# ALLOYS WITH SPECIFIED LINEAR EXPANSION COEFFICIENT FOR THE MACHINERY PARTS

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**Abstract**
Modern mechanical engineering widely uses steels and alloys which possess special properties, such as set conductivity, abnormally low resistivity at near absolute zero temperatures (superconductivity), semiconductor and magnetic properties, capacity to restore the form of an object, etc. Unusual properties of such materials are conditioned by a certain ratio of alloy components, peculiarities of their chemical structure and structural condition of phases entering their composition, their production and processing technology.

**Keywords:** Thermal linear expansion coefficient; semiconductor, high-resistance and magnetic materials; magnetostriction; thermal bimetals.

## 1. Introduction

Improvement of machines, mechanisms and devices necessitates development of materials with unique properties.
For example, advances in computer technologies, lasers, magneto hydrodynamic generators (MHD generators) initiated development of superconducting materials of a new type which have relatively high temperatures of normal-superconducting transition, sufficient raw materials sources, affordable production and processing technology.
Materials traditionally used in engineering such as semiconductor, high-resistance and magnetic materials as well as materials with specified thermal linear expansion

coefficient are constantly improving. Non-traditional approach to metal and alloy processing enabled the development of high-speed crystallization methods.

Quasi-stable amorphous state with singular structure of metal melt is realized at ultra-high speed of its cooling. Metals in amorphous state differ from those in crystalline state in increased strength characteristics and resistance to corrosive medium.

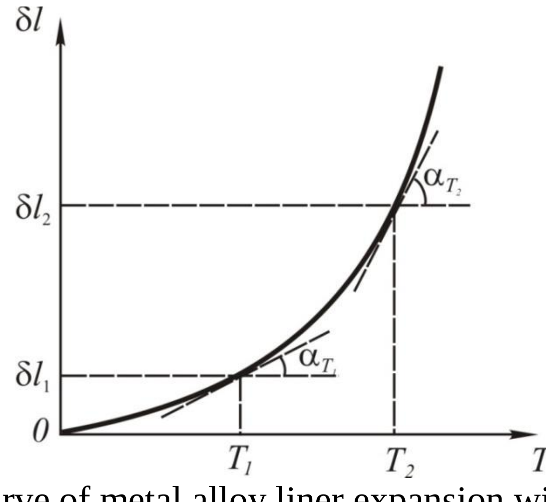
Thermal linear expansion coefficient (TLEC) of alloys which produce solid solutions (Kurnakov's alloys) changes non-linearly within the limits of TLEC values of alloy basic components depending on phase composition.

**2. Methods**

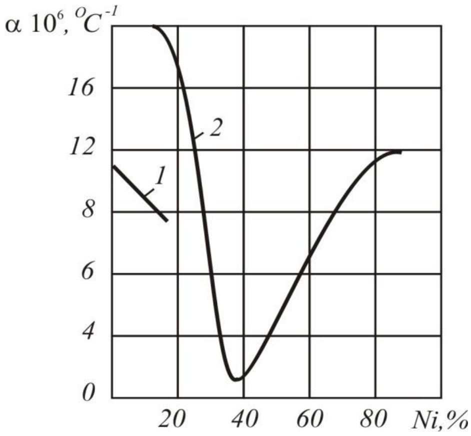
TLEC of metals normally rise with temperature growth. The picture 1 shows the temperature dependence of relative sample length increment $\delta l = \Delta l/l_0$, with $\Delta l$ and l being linear length increment and initial sample length. Slope angle $\alpha$ of tangent to curve relative to X-axis corresponds to TLEC values of metal samples under study.

For Fe–Ni alloys dependence of changes $\alpha$ from alloy composition is nonmonotonic (picture 2). It conditions the possibility to create materials with specified TLEC. The alloys with extremely little TLEC are called invar alloys.

The first invar alloy Fe–Ni (35% at.) was discovered in 1899 by Ch. Guillaume. Invar alloys have cubic lattice and are isotropic according to TLEC, that is the value $\alpha$ doesn't depend on atomic planes of lattice direction and sample texture orientation. Invar alloys have some specific physical properties. They are characterised by thermal coefficient of elastic modulus (TCEM) anomaly.




