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(72) **Inventeurs/Inventors:**
DE BOER, BERND, DE;
GEHRMANN, BODO, DE

(73) **Propriétaire/Owner:**
OUTOKUMPU VDM GMBH, DE

(74) **Agent:** FETHERSTONHAUGH & CO.

(54) **Titre : ALLIAGE FER-NICKEL**
(54) **Title: IRON-NICKEL ALLOY**

(57) **Abrégé/Abstract:**
The invention relates to a wire for a wire for a power line comprising an iron-nickel alloy having in mass %:
C > 0.1 to 0.4%
Cr > 0.6 to < 1.2%
Ni 35 to < 38%
Mn < 0.08%
Si <0.08%
Mo 2.1 to 2.8%
Nb 0.05 to 0.3%
Al 0.2 to 0.4%
Mg > 0.001 to 0.01%
V ≤0.1%
W 0.25 to 1.0%
Co 0 to < 0.5%
Fe remainder and constituents resulting from a production process, wherein: the sum, in mass%, of Mo + W is between 2.2 and 3.5%, the sum, in mass%, of Cr + W is between 1.0 and 2.0%, the sum, in mass%, of Si + Mn is < 0.1%, and the alloy has a thermal expansion coefficient of < 4 x 10^{-6}/K in the temperature range between 20 and 200°C.

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Abstract

The invention relates to a wire for a wire for a power line comprising an iron-nickel alloy having in mass %:

C	> 0.1 to 0.4%
Cr	> 0.6 to < 1.2%
Ni	35 to < 38%
Mn	< 0.08%
Si	< 0.08%
Mo	2.1 to 2.8%
Nb	0.05 to 0.3%
Al	0.2 to 0.4%
Mg	> 0.001 to 0.01%
V	≤ 0.1%
W	0.25 to 1.0%
Co	0 to < 0.5%

Fe remainder and constituents resulting from a production process, wherein: the sum, in mass%, of Mo + W is between 2.2 and 3.5%, the sum, in mass%, of Cr + W is between 1.0 and 2.0%, the sum, in mass%, of Si + Mn is < 0.1%, and the alloy has a thermal expansion coefficient of $< 4 \times 10^{-6}$/K in the temperature range between 20 and 200°C.

Iron-Nickel Alloy

The invention relates to an iron-nickel alloy having a low thermal expansion coefficient and special mechanical properties.

It is known that iron-based alloys having approximately 36% nickel have low thermal expansion coefficients in the temperature range between 20 and 100°C. These alloys have therefore been used for several decades wherever constant lengths are required, even with changes in temperature, such as for instance in precision instruments, clocks, bimetals, and shadow masks for color televisions and computer monitors.

KR 100261678 B1 is an invar alloy wire and a method for producing it. The invar alloy has the following composition (in mass %): 33 to 38% nickel, 0.5 to 1.0% cobalt, 0.01 to 1.3% niobium, 0.5 to 4% molybdenum, 0.2 to 1.5% chromium, 0.05 to 0.35% carbon, 0.1 to 1.2% silicon, 0.1 to 0.9% manganese, max. 0.1% magnesium, max. 0.1% titanium, and the remainder iron, the sum of Mo + Cr being between 1.2 and 5.0% and the sum of niobium and carbon being between 0.1 and 0.6%.

KR 1020000042608 discloses a high-strength invar alloy wire and a method for producing it. The alloy used contains (in mass %): no more than 0.1% nitrogen, 0.01 to 0.2% niobium, 0.3 to 0.4% carbon, 33 to 38% nickel, 0.5 to 4% molybdenum, 0.2 to 1.5% chromium, 0.1 to 1.2% silicon, 0.1 to 0.9% manganese, 1.0 to 10% cobalt, and, as needed, additions of up to 0.1% each Al, Mg, and Ti, and the remainder iron.

Both publications provide method parameters for cold drawing and hot drawing and annealing within defined temperature ranges.

The invention relates to a creep-resistant iron-nickel alloy having a low thermal expansion coefficient and special mechanical properties. Moreover, a production process for wire-like components made of this alloy is provided. It is possible to employ the material for specific uses, and the alloy has a low thermal expansion coefficient.

