United States Patent [19]

Sahm et al.

[11] **3,891,431**

[45] **June 24, 1975**

[54] **METHOD OF, AND APPARATUS FOR, CONTROLLING THE CRYSTALLINE STRUCTURE OF ALLOYS, AND ALLOYS SO PRODUCED**

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[22] Filed: **Apr. 17, 1972**

[21] Appl. No.: **244,652**

[30] **Foreign Application Priority Data**

May 10, 1971 Switzerland 6882/71

[52] **U.S. Cl.** .... **75/122;** 75/130.5; 75/135; 75/171; 75/65 ZM

[51] **Int. Cl.**.... **C22c 19/00;** C22c 33/00; C22c 1/00

[58] **Field of Search** ..... 75/65 ZM, 171, 122, 130.5, 75/135; 148/13 R, 125

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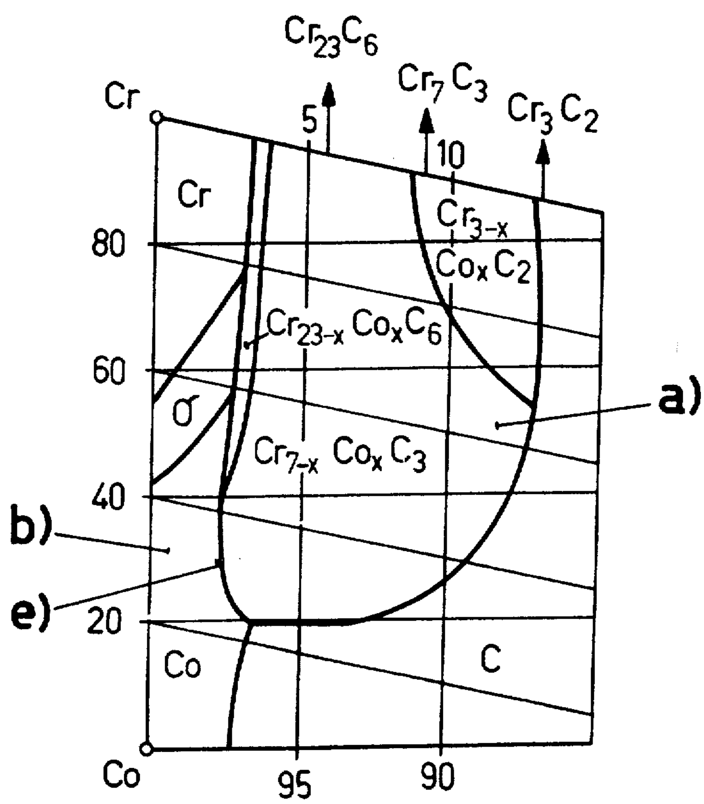
[57] **ABSTRACT**

The crystalline structure of an alloy having a structure which is at least partially eutectic is controllable by heat-treatment, by forming in a body of the alloy a zone of high temperature gradient between a melting region and an adjacent solidification region. The rate of progress of said high temperature gradient over the body may be controlled whereby to influence a predetermined crystallization in the matrix of the eutectic.

