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METHOD FOR INCREASING THE TEMPERATURE OF THE BEGINNING RECRYSTALLIZATION OF METALS AND ALLOYS

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Fig. 1

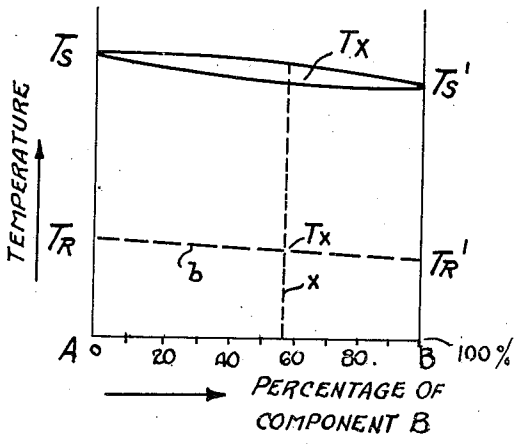
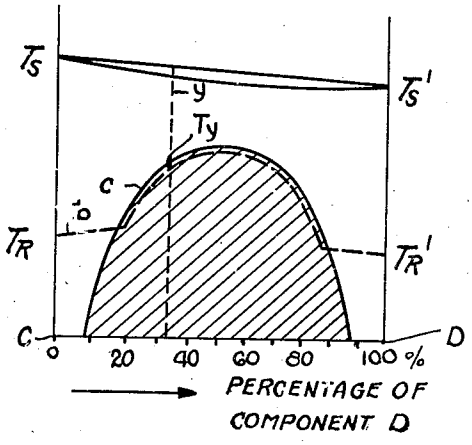


Fig. 2



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METHOD FOR INCREASING THE TEMPERATURE OF THE BEGINNING RECRYSTALLIZATION OF METALS AND ALLOYS

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3 Claims. (Cl. 75—122)

This invention relates to alloys of increased heat resistance, in particular as regards mechanical and magnetical hardness, and to methods for producing and treating such alloys. According to the invention, an increased resistance against the softening influence of elevated operating temperatures is obtained by methods and means which raise the temperature of beginning recrystallization of the metal or alloy.

By recrystallization is understood a crystallization in the solid state of a metal and alloy which takes place at elevated temperatures and causes a regeneration of deformed grains. The recrystallization phenomenon is of considerable practical importance because it is the cause of or accompanied with changes in the mechanical and magnetical properties of the material. In particular, with the beginning of the recrystallization, a mechanical softening commences as well as a magnetic softening in the case of ferromagnetic materials. It is in many cases desirable to retard the beginning of the mechanical or magnetic softening until the highest possible temperature is attained, since in many apparatus, machines or devices great mechanical or magnetic hardness is required at relatively high operating temperatures.

The temperatures of the beginning recrystallization are approximately one third to one fourth lower than the fusing temperature. In the so-called recrystallization diagrams, the temperatures are shown as being dependent upon the degree of deformation. However, the available knowledge of the phenomena of recrystallization has not been sufficient to convey an exact idea of the influence of admixtures upon the recrystallization of metals or alloys.

The invention is based on the discovery experimentally obtained that the phenomena of recrystallization of metals and alloys are defined by the period required to form the grains as well as by the velocity with which the size of the grains increases. By this period is understood the mean period necessary to regenerate the grains by recrystallization at a given temperature, while the velocity is determined by the mean distance traversed in the unity of time by the boundaries of the grains during the crystallization. The "temperature of the beginning recrystallization" is therefore the temperature at which, for instance, a radiographically detectable regeneration of grain has taken place after a given duration of test in a material deformed in a certain manner.

In order to raise this temperature required for the beginning recrystallization the invention proceeds as follows. To a base consisting substantially of a single metal or of an alloy of completely miscible metals forming homogeneous mixed crystals in any mutual proportion, is added a substance which is incompletely soluble in the base metal or alloy and thus forms with the starting substance a miscibility gap. The auxiliary substance may consist of a metal or an alloy.

For explaining the invention, two binary systems are hereinafter discussed with reference to the drawing in which Figs. 1 and 2 are diagrams showing schematically the fusing temperatures (Ts) and the temperatures of beginning crystallization (T_R) in dependence upon the composition of an alloy of two components A, B, and C, D respectively, the percentages of the components being indicated along the base line of the diagram. In Fig. 1, for instance point Ts represents the melting temperature and T_R the temperature of beginning recrystallization of a metal consisting to 100% of component A, while Ts' and T_R' indicate the corresponding temperatures of component B. Line X in Fig. 1 exemplifies an alloy composed of 60% A and 40% B, t_x indicating the fusing interval and T_X the temperature of beginning recrystallization of this alloy. In Fig. 1 the two components A and B, whose fusing points Ts and Ts' do not appreciably differ from each other, are completely miscible, i. e. capable of being mixed in any proportion with each other. The temperature of the beginning recrystallization indicated by line *b* is in this case almost independent of the composition of the alloy. The reversible Fe-Ni alloys, Cu-Ni and other mixed crystal alloys are representatives of such alloy systems.