This is attained using an iron-nickel alloy having the following composition:

C 0.05 to 0.5%

Cr 0.2 to 2.0%

Ni 33 to 42%

Mn < 0.1%

Si < 0.1%

Mo 1.5 to 4.0%

Nb 0.01 to 0.5%

Al 0.1 to 0.8%

Mg 0.001 to 0.01%

V Max. 0.1%

W 0.1 to 1.5%

Co Max 2.0%

Fe remainder and constituents resulting from the production process.

In one aspect, the invention relates to a wire for a power line comprising an iron-nickel alloy consisting of, in mass %:

C > 0.1 to 0.4%

Cr > 0.6 to < 1.2%

Ni 35 to < 38%

Mn < 0.08%

Si < 0.08%

Mo 2.1 to 2.8%

Nb 0.05 to 0.3%

Al 0.2 to 0.4%

Mg > 0.001 to 0.01%

V ≤ 0.1%

W 0.25 to 1.0%

Co 0 to < 0.5%

Zr 0 to < 0.2%

B 0 to 0.01%

Fe remainder and constituents resulting from a production process, wherein: the sum, in mass%, of Mo + W is between 2.2 and 3.5%, the sum, in mass%, of Cr + W is between 1.0 and 2.0%, the sum, in mass%, of Si + Mn is < 0.1%, and the alloy has a thermal expansion coefficient of $< 4 \times 10^{-6}$/K in the temperature range between 20 and 200°C.

One preferred variant of the inventive iron-nickel alloy is provided as follows (in mass %):

C 0.1 to 0.4%

Cr 0.5 to 1.5%

Ni 34 to 40%

Mn < 0.08%

Si < 0.08%

Mo > 2.0 to < 3.5%

Nb 0.05 to 0.4%

Al	0.2 to 0.5%
Mg	0.001 to < 0.01%
V	Max. 0.1%
W	0.2 to < 1.0%
Co	0 to 0.5%
Fe	Remainder and constituents resulting from the production process.

Another variant is formed by (in mass %):

C	> 0.15 to < 0.4%
Cr	0.6 to max. 1.2%
Ni	35 to 40%
Mn	< 0.08%
Si	< 0.08%
Mo	> 2.0 to < 3.0%
Nb	0.05 to 0.3%
Al	> 0.1 to < 0.5%
Mg	> 0.001 to < 0.01%
V	Max. 0.1%
W	0.25 to 1.0%
Co	0 to max 0.5%
Fe	Remainder and constituents resulting from the production process.

The inventive composition of the alloy is distinguished from the prior art in that the Si and Mn contents are kept as small as technically possible. It is known that there is a strong relationship between the elements silicon and manganese with respect to the thermal expansion coefficient. On the other hand, these elements are metallurgically necessary in order to ensure adequate processability. This relates in particular to hot shaping to create billets and wire rods.

Thus, using the inventive chemical composition it is possible to use the smallest possible amounts of the elements silicon and manganese so that the negative effects these elements have on the thermal expansion coefficient can be avoided and at the same time the alloy is easy to process. For this reason the sum of Mn + Si should not exceed 0.2% (in mass %). The sum of Mn + Si should be ≤0.1% where this is technically feasible.

It is of particular advantage when the inventive alloy has a nickel content between 35 and 38%, a chromium content of > 0.6 to < 1.2%, a molybdenum content between 2.1 and 2.8%, an aluminum content between 0.2 and 0.4%, and a tungsten content of > 0.25 to < 1.0%.

If necessary, the element zirconium may also be added in contents > 0 to < 0.2% and/or the element B may be added in contents > 0 – 0.01% of the inventive alloy.

B + Zr individually or together improve the hot formability of the alloy.

Moreover, it is advantageous when the sum of the elements Mo + W is between 2.0 and 4.0%.

It is likewise advantageous for the mechanical properties when the sum of the elements Cr + W is between 1.0 and 2.0%.

According to another thought of the invention, the element W may be substituted for some of the element Mo.

