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MAGNETOSTRICTIVE ELEMENTS

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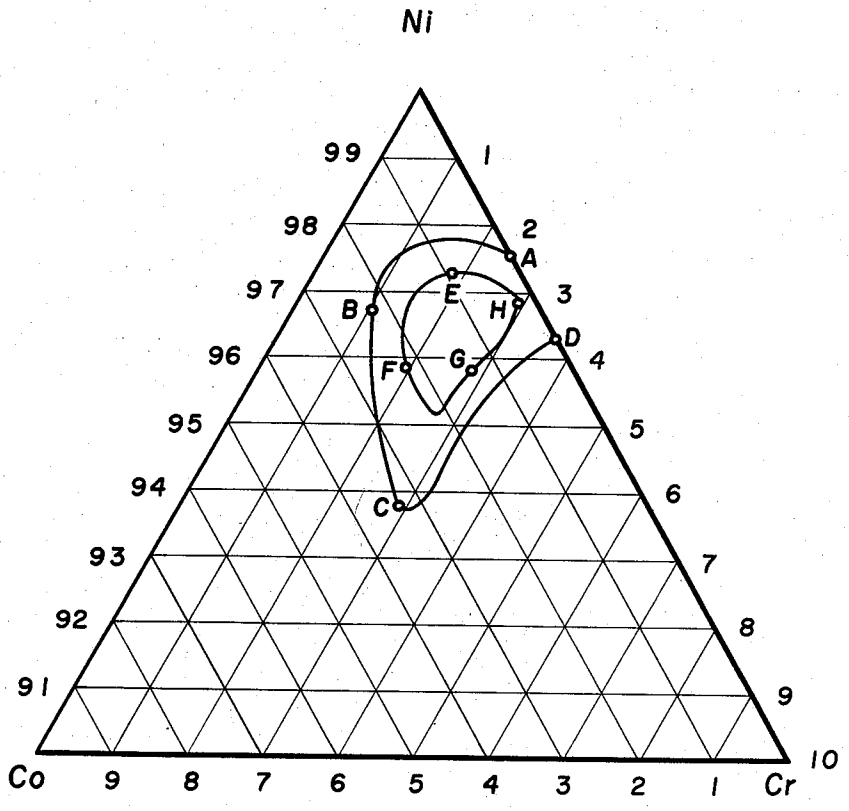

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MAGNETOSTRICTIVE ELEMENTS

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1 Claim. (Cl. 317—158)

The present invention relates to magnetostrictive elements and, more particularly, to alloys for use in transmitting magnetostrictive devices operating at high frequency.

It is well known that magnetostrictive elements are used for the conversion of electrical to mechanical oscillations and vice versa, for example, in transducers in echo-sounding apparatus and ultrasonic drilling apparatus. A measure of the efficiency of the magnetostrictive device is given by the square of its electromechanical coupling coefficient (K), which itself is a measure of the efficiency of the magnetic material in converting magnetic to mechanical energy. The definition of K is such that

$$K^2 = \frac{\text{Converted mechanical stored energy}}{\text{Input magnetic stored energy}}$$

The coefficient K may be determined experimentally and depends upon the material of the magnetostrictive element.

When the magnetostrictive element is used, for instance, in a transducer that acts as a transmitter, it is not only the value of the coefficient K that is important, but also that of a constant Q, which depends upon the material used and in fact varies (when different materials are employed in magnetostrictive elements) inversely with the electrical and magnetic losses which occur. Q is defined as

$$Q = \frac{\text{Electromagnetic stored energy}}{\text{Electrical and magnetic energy losses}}$$

It is in fact known that the product K^2Q should be as high as possible, particularly when the transducer or other device containing the element is to operate at high frequency. The value of the product K^2Q as exhibited by magnetostrictive elements employed in transmitting devices is critical, since these transmitting devices utilize high levels of electrical input energy and consequent high reactance resistance, impedance, etc., losses (e.g., eddy currents, hysteresis, etc.). Although attempts were made to provide a metallic magnetostrictive element having a high value of K^2Q, for example, a value in excess of 1.1 when employed in the frequency range of about 25 to about 50 kilocycles per second (kc./s.), none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that by employing specially restricted ranges of alloying ingredients in an alloy comprising a magnetostrictive element, a very high value of the parameter K^2Q can be attained.

It is an object of the present invention to provide a novel alloy having enhanced magnetostrictive characteristics.

Another object of the invention is to provide a novel magnetostrictive element having a high value for the K^2Q parameter.