**Picture 1.** Typical curve of metal alloy liner expansion with temperature growth




**Picture 2.** TLEC dependence of Fe – Ni alloy on phase composition and nickel content. 1 and 2 – α- and γ- phases

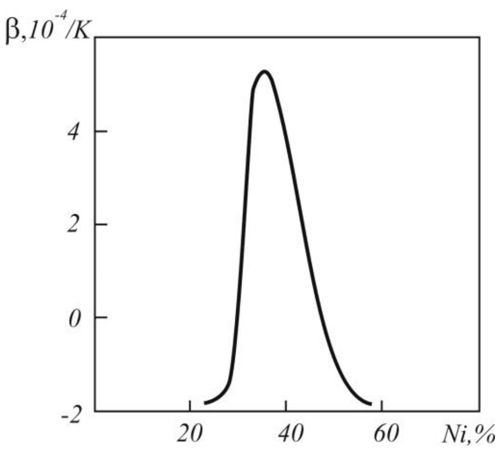
In all solid bodies including metals we observe decrease of elastic parameters which are the measure of interatomic interaction strength. Elastic parameters in invar alloys grow or remain constant with temperature growth.

Interestingly, the alloy of Fe–Ni composition which correspond to the lowest TLEC value has the maximum TCEM value (picture 3).

The alloys with elastic parameters which don't virtually depend on temperature can be developed by selecting chemical composition.

The alloys which keep constant elastic parameters at a specified temperature range are called elinvars. Abnormal change of TLEC and TCEM of invar alloys is connected to magnetic phase transition of their components.

Abnormally high values of spontaneous magnetostriction (which is size and shape change of samples at magnetization) are typical for invar alloys. When heated, magnetostrictive part of sample volume reduces; magnetostrictive deformations completely disappear above Curie temperature due to transition of the alloy to paramagnetic state. TLEC of invar alloy samples grow when heated but this growth is compensated by the reduction of magnetostriction. That is why the volume of samples doesn't change significantly when heated to Curie temperature. TLEC of such alloys can acquire negative values; that is why the volume of samples reduces when heated.




**Picture 3.** Temperature coefficient of Fe-Ni alloys elastic parameters

## 3. Results and Discussion

Tensile stresses and deformations caused by them change magnetic state of Fe–Ni ferromagnets (*mechanostriction*).

Mechanostriction in elinvar alloys is a factor which influences the change of elastic parameters at heating. Decrease of elastic parameters at heating which is typical for normal alloys is compensated by mechanostriction in this case; this leads to stabilisation of elastic parameters in elinvars at a wide temperature range.

Stable TLEC and TCEM values as well as special physical characteristics or rare combination of characteristics are typical for alloys with exact chemical composition which are carefully generated and contain minimum impurities. They are called precise alloys (Table 1).

**Table 1.** Content and properties of precise alloys

| Alloy brand | Content of components, %* | | | Indicators of properties | |
|---|---|---|---|---|---|
| | Ni | Co | Cu | $\alpha \cdot 10^6$, $°C^{-1}$ | Temperature interval of measurements $\alpha$, $^0C$ |
| 36Н (invar) | 35-37 | — | — | 1,5 | -60…+100 |
| 32НКД (superinvar) | 31,5-33 | 3,1-4,2 | 0,6-0,8 | 1,0 | -60 …+110 |
| 29НК (kovar) | 28,5-29,5 | 17-18 | — | 4,5-6,5 | -70…+420 |
| 47НД (platinite) | 46-48 | — | 4,5-5,5 | 9,0-11,0 | -70…+440 |

** Rest - Fe.*

The alloy 36H (invar) has good stress-strain properties; it is corrosion-resistant and manufacturable. In order to increase its service properties, it is hardened at 880$^0$C and drawn at 315$^0$C with further ageing.  This leads to formation of structure without residual stresses. Invar alloyed by cobalt produce superinvar.  It is used to join metal and glass parts with brazing and soldering. TLEC of superinvar and glass have close values at a wide temperature range. The alloy 29НК (29% Ni, 18% Co) called kovar is used in compounds with heat-resistant glass. When heated, a film which interacts with glass is formed on the surface of kovar parts. For non-heat-resistant glass the alloy 48H called platinite is used.

## 4. Conclusion

Thermal bimetals are widely used in instrument engineering; they are sheet material consisting of two layers of dissimilar metals and alloys with various TLEC.  They are produced by simultaneous rolling or pressing of two blanks. The alloys belonging to thermal bimetals have the brands 19НХ, 20НТ, 24НХ, 27НМ, 46Н, 45НХ, etc. Bimetal brands:

$$\text{ТВ}\mathbf{2013}\left(\frac{\mathbf{75}\text{ГНД}}{\mathbf{36}\text{Н}}\right), \text{ТБ}\mathbf{1613}\left(\frac{\mathbf{75}\text{ГНД}}{\mathbf{45}\text{НХ}}\right), \text{ТБ}\mathbf{1523}\left(\frac{\mathbf{23}\text{НТ}}{\mathbf{35}\text{Н}}\right).$$

The alloys which produce bimetals are given in brackets. Thermal bimetals are used in the production of thermal relays, compensators, fire alarm devices. Magnetostrictive thermal bimetals which deform with the change of external magnetic field have been developed.
Such materials are used in aeronautical instrument engineering.

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