Sept. 27, 1955 T. J. COUNTIS 2,719,084

SPECIAL ALLOY FOR MAGNETOSTRICTIVE APPLICATIONS

Filed Aug. 3, 1954

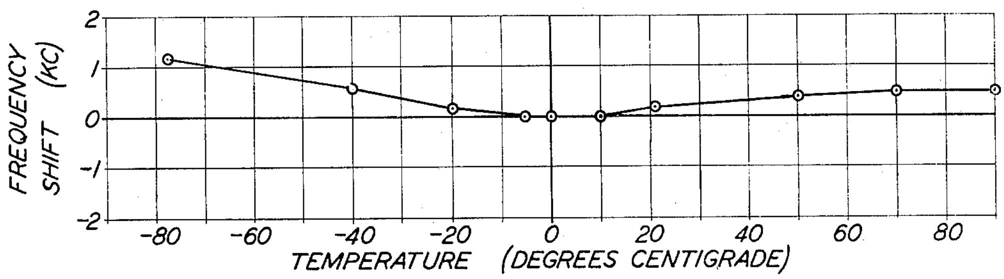

FIG 1

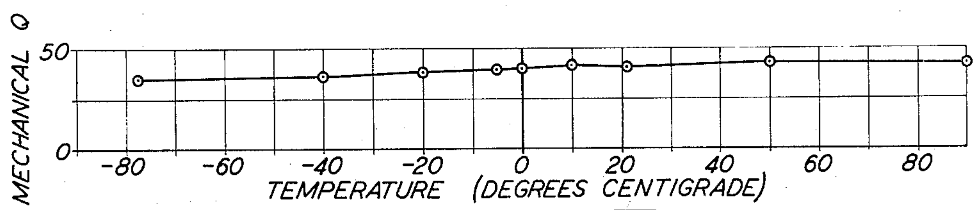

FIG 2

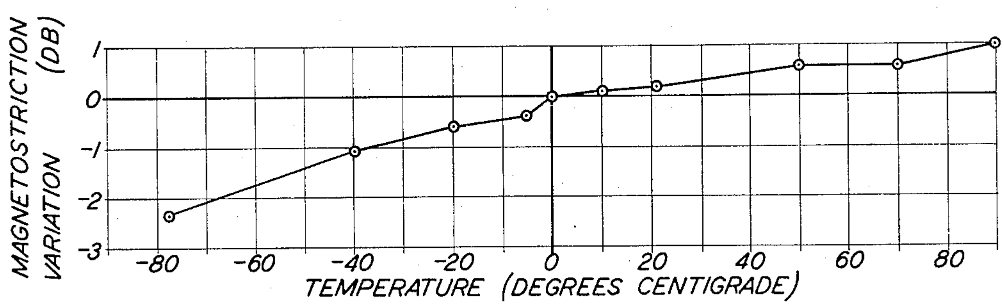

FIG 3

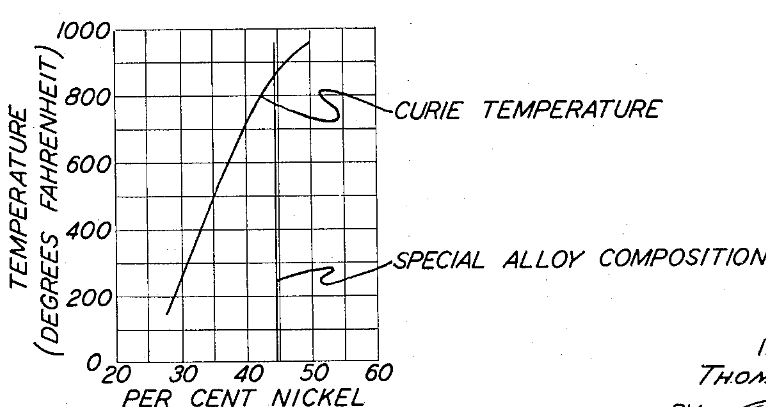

FIG 4

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United States Patent Office

2,719,084
Patented Sept. 27, 1955

2,719,084

SPECIAL ALLOY FOR MAGNETOSTRICTIVE APPLICATIONS

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Application August 3, 1954, Serial No. 447,472

4 Claims. (Cl. 75—123)

This invention relates in general to alloys and in particular to alloy for magnetostrictive applications.

In electromagnetic filters such as described in the copending application "Mechanical Filters" of Melvin L. Doelz, Serial No. 248,011, filed September 24, 1951, wires are used for coupling energy to various parts of the filter and it is very desirable to obtain the following properties:

1. Low temperature coefficient of frequency.
2. High internal friction or mechanical hysteresis in order to obtain a mechanical Q below 50.
3. High magnetostriction efficiency for low transmission losses.
4. High Curie temperature to make possible good magnetostriction at high operating temperatures.

Although a number of alloys are available that possess one or more of these properties, none has been found with all four properties. My invention relates to an alloy which possesses all four of these properties that make it good for use as a magnetostrictive resonator in mechanical filter transducers.

It is an object of this invention to provide an alloy which is superior when used as a magnetostrictive element.

Further objects, features and advantages of this invention will become apparent from the following description and claims when read in view of the drawings, in which:

Figure 1 illustrates frequency versus temperature curve for the alloy;

Figure 2 illustrates a mechanical Q plotted against temperature variations;

Figure 3 illustrates the magnetostriction variations plotted against temperature range; and

Figure 4 illustrates the Curie temperature as a function of per cent nickel.