3 Claims, 5 Drawing Figures



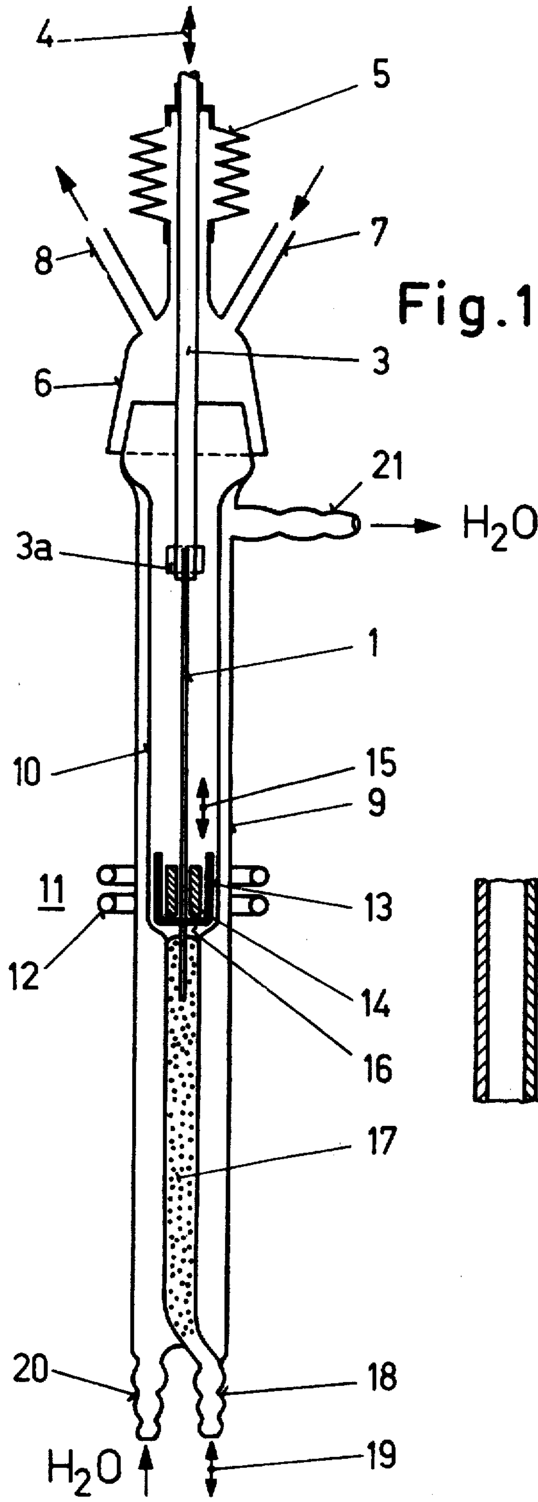


Fig. 1

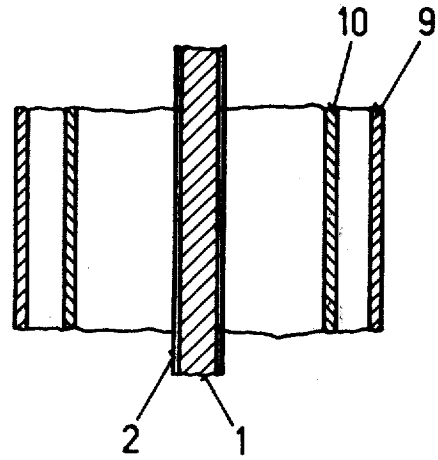


Fig. 2

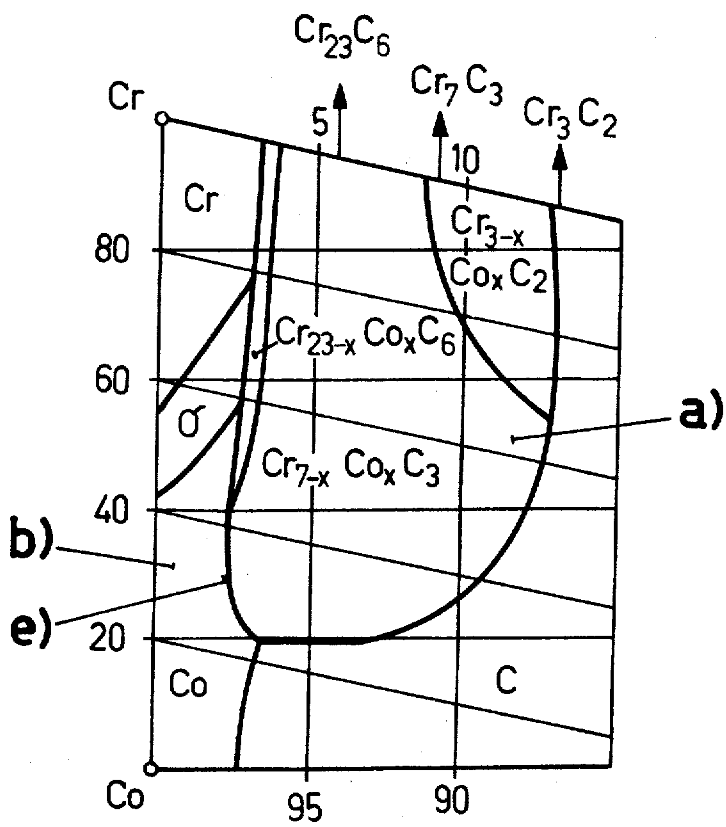

Cr
Cr₂₃C₆
Cr₇C₃
Cr₃C₂
5
10
Cr
80
60
40
20
σ
Cr₃₋ₓ
CoₓC₂
Cr₂₃₋ₓ CoₓC₆
Cr₇₋ₓ CoₓC₃
a)
b)
e)
Co
C
Co
95
90