The invention also contemplates providing a magnetostrictive device having a high value for the K^2Q parameter when said device is employed at high frequencies.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawing in which the figure is a portion of a ternary diagram whereon the relation of the percentage of nickel to the percentage of cobalt and to the percentage of chromium for the alloys of the present invention is depicted.

Generally speaking, the present invention contemplates a magnetostrictive element comprising a ternary nickel-cobalt-chromium alloy having a composition falling within the area bounded by the line ABCD in the part of the ternary diagram shown in the accompanying drawing. Substantially all these alloys have values of K^2Q, measured on specimens 0.015 centimeter (cm.) thick, of 1.1 or more. Advantageously, the composition of the alloys is such that it falls within the area bounded by the line EFGH in the ternary diagram. Substantially all the alloys defined by this area have values of K^2Q measured on specimens 0.015 cm. thick, of 1.3 or more. The invention further contemplates the use of said alloys as magnetostrictive elements in the interconversion of electrical and mechanical oscillations comprising applying one of said types of oscillations to the magnetostrictive element made of said alloy and extracting the other of said types of oscillations therefrom.

Advantageous alloys in accordance with the present invention are set forth in the following Table I:

Table I

Alloy No.	Percent Co	Percent Cr	Percent Ni
1	1.4	2.3	Bal.
2	2.0	1.3	Bal.

It is to be noted that the alloys in accordance with the present invention contain about 0.9% to about 3.6% chromium, about 0% to about 3.6% cobalt and the balance essentially nickel. More advantageous alloys within the ambit of the present invention contain about 1.6% to about 3% chromium, about 0.2% to about 2.3% cobalt with the balance being essentially nickel. These alloys fall within the area EFGHE on the graph.

Referring to the accompanying drawing, it is to be noted that the points designated by letters have ternary coordinates as set forth in Table II:

Table II

Point	Percent Cr	Percent Co	Percent Ni
A	2.4	0	97.6
B	1.1	2.2	96.7
C	2.9	3.4	93.7
D	3.6	0	96.4
E	1.8	0.9	97.3
F	1.8	2.2	96.0
G	2.7	1.4	95.9
H	2.9	0.2	96.9

It has been found that the addition of chromium to a binary alloy containing nickel and up to about 3.6% cobalt gives an enhanced value of K^2Q. No equivalent improvement is found in alloys containing 8% or more cobalt.

In carrying the invention into practice, it is advantageous to employ the alloys in the form of thin sheets or plates having a thickness of the order of about 0.01 to about 0.04 cm. In making the alloys, commercially pure nickel is normally used, and, accordingly, the usual impurities will also be present. Commercial nickel often contains small quantities of cobalt and in making the alloys it is necessary to allow for any cobalt present in the nickel.

Advantageously, the alloys are stamped into laminations and heat treated for one hour in dry hydrogen. The laminations are then insulated with varnish and built up into a transducer stack of the required dimensions. When treated in this manner and tested by measurement of the electrical impedance of the transducer as a function of

frequency, the alloys in accordance with the present invention exhibit electromechanical coupling coefficient values and K^2Q parameter values as set forth in Table III:

Table III

Alloy No.	K	K^2Q
1	0.38	1.4
2	0.44	1.2

In comparison, when tested under the identical conditions, prior art alloys such as an alloy containing 4% chromium and 96% nickel or an alloy containing 93% nickel, 2% chromium and 5% cobalt exhibit values for K of 0.25 and 0.35, respectively, and values for the K^2Q parameter of 1.0 and 0.7, respectively. The respective values for these characteristics clearly demonstrate, as pointed out hereinbefore, that the alloys and magnetostrictive elements of the present invention can provide more efficient transmitters able to operate at higher frequencies than those having metallic magnetostrictive elements in accordance with the prior art.

The present invention is particularly applicable to transmitting transducers used on echo sounding and ultrasonic cleaning equipment and ultrasonic drills.

The present application is a continuation-in-part of my co-pending U.S. application, Serial No. 9,911, filed February 19, 1960, now abandoned.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claim.

I claim:

A magnetostrictive element for use in transducing transmitting devices adapted to operate at high frequencies comprising a plurality of thin electrically insulated laminations of an alloy consisting essentially of about 1.6% to about 3% chromium, about 0.2% to about 2.3% cobalt, with the balance being essentially nickel, said alloy being represented by a point falling within the area EFGHE in the accompanying drawing and said magnetostrictive element being capable of exhibiting a high electromechanical coupling coefficient and a value of K^2Q in excess of about 1.3 when subjected to a source of alternating energy.

References Cited in the file of this patent

UNITED STATES PATENTS

1,882,396 Pierce ---------- Oct. 11, 1932
2,519,495 Nesbitt et al. ---------- Aug. 22, 1950