Temperature coefficient of frequency

Figure 1 shows a typical frequency versus temperature curve for my alloy.

For the typical case of a small diameter wire vibrating longitudinally:

$$f=\frac{1}{\lambda}\sqrt{\frac{y}{\rho}} \qquad (1)$$

where f is the resonant frequency; λ is wavelength; y is Young's modulus of elasticity; and ρ is density.

By differentiating the above equation with respect to temperature:

$$\frac{df}{fdt}=\frac{1}{2}\left[\frac{dy}{ydt}-\frac{d\rho}{\rho dt}-\frac{2d\lambda}{\lambda dt}\right] \qquad (2)$$

$$\frac{d\rho}{\rho}\cong-\frac{3d\lambda}{\lambda} \qquad (3)$$

$$\frac{df}{f}=\frac{1}{2}\left[\frac{dy}{y}+\frac{d\lambda}{\lambda}\right] \qquad (4)$$

where

$$\frac{df}{f}$$

is the temperature coefficient of frequency;

$$\frac{d\lambda}{\lambda}$$

is the temperature coefficient of expansion;

$$\frac{d\rho}{\rho}$$

is the temperature coefficient of density; and

$$\frac{dy}{y}$$

is the temperature coefficient of elasticity.

It is seen from Figure 1 that as the temperature is varied from minus 78 degrees centigrade to 90 degrees centigrade that the frequency variation is approximately 1.2 kilocycles and that over the range from minus 30 degrees centigrade to 90 degrees centigrade that the frequency shift is less than 0.5 kilocycle. Thus, the alloy exhibits a stable frequency shift characteristic.

Mechanical Q

Figure 2 shows a graph of the changes in the mechanical Q when plotted against temperature variations. Q is the property of a material to pass a relatively broad band of frequencies. It is generally desirable to maintain Q of driving wires below 50.

It is seen from Figure 2 that over the range from minus 80 degrees centigrade to 90 degrees centigrade the Q varies from only 37 to 43.5 or a variation of 6.5 over a temperature range of 170 degrees.

Magnetostriction

Figure 3 illustrates the magnetostriction variation of the alloy over a temperature range and it is seen that this is substantially constant.

Since the Q of the material is a function of a peak response, this special alloy shows high magnetostriction for low Q by comparison with other magnetostrictive alloys.

Curie temperature

Figure 4 illustrates the Curie temperature as a function of per cent nickel. It is important that the Curie temperature be well above the operating temperature to insure that no loss occurs in the magnetostriction. This alloy possesses a Curie temperature of 430 degrees centigrade, insuring good high temperature magnetostriction.

The composition of an alloy to obtain the above described properties is:

	Per cent
Nickel (high purity)	44.2
Iron (high purity)	55.7
Manganese	0.1

Processing technique

Great care is exercised in selecting high purity nickel and iron for the alloying elements, since trace quantities of impurities such as sulphur and carbon have an adverse effect on the ductility and the mechanical Q of the alloy.

Melting may be done in both vacuum and in inert or reducing atmospheres.

Castings may be made by inserting a quartz or Pyrex tube into the melt and by sucking the melt into the tube with the aid of a mechanical suction pump.

In one application the castings were swaged from approximately ¼ inch diameter to ¹⁄₁₆ inch diameter and then drawn through wire dies to 0.006 inch diameter.

The wire is then dead-soft annealed at 2000 degrees Fahrenheit for one hour in a dry hydrogen atmosphere.

The finished wire was made into mechanical filters and had a very good temperature stability.

It is seen that this invention provides an alloy which has the following desirable characteristics:

1. Good temperature coefficient of frequency;
2. High internal friction or mechanical hysteresis;
3. High magnetostriction efficiency for low transmission losses;
4. High Curie temperature to make possible good magnetostriction at high operating temperatures.

Although this invention has been described with respect to particular embodiments thereof, it is not to be so limited as changes and modifications may be made therein which are within the full intended scope of the invention, as defined by the appended claims.

I claim:

1. An alloy comprising, the composition by weight of 44.2 per cent of nickel, 55.7 per cent of iron and 0.1 per cent of manganese.

2. An alloy which has a good mechanical Q versus temperature characteristic comprising, the composition by weight of nickel 44.2 per cent, iron 55.7 per cent, and manganese 0.1 per cent.

3. The process for making a magnetostrictive material with a good temperature coefficient of friction, high internal friction, and high magnetostrictive frequency response comprising, melting a melt of 44.2 per cent of nickel, 55.7 per cent of iron and 0.1 per cent of manganese by weight in an inert atmosphere, casting the melt, swaging the casting, drawing said casting into wire, and dead-soft annealing it at about 2000 degrees Fahrenheit in a dry hydrogen atmosphere.

4. The process for making a magnetostrictive material with a good temperature coefficient of friction, high internal friction, and high magnetostrictive frequency response comprising, melting a melt of 44.2 per cent of nickel, 55.7 per cent of iron and 0.1 per cent of manganese by weight in an inert atmosphere, casting the melt, swaging the casting, drawing said casting into wire, and dead-soft annealing it at about 2000 degrees Fahrenheit in a dry hydrogen atmosphere for one hour.

No references cited.