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MANUFACTURE OF WATCH SPRINGS UTILIZING WIRE CONVERTED INTO STRIP

Reinhard Straumann, Waldenburg, Switzerland

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The present application is a continuation-in-part application to my copending application Ser. No. 330,892, filed on January 12, 1953, now abandoned.

This invention relates to the production of alloys in strip form suitable for the manufacture of watch springs and the like and more particularly to improvements in processes for the production of clock or watch-springs and springs produced thereby.

It is well known that metal crystals are anisotropic in respect of their elastic properties. Thus, for example, the modulus of elasticity in a cubic crystal lattice has a decided maximum value in the direction of the diagonal of the cube and on the other hand a minimum along the edge of the cube.

In a series of publications (e. g. Zeits, für Metallkunde, vol. 41, part 2, page 45) it has been shown that in cubic body centred as also in cubic face-centred material the modulus of elasticity, as well as the other elastic properties and the tenacity values, shows marked anistropy, and that in the cubic body-centred lattice as also in the cubic face-centred lattice the maximum value of the modulus of elasticity lies chiefly in the direction of the diagonal of the cube.

In German Patent No. 833,058 there is described a process for the production of springs from steels and metallic materials of anisotropic character, in which the springs are cut out of rolled sheet metal in the direction of the optimum elastic properties.

Moreover, it is well known that so far mainly carbon-steels have been used in the production of clock or watch springs. They are hardened by the classical method and preferably show a martensitic structure and a modulus of elasticity of 19,000 to 21,000 kg./mm.^{2}. Before hardening such springs are either rolled by the broad band method and then cut, or they are rolled to a strip from wire. These springs are characterised by being hardened and by not showing any texture when finished.

I have now, after a series of systematic investigations, succeeded, by a suitable rolling process, in laying the direction of the cube diagonal preferably parallel to the direction of rolling, whereby a considerable increase of the modulus of elasticity amounting to 10–30% is obtained in a lengthwise direction in the resulting spring strip.

The main object of the present invention consists in a method according to which an alloy which can be precipitation hardened and which shows a cubic face-centred crystal lattice is homogenised in the form of wire at high temperature, the wire quenched to an unhardened condition and drawn, preferably in the cold state, and then rolled, preferably in the cold state, to produce a flat spring strip so that the ratio of the decrease in cross-sectional area by the cold-drawing operation to the decrease in cross-sectional area by the flat rolling operation is selected so as to result in the predominant orientation of

the direction of maximum modulus of elasticity substantially parallel to the direction of rolling of the strip and is then heat-treated at a temperature of between 200° and 600° C. for preferably not more than 24 hours to give a modulus of elasticity of at least 21,000 kg./mm.^{2}.

According to a further object of this invention the flat rolling operation is preferably carried out in such a way as to obtain a decrease in cross-section of at least 80 percent.

Still a further object of my invention consists in a process for the production of a watch-spring in which an iron alloy with cubic body-centred crystal lattice is homogenised and quenched to the sorbitic condition in the form of wire, then cold-drawn and rolled to a band, whereby the ratio of decrease of the cross-section during cold-drawing operation of the wire to the decrease of cross-section during cold-rolling is so arranged that the direction of maximum modulus of elasticity is substantially parallel to the direction of the rolling. The strip is then subjected to heat-treatment at temperatures of 200°–600° C. to obtain a modulus of elasticity of at least 21,000 kg./mm.^{2}. After tests it has been observed that in alloys with cubic body-centred lattice, direction 111 as well as direction 110 show maximum values of the modulus of elasticity quoted above.

The alloy used should be susceptible to heat hardening, more commonly called precipitation hardening, and is essentially an alloy containing at least one element selected from the 4th row of the 8th group of the periodic system, i. e. iron, nickel and/or cobalt and at least one element selected from the group 6*a* of the periodic system having an atomic weight and at least ranging from 52 to 184 inclusive, i. e. chromium, tungsten and/or molybdenum, together, if desired, with small quantities of one or more elements which facilitate heat hardening, e. g. beryllium, titanium, columbium and carbon.

