alloy of the class consisting of molybdenum, tungsten, columbium, and titanium, and characterized by a structure including a faintly visible but not clearly distinct precipitation of the phase resulting from its content of said class of alloy.

6. A method of improving the creep strength of low and medium alloy ferritic steel of the type designed for elevated temperature service and including an alloy of the class consisting of molybdenum, tungsten, columbium, and titanium, said method comprising heating said steel above its solubility temperature for the phase resulting from its content of said class of alloy, cooling said steel at a rate preventing visible precipitation of said phase, reheating said steel to a temperature below said solubility temperature and above the service operating temperature of said steel, and holding said steel at the second named temperature for a time producing a faintly visible but indistinct precipitation of said phase.

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