

Low nickel content fcc alloys: recent evolution and applications

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For a century, Fe-Ni based fcc soft magnetic alloys have been studied and developed toward many applications. First of all, the Invar[®] and more generally the low and tailored thermal expansion coefficients, discovered at the end of the XIXth century by Ch.Ed. Guillaume and Imphy co-workers started the exploration of this alloy family. In the 1920's P.Chevenard [1] broadened this previous research field to the Invar alloys and the Fe-Ni-Cr ferromagnetic alloys such as Elinvar[®] with its noticeably stable elastic modulus with temperature. These early studies followed by many other ones in the world have drawn the rough framework for further alloy developments up to now. Taking into account the technology evolution from the standard meter (at the origin of Invar discovery) till recent evolutions in modern electric and electronic devices (quartz watches, modern transformer, advanced induction processes, watt-hour metering, energy saving actuators and sensors), the low nickel content fcc soft magnetic alloys have never stopped the innovation to conciliate efficiency, low raw element content and dedicated properties.

This paper deals with the recent development of such a Fe-Ni binary based family with the help of ternary and quaternary alloying additions (Cr, Cu, Mo), as examples of dedicated materials optimised for modern requirements, presented; a special attention will be paid to the following topics:

- low and very low nickel content with 0,7-0,8T polarisation to saturation and high dynamic permeability for clock motor parts: it is shown that this last feature can be reached without high grade 80%Ni content Permalloys (and their high DC permeability) in saturating stator parts.
- Following the first studies of Khomenko [2] and in order to reduce nickel content, new Fe-Ni-Cr-Cu alloys have been intensively studied. In a range of 28-32%Ni new fcc soft magnetic alloys exhibit rather high polarization to saturation (0,7 – 1,2T), with low coercive field and a high electrical resistivity.
- Merging from old Fe-Ni-Cr studies [1] and taking into account the needs of induction cookware for self regulated temperature, good corrosion resistance, and some thermal expansion coefficient consistent with the other clad materials, new industrial materials with well-controlled Curie point will be presented.

As a conclusion, ternary and quaternary alloying additions to Fe-Ni fcc low nickel content soft magnetic materials appears as some degree of freedom very suitable to conveniently design and optimise some new alloys with respect to modern applications (connected to the merging technologies) asking for low cost material, high dynamics, easy shaping, chosen Curie point and thermal expansion, properties stability with temperature ... so usual features reviewed with some extended use of alloying and application needs.

[1] P. Chevenard, Revue de Métallurgie, 25 (1928) p. 14

[2] O.A. Khomenko et al , Fiz. Metal. Metalloved, 26 (1968) p. 84