Fig.3

Fig. 5

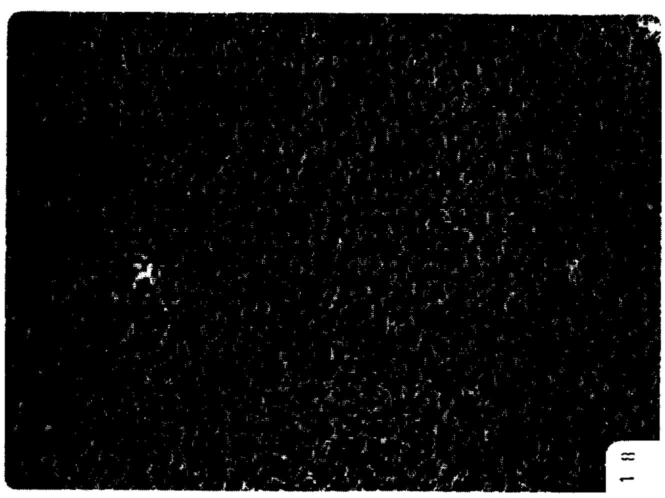


Fig. 4

METHOD OF, AND APPARATUS FOR, CONTROLLING THE CRYSTALLINE STRUCTURE OF ALLOYS, AND ALLOYS SO PRODUCED

The invention relates to a method of controlling, by heat treatment, the crystalline structure of alloys which have a structure which is at least partially eutectic. The invention also includes an apparatus for carrying out the method, and also a determined application of the method in the cases of certain alloy compositions.

Because of their widespread availability and their properties, alloys which have a structure which is at least partially eutectic are of great technological interest. The same therefore also applies to the heat treatment of such alloys with the object of directing their structure towards determined improvements of properties. The aim of such improvements is in many cases the attainment of a uniform and/or symmetrical crystalline structure of the eutectic, particularly in respect of the shape and arrangement of the crystals embedded in the matrix of the eutectic. The problem underlying the invention therefore consists in providing a method of heat treatment and an appertaining apparatus or a corresponding application of the method whereby structure control of the kind mentioned can be achieved.

The method according to the invention for the solution of the problem is characterized in that a zone with a high temperature gradient between a melting region and a solification region is produced in the alloy. Taking as starting point an apparatus for the treatment of workpieces of an alloy having a partly, or wholly, eutectic structure, the apparatus according to the invention for the solution of the problem is characterized in that a heating apparatus acting on the workpiece and a cooling apparatus, likewise acting on the workpiece are disposed a short distance apart so as to form a transition region with a high temperature gradient. Furthermore, according to the invention a method of the kind described above can be applied by forming the zone having a high temperature gradient between a melting zone and a solification zone in an alloy the eutectic portion of which has a first, at least substantially isotropic, phase and a second, comparatively highly anisotropic, crystalline phase.

Further features and advantages of the invention will be seen from the following description of the examples of embodiment, which is given with reference to the appended drawing in which:

FIG. 1 is a diagrammatical longitudinal section of an apparatus for the continuous heat treatment of a workpiece in wire form;

FIG. 2 is a partial longitudinal section in the region II in FIG. 1, on a larger scale;

FIG. 3 shows a part of a ternary phase diagram for a Co—Cr—C system;

FIG. 4 shows a microscopic polished section of an alloy from the diagram shown in FIG. 3, produced by the conventional method; and

FIG. 5 shows a corresponding polished section after continuous treatment with a high temperature gradient.

In an apparatus according to FIG. 1 a workpiece **1**, which is in wire form and is surrounded by a thin-walled, high-temperature resistant tube **2** in the manner illustrated in FIG. **2**, is inserted into a holder **3***a* of the push-rod **3** of a driving device indicated by a double arrow **4**. Despite the relative movement, the drive device is sealed by means of a bellows **5** in relation to the gas-carrying system of the apparatus, which system comprises a bell **6**, an inlet pipe **7**, and an outlet pipe **8**. By means of these pipes the workpiece is bathed in an inert gas, for example argon, in the region of the heating and melting zone.

The sheathed workpiece **1** passes in the downward direction through the passage of a heating device **11** and, by way of an intermediate space **16**, penetrates into a cooling bath **17**. The heating device **11**, for example a high frequency induction heater, comprises a winding **12** together with a susceptor **14** which surrounds the workpiece, and which for example is made of tantalum, and an outer heat shield **13**, made for example of alumina. The heating device can be raised and lowered by means of an adjusting device, indicated diagrammatically by a double arrow **15**, whereby the height of the intermediate space **16** is varied accordingly. For a given temperature difference between the outlet of the heating device **11** and the inlet of the cooling bath **17**, the temperature gradient acting in the intermediate space **16** can thus be adjusted.

With the aid of suitable measuring and control means for temperature and distance, control is also optionally possible for the purpose of maintaining a predetermined ratio between, on the one hand, the difference in temperature between the heating device and the cooling device, and, on the other hand, the distance between these two devices. In the case of the example, the temperature of the cooling bath, which latter may conveniently consist of a molten bath, — for example, of a eutectic alloy having a correspondingly low melting point, — is controlled additionally. For this purpose a current of a heat transfer medium, for example water, is provided in a cavity which surrounds the cooling bath **17** and is formed between an outer tube **9** and an inner tube **10** and which is provided with connecting pipes **20** and **21**.