It is significant that the alloy elements Mo, W, Cr, and C are available in sufficient quantities and that the ratio of (Mo + W + Cr)/C is selected such that it is possible to achieve a balanced mix of carbide strengthening, mixed crystal hardening, and cold hardening in the final product. An optimum ratio is considered to be in the range between 13.5 and 14.5, e.g. 14 and 15.

According to another thought of the invention, the W:Cr:Mo ratio should be approximately 1:2:5. However, the portion of the aforesaid elements in the inventive alloy must be specified such that the thermal expansion coefficient sought is not exceeded.

In the temperature range between 20 and 200°C the inventive alloy has a thermal expansion coefficient of $< 4 \times 10^{-6}$/K, especially $< 3.5 \times 10^{-6}$/K.

Furthermore, the invention relates to a method for producing components from the inventive alloy in an arc furnace, an induction furnace, or a vacuum furnace (where necessary with VOD treatment), with subsequent ingot casting, hot rolling (or forging) to create billets and wire rods on wire of a pre-specifiable thickness, and subsequent drawing to create wire-shaped pre-products with a pre-specifiable diameter, annealing processes occurring when necessary between individual drawing steps. Since the degree of cold strengthening is critical for the usage properties, both with regard to the thermal expansion coefficient and with regard to strength, the wire rod diameter must be adjusted such that adequate cold forming can be performed prior to and after intermediate annealing, which may take place in multiple stages.

In one method aspect, the invention relates to a method for producing a wire-shaped component from the alloy in accordance with any one of claims 1 to 18, comprising: casting a melt of the alloy into blocks; rolling the blocks to create billets; drawing the billets to create a pre-product wire with a pre-specified diameter; a luminizing pre-product wire; and drawing the pre-product wire to a final dimension.

According to another thought of the invention, the inventive alloy may be used as wire for power lines, especially as the core wire for power lines.

The inventive alloy may moreover be advantageously used for:

-- Lead frames

-- Shaped parts, especially carbon fiber molded parts

-- Components in chip production.

For the preferred uses the inventive alloy may be present in the form of sheet, bar, strip, or wire material.

CLAIMS:

1. A wire for a power line comprising an iron-nickel alloy consisting of, in mass %:

C	> 0.1 to 0.4%
Cr	> 0.6 to < 1.2%
Ni	35 to < 38%
Mn	< 0.08%
Si	< 0.08%
Mo	2.1 to 2.8%
Nb	0.05 to 0.3%
Al	0.2 to 0.4%
Mg	> 0.001 to 0.01%
V	≤ 0.1%
W	0.25 to 1.0%
Co	0 to < 0.5%
Zr	0 to < 0.2%
B	0 to 0.01%
Fe	remainder and constituents resulting from a production process,

wherein:

the sum, in mass%, of Mo + W is between 2.2 and 3.5%, the sum, in mass%, of Cr + W is between 1.0 and 2.0%,

the sum, in mass%, of Si + Mn is < 0.1%, and

the alloy has a thermal expansion coefficient of < 4 x 10^{-6}/K in the temperature range between 20 and 200°C.

2. The wire in accordance with claim 1, wherein the alloy has in mass %:

C > 0.15 to < 0.4%

W 0.25 to 1.0%.

3. The wire in accordance with claim 1 or 2, wherein the alloy has in mass %:

Zr > 0 to < 0.2% and/or

B > 0-0.01%.

4. The wire in accordance with any one of claims 1 to 3, wherein for the alloy the ratio (Mo + W + Cr)/C is 13.5 – 15.5.

5. The wire in accordance with any one of claims 1 to 4, wherein for the alloy the element W is substituted for some of the element Mo.

6. The wire in accordance with any one of claims 1 to 5, wherein the alloy has a thermal expansion coefficient of 3.5 x 10^{-6}/K in the temperature range between 20 and 200°C.

7. A method for producing the wire in accordance with any one of claims 1 to 6, comprising: casting a melt of the alloy into blocks; rolling the blocks to create billets; drawing the billets to create a pre-product wire with a pre-specified diameter; aluminizing the pre-product wire; and drawing the pre-product wire to a final dimension.

8. The method is accordance with claim 7, wherein between individual drawing steps there is an annealing process.

9. A use of the wire as defined in any one of claims 1 to 6, as a core wire for a power line.