The invention is further concerned with such springs as are obtained by the methods according to this invention.

The composition of the alloy may naturally vary within wide limits, and watch springs made from such alloys show an increased modulus of elasticity and are therefore better suited than those springs on the market now.

By X-ray examination it is further observed that concentration in the direction 110 or 111 is marked in those springs produced according to the invention from an alloy with cubic face-centred lattice, i. e. an orientation of direction 110 or 111 parallel to the direction of rolling, as contrasted with spring bands hitherto made from alloys of the same composition. In contrast to springs produced before, better elastic properties and higher values of tensile strength are shown by the springs made according to the invention. The modulus of elasticity can, for example, reach as high as 24,000 kg./mm.^{2} and higher, compared with the 18,000 to 21,000 kg./mm.^{2} maximum hitherto observed.

As mentioned before, the composition of the alloys used can vary. Alloys containing the following maxima can be used:

Ni	Maximum content 68%.
Fe	Maximum content 99.5%.
Cr	Maximum content 30%.
Co	Maximum content 50%.
Mo or W or both	Maximum content 20%.
Be	Maximum content 3%.
Ti	Maximum content 5%.
C	Maximum content 1.5%.
Mn	Maximum content 20%.
Si	Maximum content 4%.
Nb	Maximum content 6%.

Two preferred ranges of composition of the alloys are the following ones:

A

	Percent
Nickel	10–68
Iron	5–25
Chromium	10–30
Cobalt	0–50
Molybdenum or tungsten or both together	0–20
Beryllium	0.01–2
Titanium	0–3
Carbon	0–0.6
Manganese	0–4
Silicon	0–4
Columbium	0–6

B

Iron	95–99.5
Carbon	0.6–1.5
Silicon	0–1.0
Manganese	0–1.0

Amongst these alloys those consisting of the following compositions are to be preferred:

Type I

	Percent
Ni	10–68
Fe	5–25
Co	5–50
Cr	10–25
Mo or W or Mo+W	1–20
Be	0.1–2
Ti	0.1–3
C	0.05–0.6
Mn+Si	1–4

Type II

	Percent
Ni	50–68
Fe	5–25
Cr	12–25
Mo	0–20
W	0–20
Be	0–2
Ti	0–3
Mn	0–4
Si	0–4
C	0–1
Nb	0–6

As illustrative examples of specific alloys which may be used according to the invention, those having the following composition are mentioned:

Alloy 1

	Percent
Co	40
Cr	12
Mo	8
Ni	16
Ti	1
Be	0.8
Mn+Si	2
Fe	Remainder

Alloy 2

	Percent
Co	40
Cr	20
Ni	15.5
Mn+Si	2
C	0.015
Be	0.08
Mo	7
Fe	15

Alloy 3

	Percent
Ni	34.8
Cr	11.2
Fe	5.8
Mn	1.2
Si	0.3
W	5.6
Nb	4.0
Mo	---
Ti	2.4
Co	34.1

Alloy 4

	Percent
Ni	60
Cr	15
Mo	7
Be	1
Ti	1
Mn+Si	2
Fe	Remainder

Alloy 5

	Percent
C	0.1
Cr	4
Ni	8
Mn+Si	2
Fe	Remainder

Alloy 6

	Percent
C	0.2
Cr	8
Ni	4
Mn+Si	1
Fe	Remainder

Alloy 7

	Percent
C	0.6
Cr	4
Ni	8
Mn+Si	1
Fe	Remainder

In all the alloys the usual impurities may be present.

Hitherto spring bands of heat treated iron-nickel or iron-nickel-cobalt alloys, as also the commonly used steel bands, have been rolled to a minimum thickness in the form of a wide band, which is then cut into narrow strips. The modulus of elasticity of the bands so made was at most 21,000 kg./mm.^{2} for steel and 19,000 kg./mm.^{2} more often 17,000 to 18,000 kg./mm.^{2} for the modern iron-nickel-cobalt alloys which can be heat hardened.

