United States Patent Office 3,063,833 Patented Nov. 13, 1962

3,063,833

NEW METAL ALLOY MATERIAL AND METHOD OF HEAT TREATING

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No Drawing. Filed Dec. 14, 1959, Ser. No. 859,162
2 Claims. (Cl. 75—159)

This invention relates to a new metal alloy material and to a method of heat treating the material to increase its physical properties.

The investigation leading to the discovery of this new metal was prompted by the need for a metal which is highly resistant to corrosion and in which castings of the material are capable of withstanding high pressure and are hydrostatically sound. Specifically, the investigation related to the production of a metal which could be used in a high pressure pump for use in pumping salt water or a similar corrosive liquid.

It is known that a 70/30 copper-nickel alloy has the necessary characteristic of resisting corrosion, however it has relatively low physical characteristics which makes it unsatisfactory for the purpose mentioned. It is also known that the addition of silicon to this cupro-nickel will increase its physical characteristics, for example, a copper-nickel alloy containing about .5% silicon and .7% iron, about 25,000 p.s.i. yield strength is obtainable with a tensile strength of approximately 55,000 p.s.i. Unfortunately, however, the addition of this amount of silicon very seriously affects the weldability of the material. This is an extreme disadvantage in using the material in, for example, pump casings.

In an effort to overcome this disadvantage and to increase the physical characteristics of a basically copper-nickel alloy containing 70% copper and 30% nickel, it was found that the addition of columbium and silicon resulted in a new material having a dramatic increase in the physical properties and which is weldable even with relatively high silicon content.

The first experiment was conducted using a 70/30 copper-nickel alloy containing columbium in the range of .33% to .83%; manganese within the range of .83% to 1.41% and iron in the range of .50% to 1.07%. It is preferable that the manganese percentage be about twice that of silicon at the lower levels, and the iron percentage around .3% to provide corrosion resistance. Insofar as this invention is concerned it is believed that the specific percentage of the manganese and iron content is relatively unimportant and do not in any way affect the results obtained by the addition of various quantities of silicon and columbium. It is merely desirable that these two elements be present and in percentages within the stated ranges. Further reference to these elements—namely, iron and manganese, will be omitted although it is to be understood that these two elements in approximately this proportion were present in all the tests conducted.

In this particular test, the percentage of silicon was varied over a range of from .25% to .69%. The tensile strength of the material, as compared to a material of similar composition except for columbium, was increased approximately 15,000 p.s.i. at the lower silicon level and approximately 27,000 p.s.i. at the upper level. More particularly, the alloy with .25% silicon, but without columbium, has a tensile strength of about 47,000 p.s.i. and with .69% silicon the tensile strength is about 68,000 p.s.i., whereas when columbium was added in the quantities stated, the tensile strength at .25% silicon content was increased to approximately 62,000 p.s.i. whereas at the silicon level of .69% the tensile strength was found to be in the neighborhood of 95,000 p.s.i.

Similar gains were also made in the yield strength. At the .25% silicon level, the yield strength was increased from about 18,000 p.s.i. to about 26,000 p.s.i. and at the .69% silicon level the yield strength was raised from about 42,000 p.s.i. to approximately 68,000 p.s.i. by the addition of columbium.

Another point of considerable interest that was noted as a consequence of these comparative tests was that the alloy containing silicon, but no columbium, and the alloy containing both silicon and columbium had about the same percent of elongation or hardness for a given yield and tensile strength.

Subsequent to this test, additional experiments were conducted in which the amount of columbium for the percentage of silicon was varied over the silicon range to determine the effect of columbium on the increased physical characteristics and weldability of the new material. In this particular test, the combined percentage of silicon and columbium was varied over the range of from .6% to 1.5%. It was concluded that although there seemed to be a rather broad range of relationship between the comparative percentages of silicon to columbium over the range investigated, it was found that the addition of columbium at the lower silicon level very greatly increased the effectiveness of silicon in increasing the physical properties of the material. This was noted to be true particularly below silicon levels of about .3%. On the other hand, at the silicon levels above .3% it was found desirable to have the columbium at least equal to and preferably greater than the percentages of silicon. It is believed that this excess of columbium is necessary primarily in order to obtain weldability of the material; the excess of columbium over silicon would not be required at this higher silicon level, however, if it is not necessary or desirable to make the material weldable.