In a particularly simple and therefore convenient manner the height of the intermediate space and, consequently, if the temperature difference remains unchanged, the value of the temperature gradient between the melting zone and the solidification zone can be adjusted by raising or lowering the level of the cooling bath or, in conjunction with suitable measuring and control elements, can also be automatically controlled. A suitable inlet and outlet device for the cooling medium is indicated in FIG. **1** by the double arrow **19** at the cooling medium connection **18**.

With the aid of the illustrated apparatus it is possible to obtain a zone of high temperature gradient which progresses over the volume of the workpiece, — that is to say, in the case of the example in the lengthwise direction of the wire, in accordance with a predetermined rate of speed of solidification. At the same time the temperature gradient can be adjusted or automatically controlled with the aid of the devices described.

The above-described treatment with a high temperature gradient has been found particularly effective for alloys with a eutectic which has a crystalline carbide phase embedded in a metallic matrix. The relative region of a phase diagram of a ternary system of this kind is shown in FIG. **3**. This relates to a Co—Cr—C system with a carbide phase of the variable composition $Cr_{7-x}Co_xC_3$ in accordance with region a, and also with a metallic matrix of the composition $Co_{1-x-y}Cr_xC_y$ in accordance with region b. A eutectic channel e extends between these regions. Investigations have shown that the symmetrizing effect or the field of application of the method requires the presence of an at least substantially isotropic crystalline phase and a relatively highly anisotropic crystalline phase in a eutectic.

In the special system mentioned above as an example, values of the temperature gradient above about 2500°C/cm have been found particularly favorable, and the effect was also observed up to values of 10,000°C/cm, so that no restrictive limitation in the upward direction can be seen. On the other hand, in the case of the example the effect of morphological structure symmetrization was observed at speeds of solidification between 1 and 100 cm/hour. Relatively high values of speed of solidification or speed of passage of a workpiece can therefore be attained, while small diameters or layer thicknesses in the case of workpieces in wire or strip form facilitate the attainment of a high temperature gradient.

A particularly clearly defined symmetrizing effect was obtained with a ternary system according to FIG. 3 within a range embraced by the following corner compositions:

1.)	Co = 53.1 %;	Cr = 44.7 %;	C = 2.2 %;
2.)	Co = 50.25 %;	Cr = 47.0 %;	C = 2.75 %;
3.)	Co = 67.15 %;	Cr = 30.0 %;	C = 2.85 %;
4.)	Co = 62.5 %;	Cr = 34.0 %;	C = 3.5 %.

An example of the attainable structure symmetrization can clearly be seen from comparison of the microscopic polished sections shown in FIGS. 4 and 5, in respect of both the shape and the arrangement of the carbide crystals (dark areas) in their statistical distribution inside the matrix (light ground).

Therefore, whereas in the untreated condition the carbide phase solidifying in fiber form has a very irregular formation and distribution, thus impairing the advantageous properties of the alloy, through the treatment with a high temperature gradient and the structure symmetrization achieved there is obtained better high temperature resistance to structure coarsening and consequently improved fatigue strength. Consequently it is now possible to make full use of the inherently good properties of the alloy in respect of high temperature strength and high temperature corrosion resistance.

We claim:

1. In a method of controlling by heat treatment the crystalline structure of an at least partially eutectic alloy having a crystalline $(Cr, Me)_7C_3$ phase embedded in a Me-chromium-carbon matrix phase, wherein Me is selected from the group consisting of Fe, Co, Ni, Mn and combinations thereof, wherein one of said phases is at least substantially isotropic, and the other phase is characterized by a highly anisotropic crystalline structure, the improvement comprising symmetrizing said structure by passing said body through a melting zone and a solidification zone, wherein the temperature gradient between the melting zone and the solidifcation zone is at least 2,500°C/cm, and wherein the speed of said body is advanced through said zones is a rate of from 1–100cm/hr.

2. The method of claim **1**, wherein said metal is cobalt and wherein the total composition of the resulting cobalt-chromium-carbon alloy lies within the following corner compositions in percentages by weight:

1)	Co = 53.1 %	Cr = 44.7%	C = 2.2 %
2)	Co = 50.25%	Cr = 47.0%	C = 2.75%
3)	Co = 67.15%	Cr = 30.0%	C = 2.85%
4)	Co = 62.5 %	Cr = 34.0%	C = 3.5 %

3. The method of claim **1**, wherein the upper limit of the temperature gradient is 10,000°C/cm.

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