One half of the same smelting of each of the Alloy 1 and Alloy 4 (see table above) was converted into spring bands using the broad band method, each of the other half having been made into wire using the wire method according to the invention. The bands and the wires were homogenised at the same temperature, say at 1000–1100° C., and quenched before the cold rolling. The wide bands were subjected to a heat treatment for maximum tenacity and tensile strength. Then the wide bands as well as the narrow strips rolled from the wire, were fully (about 90%) cold formed and rolled to a thickness of 0.1 mm. Test strips 0.1 x 1.5 mm. were prepared and their elastic properties determined after heat treatment. The wires were homogenised at a diameter of 1 mm., cold-worked or quenched to a diameter of 0.6 mm. and rolled to a thickness of 0.1 mm. The broad band was cut into narrow strips 1.5 mm. wide.

The results obtained were the same for Alloy 1 as for Alloy 4 and were as follows:

Test	Broad Band Method	Wire Method
1. X-ray examination of texture	No cube diagonal parallel to direction of rolling.	Concentration of direction 111 (cube diagonal) parallel to direction of rolling.
2. Modulus of elasticity (kg./mm.²)	18,000–18,500	21,200–24,000.
3. Permanent deformation after bending.	2° to 3°	1° to 2°.
4. Break by bending round sharp-edged angle of 90°.	55°–60°	80°–90° (some tests no break).

No orientation of direction 111 parallel to the direction of rolling is observed in the hitherto used springs or the springs made from the known Ni-Co-Fe alloys, which can be heat-hardened. The modulus of elasticity for the Ni-Co-Fe alloys rolled by the broad-band-method is 17,000 to 19,000 kg./mm.². The permanent deformation according to test 3 for the Ni-Co-Fe alloys is 2° to 3°.

Tests have further shown that a steel wire containing 0.6–1.0% C. for instance, which has been homogenised at a temperature of over 700° C. and then quenched to 400° to 600° C. by an isothermal process, mainly shows a troostite-sorbite-pearlite structure. This structure results in the preferred orientation during the cold-working and rolling of the strip, i. e. in the concentration of direction 111 and 110. In contrast, tests have shown that steel strips hardened by the martensite method do not show the preferable direction (111 and 110 in the direction of rolling). To obtain a sharply defined texture, the total degree of cold-working should reach 90% and more. The initial wire, after homogenising and cold-working should, depending on the diameter, have a tensile strength of between 180 and 260 kg./mm.². The strip cold-rolled from such a wire increases in sharpness of texture the more completely the cold-forming is carried out. Direction 110 is here mainly found in the direction of rolling and in the rolling-plane, direction 111 mainly in the direction of rolling and in an acute angle to the rolling plane. Such a texture rolling results in an increased value of the modulus of elasticity and of the elasticity limit. At the same time the position of crystals with direction 110 in the rolling plane and in the rolling direction, and the cube-surface in the rolling plane results in the maximum resistance against a break of the spring across the length of the strip.

The rolling of bands from the so-called "patented" wire is well known. These strips are rolled from wires which have a tensile strength of less than 200 kg./mm.². Sometimes heat-hardening is carried out between the single stages of rolling, or the material is tempered between the stages of rolling. "Patenting" also, i. e. hardening by the isothermal method, must be arranged according to the carbon contents in relation to the glow-temperature and the temperature of the quenching bath. The "patented" spring wire, as commonly used by the trade, is mostly not suitable for "texture rolling." For this reason the texture described above is only partly or not at all shown by the strips for watch-springs which have been rolled from "patented" wire. The importance of the formation of texture for watch springs has not been realised so far.

Further it has been determined that a spring with the best texture is produced when the iron-carbon alloy is used in the state of sorbite without martensite, and when the tensile strength of the cold-worked wire is more than 200 kg./mm.².

