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TechNote
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Why Single-Piston Compressor?

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Most of the modern commercially available tactical split Stirling linear cryocoolers rely on a dual-piston, internally counterbalanced compressor, and a single-piston resonant pneumatic expander interconnected by a flexible transfer line.

The industry adopted this concept in the late 90s when cryogenic technology reached the maturity level sufficient for integration with inherently vibration-sensitive cryogenically cooled infrared detectors.

In the dual-piston compressor, the vibration export is, to a specific extent, counterbalanced by the opposite motion of the 'should be similar' moving sub-assemblies.

In the expander, the imbalanced motion of the displacer assembly generates vibration export, which is inherently small because of the relatively low weight of the moving assembly. It is interesting to note, nevertheless, that the vibration export produced by such an expander may be higher in comparison to the dual-piston compressor and, therefore, cannot be disregarded.

In the most general case, the vibration export produced by such a cryocooler comprises force and moment components. The resulting cryocooler-induced vibration, therefore, comprises translation and tilt eventuating, in some cases, in the excessive line of sight jitter. It is worth noting that vibration export produced by the expander may be a major contributor to the tilting components of cooler-induced vibration resulting in smeared imagery.

The penalties of using the dual-piston concept are many:
- Increased cost of BOM because of the doubled amount of mechanical components
- Increased size, weight, and power consumption as compared with a single-piston compressor having the same acoustic power output
- Increased cost of labor because of the need for mechanical and dynamical matching of sub-compressors
- Deterioration of initial (factory) counterbalancing because of uneven wear and contamination build-up in rubbing piston/cylinder seals
- Central location of the transfer line results in additional constraints imposed on the module packaging

By saying all this, CryoTech claims that:
The upcoming infrared imagers are highly sensitive to vibrations and have high-resolution and small-pitch, high-temperature detectors. **However, they use a dual-piston compressor, which is not cost-effective and cannot be considered the best solution for vibration control anymore.**

CryoTech adopted a complex approach to developing **cost-effective** and low-vibration cryogenic technology.

Our novel product includes a single-piston compressor with a unique 'inverted' moving magnet actuator. This actuator has a built-in magnet spring (which is currently pending patent) and features an edgewise driving coil having a 90% copper fill factor and a split magnet system that includes both static and moving components.

In this design, we reduced the weight of the moving magnets but compensated for it by adding weight to the stationary magnets and coil copper. In this concept, static magnets are used not only for the construction of the magnet spring but also for contributing to the favorable bias magnetic flux in back iron and air gaps.

Thus, without affecting performance, **the weight of the moving assembly in the compressor was substantially reduced.**

We have developed a plunger-less displacer (patent pending). This displacer has a regenerator made of nylon microfiber and a magnet spring.

By getting rid of the usual metal differential pneumatic driver mechanism and anchoring features of the typical metal support spring—and replacing the metal stacked screens in the regenerator with nylon microfiber—**we have significantly reduced the weight of the moving displacer assembly.** As a result, the amount of vibration export is now extremely small.

Therefore, the vibration export produced by CryoTech's cryocooler comprises the force component primarily; the tilting component in the cooler-induced vibration may be practically eliminated.

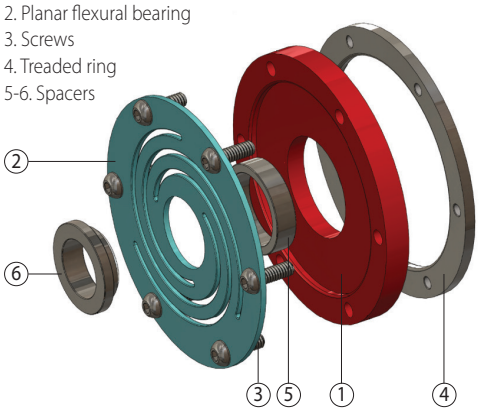
The result: The vibration export consists mainly of the force component, and it is possible to almost completely eliminate the tilting component in the cooler-induced vibration.
This allows using CryoTech's cryocooler as is in a wide range of applications as is.
For vibration-sensitive applications, CryoTech offers an optional low-weight and low-cost tuned dynamic absorber. This technology reduces the cryocooler-induced vibration levels to even lower levels than what can be achieved by competing technologies.
The **advantages** as compared with dual-piston topology are many:

- Lower cost of BOM and labor
- Better performance (cooldown time and power consumption)
- Higher yield
- Convenient side connection of transfer line, offering more flexibility in module design
- More options for effective vibration control

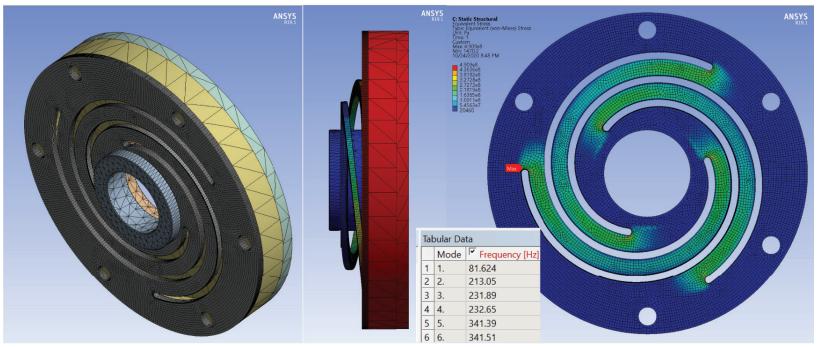
Practical implementation of tuned dynamic absorber (TDA)

Mechanical design

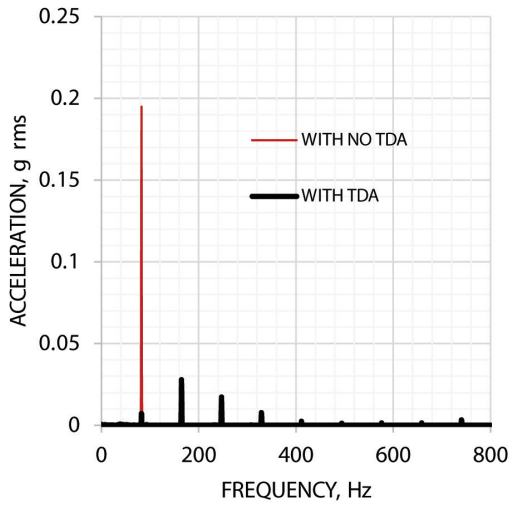
1. Proof ring
2. Planar flexural bearing
3. Screws
4. Treaded ring
5-6. Spacers



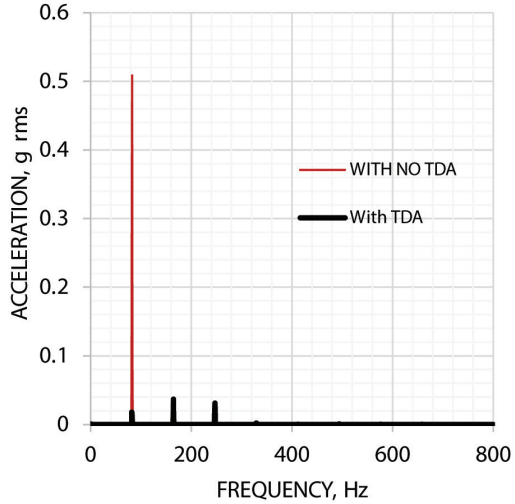
Finite elements analysis



Attainable performance (2kg platform)



30- fold attenuation of axial vibrational component:
19 µm rms to 0.6 µm rms



28-fold attenuation of lateral vibrational component:
7.25 µm rms to 0.26 µm rms