

Beyond stability & reliability

The development of 100 per cent Invar tuning screws and additional manufacturer in-house testing are taking components beyond the conventional limits for stability and reliability, as Charcroft's Roger Tall explains



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Beyond brass: 100 per cent Invar tuning screws

In high-frequency communications the performance of a microwave filter over temperature is becoming increasingly important, especially for narrow bandwidth high-frequency filters. The use of miniaturised cavity filters and higher Ka, Ku and Q-band frequencies demand higher thermal stability than is currently achievable with conventional brass tuning screws.

Of course there are other materials, such as Invar, which provide a lower Coefficient of Thermal Expansion (CTE or α) than brass but this presents other barriers, including a reputation for being almost impossible to machine.

In researching the possibility of manufacturing tuning screws in 100 per cent Invar, Exxelia Temex began by looking at the different alloys of nickel (Ni) and iron (Fe) used to create Invar.

Figure 1 shows how the change in the percentage of nickel in the iron-nickel alloy has an impact on the TCE of Invar. Between 0°C and 100°C, the lowest coefficient of thermal expansion and the highest stability of 1.1ppm K⁻¹ are achieved with 36 per cent nickel. At this ratio, Invar-36 achieves stability over temperature which is 17 times higher than brass.

The next challenge was to explore new manufacturing techniques which would allow Invar-36 to be machined with such precision that it could attain the level of miniaturisation demanded by high-frequency Space applications.

Exxelia Temex considered each aspect of the conventional manufacturing

process used for brass screws before developing a viable machining process for the Invar-36 screws. Whilst brass screws are typically machined in a single process, the equivalent Invar-36 screws needed to be machined up to seven times. This highly complex machining process, which included the option of gold plating, was the only way to guarantee a perfect thread quality and achieve the significantly higher precision and stability demanded by Space applications. Tuning screws manufactured in 100 per cent Invar, are shown in Figure 2.

Increasing stability with self-locking screws

The next stage of the development process was to introduce a self-locking mechanism to further increase the stability of the screw.

Two threaded segments, separated by two parallel slots, are used to create the self-locking mechanism. The two threaded segments are off-set by compressing the rotor, lengthwise, after the parallel slots have been incised into the material. The plastic deformation created by the compression generates a constant tensile stress in the rotor from the moment threaded segments are inserted and screwed into place.

The controlled torque delivered by the spring effect of the self-locking system ensuring a high electrical contact in addition to eliminating the need for an additional locking nut. The addition of a brass bushing, machined to provide an exact fit with the Invar rotor, can be used to ensure the best setting drift to allow for tight control of the screwing torque.

The addition of a self-locking mechanism enables Invar-36 tuning screws to achieve increased miniaturisation whilst also enabling higher precision by minimising slack during tuning.

Beyond space-level testing

Another area in which component manufacturers are going beyond the conventional limits is with in-house testing for space-grade components. These tests can be applied to MIL-PRF and Qualified Product Listing (QPL) components to ensure even higher levels of reliability but this can be a complex decision for engineers.

The complexity is compounded by the fact that the standard and optional tests are not consistent within each product type, such as tantalum or ceramic capacitors, but vary between different product families within product type.

One example of this is Kemet's QPL-grade M123/x and GR900 multilayer

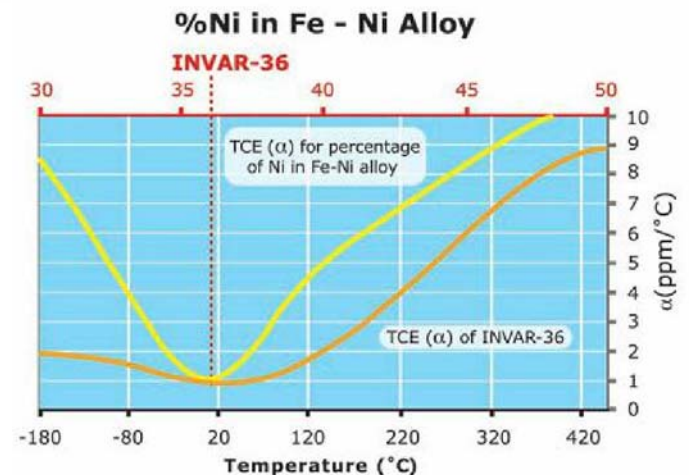


Figure 1: Coefficient of Thermal Expansion (CTE or α) of Invar-36

ceramic chip capacitors in which C-Mode Scanning Acoustic Microscopy (C-SAM) is a standard test for the M123 parts but optional for the GR900 family.

In a move designed to simplify the testing options, Kemet has created three test groups which include between 10 and 25 individual tests in each category. Each of these standard test groups also offers additional test options and, sometimes, further tests may be added which do not appear in either the standard or optional tests. As designers are faced with balancing the risk of component failure, and

potentially the mission, against the additional cost of testing these test groups, in addition to specialist technical support, can help to simplify a complex decision.

The ability to go beyond the limits of brass tuning screws in high-frequency Space applications, and beyond the standard test protocols for Space-grade components, is a significant step in helping to ensure higher stability and reliability for systems designed to operate outside the boundaries of our planet.

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Figure 2: 100 per cent Invar tuning screws for high-frequency Space applications