The following test was carried out with a cubic solid-centred iron-carbon alloy, containing 0.85% C. The steel wire, which had been homogenised under high temperature and quenched according to the "patent-method,"

was cold-worked to a tensile strength of 260 kg./mm.², and to a thickness of 0.6 mm. and then cold-rolled to a strip 0.1 mm. thick and 1.5 mm. wide. Heat-hardening at 250° C. for an hour was then carried out. The X-ray examination of the texture showed spot-reflexes, i. e. a very sharply marked texture with directions 111 and 110 in the direction of rolling, whereby direction 110 is found in the rolling-plane. Thereby the maximum value of the modulus of elasticity is found lengthwise in the spring. The strip, showing a hardness of 700 Vickers before heat-hardening, has a hardness of 820 Vickers after one hour's heat-hardening at 250° C. The modulus of elasticity was determined as 22,000 kg./mm.². Watch-springs made from this strip showed a stiffness of 840 gr./mm., which is more than the stiffness of a steel spring without texture hardening by the martensite process, and it does not show the brittleness of the same. The spring broke in the spring housing at 9,300 windings, in contrast to the steel springs of the same strength but hardened by the old method, which broke after 200 to 600 windings.

A second spring strip was also prepared from the same Fe-C alloy, in which a wire with a tensile strength of 200 kg./mm.² was cold-worked to a thickness of 0.6 mm. The strip rolled from this wire, 0.1 mm. thick and 1.5 mm. wide, showed a marked dispersion of directions 110 and 111 of the texture. This undefined texture showed a modulus of elasticity of only 19,500 kg./mm.² and a stiffness of the spring of only 700 gr./mm. The hardness of this strip was only increased by about 100 Vickers units after heat-hardening. This example illustrates clearly how an increase in the modulus of elasticity of more than 10% can be achieved by the use of the right ratio of the cold-working of the wire by drawing to the cold-working of the wire by rolling, resulting in strongly marked texture (direction of the maximum values of the modulus of elasticity in the direction of the band). So this example too of a cubic solid-centred alloy demonstrates the advance attained by the new method.

These comparisons convincingly show the superiority of the metal strips made by the new methods in contrast to the strips rolled according to the old methods of rolling on the broad band principle.

The composition of the alloy can indeed vary in respect of the carbon content, and the amount of the usual additions like manganese and silicon. The isothermal hardening will depend on the composition, and must aim at avoiding martensite.

It may be noted that the wire for the above mentioned alloys 5 to 7 inclusive too is hardened isothermally and the glow-temperature and the temperature of the quenching bath have to be arranged according to the composition of the alloy. They should be arranged so as to avoid the deposition of martensite, but not of troostite and/or sorbite, which are to be preferred.

Depending on the type of alloy, it can be of advantage to add niobium or titanium, singly or together, up to a total of 10% of the alloy.

Other possibilities are in no way excluded by the examples illustrated.

What I claim is:

1. A process for the production of flat springs comprising homogenising a wire of an alloy which is precipitation hardenable, specifically an alloy taken from the group consisting of steel alloys which are precipitation hardenable, iron-nickel-chromium precipitation hardenable alloys, iron-nickel-chromium-cobalt precipitation hardenable alloys, and nickel-chromium-cobalt precipitation hardenable alloys at a high temperature and quenching the said wire to an unhardened condition, drawing the quenched wire to reduce its cross section and, after decreasing the cross-section, rolling the wire to produce a flat strip, the total decrease in cross-sectional area by said rolling and drawing exceeding 80% and the decrease in cross section by drawing being a major part of the 80% decrease, the drawing and roll-

ing being for orienting the direction of the maximum value of the modulus of elasticity essentially in a direction parallel to the direction of rolling, and precipitation hardening the strip at a temperature of from 200° to 600° C. to give it a modulus of elasticity of at least 21,000 kg./mm.².

2. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Nickel	5–68
Iron	0–75
Chromium	10–30
Cobalt	0–50
Molybdenum and/or tungsten	0–30
Beryllium	0–3
Titanium	0–5
Carbon	0–0.6
Manganese	0–20
Silicon	0–4
Columbium	0–10

3. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Nickel	50–68
Iron	5–25
Chromium	12–25
Molybdenum	0–20
Tungsten	0–20
Beryllium	0–2
Titanium	0–3
Columbium	0–6
Manganese	0–4
Silicon	0–4
Carbon	0–1

4. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Nickel	10–60
Iron	5–20
Cobalt	5–50
Chromium	10–30
Molybdenum	0–20
Tungsten	0–20
Beryllium	0.01–2
Titanium	0–3
Carbon	0–0.6
Manganese	0–4
Silicon	0–4
Columbium (Nb)	0–6

5. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Nickel	5–31
Iron	0–18
Cobalt	20–50
Chromium	15–30
Molybdenum	0–10
Beryllium	0.01–0.1
Carbon	0–0.3
Manganese	0–3
Silicon	0–3
Columbium (Nb)	0–6

6. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Cobalt	40
Chromium	12
Molybdenum	8
Nickel	16
Titanium	1
Beryllium	0.8
Manganese+silicon	2
Iron	Remainder

7. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Cobalt	40
Chromium	20
Nickel	15.5
Manganese+silicon	2
Carbon	0.015
Beryllium	7
Molybdenum	7
Iron	15

8. Process as claimed in claim 1 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Nickel	34.8
Chromium	11.2
Iron	5.8
Manganese	1.2
Silicon	0.3
Tungsten	5.6
Columbium (Nb)	4.0
Molybdenum	0
Titanium	2.4
Cobalt	34.1

9. A process for the production of flat springs comprising homogenising a wire of a steel alloy which is precipitation hardenable at a high temperature, quenching the wire to the sorbitic condition, drawing the quenched wire to reduce its cross section and, after decreasing the cross-section, rolling the wire to produce a flat strip, the total decrease in cross sectional area by said rolling and drawing exceeding 80% and the decrease in cross section by drawing being a major part of the 80% decrease, the drawing and rolling being for orienting the direction of the maximum value of the modulus of elasticity essentially in a direction parallel to the direction of rolling, and precipitation hardening the strip at a temperature of from 200° to 250° C. to give it a modulus of elasticity of at least 21,000 kg./mm.².

10. Process as claimed in claim 9 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Carbon	0.01–1.5
Chromium	0–16
Nickel	0–16
Manganese+silicon	0–4
Iron	Remainder

11. Process as claimed in claim 9 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Carbon	0.1
Chromium	4
Nickel	8
Manganese+silicon	2
Iron	Remainder

12. Process as claimed in claim 9 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Carbon	0.2
Chromium	8
Nickel	4
Manganese+silicon	1
Iron	Remainder

13. Process as claimed in claim 9 in which the alloy has a composition (apart from impurities) within the following ranges:

	Percent
Carbon	0.6
Chromium	4
Nickel	8
Manganese+silicon	1
Iron	Remainder

14. A process for the production of alloys in strip form suitable for conversion into watch springs which comprises homogenizing at high temperatures a wire made from an alloy which is precipitation hardenable, specifically an alloy taken from the group consisting of steel alloys which are precipitation hardenable, iron-nickel-chromium precipitation hardenable alloys, iron-nickel-chromium-cobalt precipitation hardenable alloys, and nickel-chromium-cobalt precipitation hardenable alloys, quenching the wire to the unhardened condition, cold drawing the quenched wire to attain a reduction of the original of about 64–80%, rolling the wire to a flat strip with a total decrease in cross-section of at least 80% based on the original cross-section of the quenched wire, whereby the direction of highest modulus of elasticity in the flat strip is oriented substantially parallel to the direction of rolling.

15. A watch spring made of an alloy which is precipitation hardenable, specifically an alloy taken from the group consisting of steel alloys which are precipitation hardenable, iron-nickel-chromium precipitation hardenable alloys, iron-nickel-chromium-cobalt precipitation hardenable alloys, and nickel-chromium-cobalt precipitation hardenable alloys, quenched to an unhardened condition, subjected to cold drawing to about a 64–80% reduction in cross-section and then cold rolling to a total decrease in cross-section of at least 90% and precipitation hardened to give a modulus of elasticity of at least a 21,000 kg./mm.^{2} parallel to the direction of rolling.

16. The watch spring of claim 15 comprising a steel alloy quenched to a sorbitic state prior to the cold drawing.

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