It was further noted that when the silicon content was increased above .8%, the hardness of the material was correspondingly greatly increased and the percentage of elongation was reduced to something less than 10%. This is believed to be generally undesirable and it was accordingly concluded that the silicon content should be not greater than about .8% due to the loss of ductility, and the combined percentage of columbium and silicon should not exceed about 1.75% and in which the columbium would be equal to or greater than the silicon percentage whenever the silicon percentage was greater than about .3%.

It was discovered further that the mechanical properties of this alloy, containing columbium and silicon in the percentages and ratios heretofore discussed, can be increased by controlling the cooling rate of the alloy. Accompanying the increase in yield and tensile strength, there was a corresponding change in the percent of elongation. That is, the percent of elongation remained about the same for given yield and tensile strengths regardless of the cooling rate.

In the first test, several test bars were knocked out of their molds about twenty minutes after the bars were poured and, at which time, the bar temperatures were approximately 1400° F. A second group of bars was permitted to cool for approximately two hours in the molds. The temperature of the bars of the second group was 500° F. at the time of knocking the bars free of the molds. The slowly cooled bars had approximately 10% higher yield strength and approximately 5% higher tensile strength than the more quickly cooled bar.

Following this test, an additional experiment was performed in which the cast bars were subjected to what I call "homogenization heat treatment." This comprised reheating the cast bars up to a temperature of within the range of 900° F. to 1550° F. and holding at that tem-

perature for a period of time and then cooling either rapidly, as by air cooling, or slowly by furnace cooling for a period of about eight to ten hours.

It was learned that heating the casting to a temperature within said range for a period of one hour followed by air cooling, resulted in no observable change in the strength of the material. However, when the temperature was held at a value within said temperature range for a period of one hour and allowed to cool slowly in a laboratory furnace overnight down to a temperature of approximately 500° F., a very significant increase in yield and tensile strength was obtained. For example, several tests were conducted using test bars containing various percentages of silicon varying from .25% to .65% in which the bars were heated to 1200° F. and held at this temperature for a period of one hour and then permitted to cool in the furnace down to a temperature of about 500° F. There was an increase of tensile strength of between 11,000 p.s.i. and 7,000 p.s.i. as compared to the same bars when knocked out of the mold two hours after pouring and permitted to air cool.

Other tests were conducted in which the casting was held at a temperature of 900° F. for a period of twenty-four hours and thereafter air cooled. This, also, resulted in a significant increase in the physical characteristics of the casting. This indicates that the homogenizing treatment to increase the yield and tensile strength of the material may be obtained either by heating for a relatively short period—e.g., approximately one hour, at a temperature within the range of 900° to 1550° F. and thereafter cooling slowly over a relatively long period—e.g., around six to ten hours; or reheating to a temperature within such range and holding it at that temperature a relatively long period—e.g., six to ten hours, and then cooling more rapidly. In either case, it is believed necessary to hold the temperature of the alloy at an elevated value for a sufficiently long period to permit the homogenizing process to condition the material for the cooling process.

It is generally believed that when heretofore known metals are subjected to normal foundry practice to form castings, the more rapidly cooled sections of the casting have higher mechanical properties than the more slowly cooled sections. Thus, thin sections are generally credited with superior mechanical properties to the heavier sections, which cool more slowly. It is evident from the foregoing that in this particular alloy the thin sections will have lower mechanical properties due to more rapid cooling. The homogenizing treatment will cancel the variations in cooling rates and enable the maximum strength potential to be realized in both thick and thin sections of the same casting.

I claim:

1. A cupro-nickel alloy comprising copper within the range of about 66% to about 70%, manganese within the range of about .83% to about 1.41%, iron in the range of about .50% to about 1.07%, silicon and at least one metal of the group consisting of tantalum and columbium the combined percentages of which do not exceed 1.75% and in which the percentage of the metal in said group consisting of tantalum and columbium is equal to or greater than the percentage of silicon when the silicon percentage exceeds .3%, and the balance nickel.

2. A cupro-nickel alloy comprising copper within the range of about 66% to about 70%, manganese within the range of about .83% to about 1.41%, iron in the range of about .50% to about 1.07%, silicon in an amount not exceeding .8% and at least one metal of the group consisting of tantalum and columbium in a percentage equal to or greater than the silicon percent when the silicon percent is greater than or equal to .3% and the balance nickel.

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