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STEEL HAVING A HIGH RESISTANCE TO CREEP

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The present invention relates to steel and more particularly to steel which is subjected to creep stress at elevated temperatures.

In steam turbine construction, in order to maintain economy of design, it is desirable that the materials employed be of high strength, and it is imperative that when a certain material is utilized it always should have the strength expected of it without exception. A material with a nominal creep strength of 30,000 pounds per sq. in. to produce a creep rate of 1 per cent per 100,000 hours at a temperature of 450° C. must always be able to stand such a stress and not prove satisfactory in one application and unsatisfactory in another. Prior to the present invention various means have been employed in attempts to reduce or eliminate creep and to consistently produce steel having a high creep value. Various alloys and heat treatments have been employed to accomplish this end but so far as the present applicant is aware none of these have been successful.

Applicant has made a great number of tests for creep strength of various pieces of material. In all of these tests the material was first subjected to sufficient stress, for example 40,000 lbs. per square inch to produce an elongation of 0.1% in two or three days. The load was then successively stepped down to that load which would give a creep rate of 1% per 100,000 hours, this stress then being the nominal creep strength of the steel for that rate and total strain. An analysis of these tests shows that chemical composition is not the determining factor in creep since great variations in creep strength may be obtained in metals of similar composition. These tests also show that variations in creep strength generally are not due to heat treatment. It has been found for example that a steel may have practically the same creep strength when annealed as when heat treated. On the other hand, some steels when annealed are superior to the heat treated steel, whereas with other steels the heat treated material is better than the annealed.

I have discovered that if steel is substantially free from banding or dendritic segregation, it always has a high resistance to creep at elevated temperatures and that the degree of banding or dendritic segregation in steels is in direct ratio to their creep properties in the annealed state. I have also found that with material having no banding or dendritic segregation there is practically no difference in creep strength due to the form of heat treatment, whereas with a moderate degree of banding the heat treatment may or may not increase the creep strength and that in cases of severe banding heat treatment usually is advantageous.

To have a material of high creep strength it is desirable that the material should be substantially uniform in its metallographic structure and substantially free from banding or dendritic segregation. Freedom from banding may be effected by forging but such treatment is not always practical since many tests have shown that a forging reduction of 10 to 1 in diameter is necessary to produce a structure which is substantially uniform and which has acceptable creep strength. However, in certain cases, a reduction of as much as 20 to 1 may be required to produce satisfactory results. When the great size of some turbine forgings is considered, it will be realized that a reduction of 20 or even 10 to 1 would demand an extremely large size ingot and would be entirely impractical especially when it is considered that dendritic segregation increases with increased ingot size.

More efficient methods than forging for producing a uniform steel substantially free from banding or dendritic segregation have been discovered, one of which is disclosed in the copending application of Gerald Brophy, Serial No. 12,261, filed March 21, 1935. In the process disclosed in the Brophy application, banding or dendritic segregation is substantially reduced or eliminated by pouring molten metal into a hot mold while the metal is at a temperature slightly above its freezing point.

The formation of dendrites from metal in the process of solidification in a mold is a problem in heat control. For example, the process of the formation of crystallite solid from a freezing melt is a function of the rate of cooling. The solid grains grow from tiny nuclei, groups of atoms which, under proper conditions, orientate themselves to form the nucleus of the grain or crystallite into which they grow. Furthermore, the relationship between cooling rates and nuclei formation are not straight line functions but on the contrary under definite conditions there is a pronounced maximum in the nuclei formation rate. When this is considered together with the fact that the objectionable banded structure is caused by a condition of cooling where a few large dendrites grow so large that a normal amount of forging cannot eliminate them, it is clear that the condition most advantageous to the attainment of a uniform structure is that in which as many nuclei as possible are formed simultaneously. This condition results in a min-

imum dendrite size In the process disclosed in the Brophy application, the molten metal is cooled at a controlled rate so as to give this maximum nuclei formation and minimum dendrite size.

The elimination of banding or dendritic segregation in any steel results in a product which is very resistant to creep at elevated temperatures. Particularly satisfactory results have been obtained with a steel containing about 0.30% carbon, about 0.6% molybdenum, about 2.5% nickel and about 0.8% chromium. Such a steel when substantially free from banding or dendritic segregation is capable of resisting stresses in excess of 35,000 lbs. per square inch at 450° C. for long periods of time without excessive strain. For instance, after 2000 hours at 450° C. and under a stress of 38,600 lbs. per square inch, a test bar of the above composition showed a total permanent elongation of but 0.00034 inch per inch with a rate of extension of about 1% in 100,000 hours.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A steel subject to continued creep stress at elevated temperatures, said steel being substantially free from banding or dendritic segregation.

2. A turbine element subject to continued creep stress at elevated temperatures, said element consisting of steel substantially free from banding or dendritic segregation.

3. A steel subject to continued creep stress at elevated temperatures, said steel containing about 0.30% carbon, about 0.6% molybdenum, about 2.5% nickel, about 0.8% chromium, with the remainder substantially iron said steel being substantially free from banding or dendritic segregation.

4. A steel subject to continued stress at elevated temperatures, said steel being substantially free from banding or dendritic segregation, said steel being capable of resisting stress in excess of 35,000 lbs. per square inch at 450° C. for long periods of time without excessive strain.

5. A turbine element subject to continued creep stress at elevated temperatures, said element consisting of steel substantially free from banding or dendritic segregation, said steel being capable of resisting stress in excess of 35,000 lbs. per square inch at 450° C. for long periods of time without excessive strain.

6. A steel subject to continued creep stress at elevated temperatures, said steel containing about 0.30% carbon, about 0.6% molybdenum, about 2.5% nickel, and about 0.8% chromium with the remainder substantially iron, said steel being substantially free from banding or dendritic segregation, said steel being capable of resisting stress in excess of 35,000 lbs. per square inch at 450° C. for long periods of time without excessive strain.

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