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SPRING

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This invention relates to improvement in springs formed of copper-base alloys.

One object of this invention is to provide improved springs formed of copper-base alloys and characterized by exceptionally-high spring qualities.

Other objects of this invention will appear from the present disclosure.

We have found that springs, when formed of certain copper-base alloys and treated as hereinafter set forth, possess exceptionally-high spring qualities.

The copper-base alloys to be formed into the improved springs by subjecting them to the special series of treatments hereinafter set forth, are age-hardenable by precipitation of nickel and phosphorus, and contain by weight, nickel from 0.7% to 1.7%, phosphorus from 0.11% to 0.36%, the ratio of the nickel to the phosphorus being from 3 to 1, to 10 to 1, with or without tin from 0.5% to 1%, with or without cadmium from 0.5% to 0.8%, and copper at least 88%, with or without one or more additional elements in such substantially-innocuous amounts as do not seriously impair the characteristic properties of the alloy, that is, in such amounts as do not essentially change the nature of the alloy.

The additional substantially-innocuous elements may range up to a total of about 11%, depending on what element is added, some being less harmful than others. Thus, while each of the elements aluminum, chromium and silicon should not be present in excess of 0.1%, zinc, which is comparatively innocuous, may be present up to as high as 10%. Silver can be present up to 5%. Manganese can be present up to 0.3%. Each of the elements iron and cobalt can be present up to 0.2%. The foregoing amounts of additional elements have been given on the basis that only one of these additional elements is to be present in the alloy. But where two or more additional elements are to be present together in the alloy, then, generally speaking, less of each of such additional elements can be tolerated, depending on which elements are added and the number of them.

A more preferred range for the nickel and phosphorus is to have the nickel from 0.9% to 1.35%, and the phosphorus from 0.15% to 0.28%.

In order to produce springs from alloys in accordance with the present invention and having high spring qualities, the alloy to be produced as a spring must contain the hereinbefore given essential amounts of the essential elements nickel, phosphorus and copper, which alloy is annealed for a suitable length of time at temperature in the range from 1275° F. to 1650° F., and preferably from 1400° F. to 1500° F., is then quenched or otherwise suitably cooled sufficiently rapidly to give it a solution treatment, is then given a precipitation or aging treatment at temperature in the range from 750° F. to 975° F., and preferably from 775° F. to 925° F., for a suitable length of time, and is then cold-worked as, for example, by wire drawing, to give it an area reduction in the range from 70% to 98%, and preferably at least 75%. The 70% cold-working is critical, as at or above this degree of cold-working, an unexpected large desirable increase in fatigue resistance occurs, as is evidenced by the unexpected high endurance limits obtained. If desired, additional cold-working could be given before the aging treatment. Air-cooling of material as finished by hot-working procedures such, for instance, as rolling, forging, extruding, etc., ordinarily constitutes the equivalent of a quench or solution treatment.

Our improved springs made in accordance with the present invention have a number of outstandingly superior characteristics. They are surprisingly and outstandingly superior in resistance to repeated or dynamic stresses, otherwise also known as fatigue resistance or endurance, having outstandingly-high endurance limits which are superior to those of springs made of usual copper-base alloys of silicon bronze, phosphor bronze, and 70–30 brass in spring tempers. They can be subjected to repeated stresses which are higher than those which can be successfully withstood by the other springs referred to. Furthermore, the ratio of endurance limit to tensile strength of our springs is higher than the corresponding ratios for the other springs referred to. And notwithstanding the superior characteristics of our springs, they are more readily shaped or formed than are the other springs referred to. Our springs when made in accordance with the present invention, can be given an endurance limit of at least 33,000 p. s. i., and, when so desired, can be given any desired endurance limit up to as high as 40,000 p. s. i., a figure well in excess of that shown by springs of any of the other alloys herein referred to.

Springs in accordance with our invention have high resistance to what are known as "creep" and "relaxation," that is, they maintain a high degree of their initial spring characteristic on prolonged subjection to either stress or strain. Our improved springs have good corrosion resistance, and also have high resistance to stress-corrosion

cracking, and when given an area reduction of 84% by cold-working, did not fail by stress-corrosion cracking, whereas silicon bronze and 70–30 brass when given a similar area reduction, did fail by stress-corrosion cracking.

Also, springs made in accordance with the present invention resist softening under heat better than any of the other springs referred to. Also, heat can be dissipated through or along our springs from two and one-half to more than six times as rapidly as the other springs, thus ensuring more even distribution of temperature, and a minimum of local overheating in our springs. Therefore, since applicants' springs also can stand a higher temperature than the other springs without softening or losing hardness or spring or tensile strength, it will be seen that applicants' springs have a vastly superior quality for being able to successfully withstand conditions of heat compared to those of the other springs mentioned.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

We claim:

1. A spring characterized by high endurance limit, high resistance to creep and relaxation, high resistance to stress-corrosion cracking and high resistance to softening by heat, and formed of an age-hardenable copper-base alloy containing: nickel from 0.7% to 1.7%; phosphorus from 0.11% to 0.36%, the nickel and the phosphorus constituting the main age-hardening material of the alloy; and copper at least 88%; which said alloy has been age-hardened by giving it a solution treatment and a precipitation treatment, and after being age-hardened has been cold worked to give it an area reduction in the range from 70% to 98%.

2. A spring characterized by high endurance limit, high resistance to creep and relaxation, high resistance to stress-corrosion cracking and high resistance to softening by heat, and formed of an age-hardenable copper-base alloy containing: nickel from 0.9% to 1.35%; phosphorus from 0.15% to 0.28%, the nickel and the phosphorus constituting the main age-hardening material of the alloy; and copper at least 88%; which said alloy has been age-hardened by giving it a solution treatment and precipitation treatment, and after being age-hardened has been cold worked to give it an area reduction in the range from 70% to 98%.

3. A spring characterized by high endurance limit, high resistance to creep and relaxation, high resistance to stress-corrosion cracking and high resistance to softening by heat, and formed of an age-hardenable copper-base alloy containing: nickel from 0.7% to 1.7%; phosphorus from 0.11% to 0.36%, the nickel and the phosphorus constituting the main age-hardening material of the alloy; tin from 0.5% to 1%; and copper at least 88%; which said alloy has been age-hardened by giving it a solution treatment and a precipitation treatment, and after being age-hardened has been cold worked to give it an area reduction in the range from 70% to 98%.

4. A spring characterized by high endurance limit, high resistance to creep and relaxation, high resistance to stress-corrosion cracking and high resistance to softening by heat, and formed of an age-hardenable copper-base alloy containing: nickel from 0.7% to 1.7%; phosphorus from 0.11% to 0.36%, the nickel and the phosphorus constituting the main age-hardening material of the alloy; cadmium from 0.5% to 0.8%; and copper at least 88%; which said alloy has been age-hardened by giving it a solution treatment and a precipitation treatment, and after being age-hardened has been cold worked to give it an area reduction in the range from 70% to 98%.

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