In contrast thereto, Fig. 2 shows a binary alloy system whose two components C and D are of limited solubility relative to each other so that they form a miscibility gap. This gap is indicated in Fig. 2 by the shaded area enclosed by curve *c* and the base line. The solubility limit represented by curve *c* depends upon the ratio of the two components C and D as well as on the temperature of the composition. In such an alloy, the temperature of beginning recrystallization, indicated by curve *b*, depends considerably on the percentile composition, and it is an essential point in connection with the present invention that this dependency is similar to the dependence of the solubility limit (curve *c*) on the percentile composition. In other words, the curve *b* representing the relationship between the temperature of the beginning recrystallization

and the composition of the alloy coincides practically with the solubility limit c within a considerable range of composition. Representatives of such an alloy type are, for instance, Al-Mg, Fe-Cu, and similar systems.

In cases as exemplified by Fig. 2, a small amount of component D added to C, or a small amount of C added to D, which is still fully soluble according to the diagram, i. e. outside the shaded area, produces but a slight increase in the temperature of the beginning recrystallization. If, however, so much substance is added that the solubility limit is exceeded so that the composition lies within the shaded area the temperature of the beginning recrystallization increases considerably. The alloy represented by line *y*, for instance, begins to recrystallize at a temperature T_Y considerably above the corresponding temperature values T_R and T_R' of the alloying components.

It is understood that the method according to the invention is not limited to binary systems but may generally be applied to any alloy consisting of a plurality of substances. As an example of such an alloy the ternary system Fe-Ni-Cu is hereinafter dealt with more specifically. The ternary Fe-Ni-Cu system may be regarded as a composition of a base alloy of the completely miscible components Fe and Ni with an addition of Cu forming a miscibility gap with the Fe-Ni base. The following table indicates various Cu percentages of alloys in which the remainder consists substantially of Fe and Ni in a proportion of 60 to 40. In other words, the copper has been added to a base alloy containing about 60% Fe and about 40% Ni. The specimens tested were manufactured by rolling the cast alloy with a total reduction in thickness of 99%. The finished specimens were heated to the temperatures and for the periods indicated in the tables, and the beginning recrystallization and the recrystallization periods were determined by examining the grains of the material.

I	II	III	IV	V
No.	Base alloy (remainder)	Cu contents	Recrystallization period at 500° C.	Temperature of beginning recrystallization
		Percent	*Hours*	°C.
1	Fe+Ni in the proportion 60 to 40	0	3	490
2		1.0	4	495
3		2.7	18	500
4		6.0	Over 1000	580
5		8.1	Over 1000	710
6		10.8	Over 1000	790
7		13.1	Over 1000	835

Column IV of the table indicates a considerable increase in the time required for a recrystallization of the grains, this increase being particularly effective between 2.7% Cu and 6% Cu. The temperature of 500° C. is exceeded in many electrical and other apparatus during their normal operation. Articles of Fe-Ni alloys forming part of such apparatus therefore are magnetically and mechanically resistant to operating temperatures of such or similar magnitude if they contain an addition of for instance 6% copper. Column V indicates more exactly the minimum temperature at which the recrystallization begins with different Cu percentages. The increase of this temperature is also especially noticeable between 2.7 and 6% copper. The invention thus renders it possible to advantageously employ Fe-Ni alloys, or other metals and alloys of the type above explained, in cases for which they were believed unsuitable because of an insufficient stability of their properties at elevated temperatures.

What is claimed is:

1. A ferromagnetic article which in normal use is subjected to an elevated temperature of at least about 500° centigrade and adapted to remain magnetic at said elevated temperature, consisting substantially of a base alloy of iron and nickel containing more iron than nickel and having a temperature of beginning recrystallization below 500° centigrade, and an addition of copper in a percentage within the miscibility gap of copper and said base alloy, said percentage being at least about 6% and sufficient to raise the temperature of beginning recrystallization substantially above 500° centigrade.

2. An article of manufacture which in normal use is subjected to an operating temperature of at least about 500° centigrade and adapted to maintain hardness or magnetism at said operating temperature, consisting substantially of a base alloy of completely miscible components of the iron group, said alloy containing iron as the predominant ingredient and nickel and having a temperature of beginning recrystallization below said operating temperature, and an addition consisting of copper incompletely miscible with said base alloy so as to form a miscibility gap therewith, said addition having a percentage lying within said miscibility gap, whereby the temperature of beginning recrystallization is raised substantially above said operating temperature.

3. A heat-resistant article which in normal operation is subjected to operating temperatures above 500° centigrade, consisting substantially of a base substance selected from the group consisting of the individual metals and metal alloys of completely miscible components, said base substance having a temperature of beginning recrystallization below said operating temperature, and an addition of metal incompletely miscible with said base substance so as to form a miscibility gap, said addition having a percentage lying in said miscibility gap, and characterized by having the temperature of beginning recrystallization increased above said operating temperature due to said addition.

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