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# Executive Summary Report

on project:

# Improvement of Reliability and Lifetime of Rotary Type Stirling Coolers

## ESA Contract No. 4000134671/21/NL/GLC/rk

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| Prepared by: dr. Aljaž Osterman | Approved by: Franc Megušar |
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For: **ESA**
Contractor: Le-tehnika d.o.o., Kranj

# 1. OVERVIEW

LE-TEHNIKA develops and produces miniature Stirling cryocoolers for cooling IR detectors to temperatures in range of 77K for ground applications. Such cryocoolers are of interest for emerging commercial space industry where relatively cheap cooling is needed, provided that their lifetime and reliability are sufficiently high. Since demands for ground applications are less demanding, improvement of existing cryocooler design was needed to make it suitable for space.

Project started with a root cause analysis where failures of coolers were analyzed to find their root causes. Based on them, further analyses and tests were done with aim to eliminate them or apply countermeasures. Outcomes were used in the next phase where a concept of an improved cryocooler was made. After the concept was justified and confirmed, a design was made and prototypes were built. Testing of prototypes confirmed that design modifications had no impact on cooling performance which remained the same.

# 2. ROOT CAUSE ANALYSIS

Failures of the same type were grouped together in categories. Main categories covered working gas leakage, noise and increased friction between pistons and bushings. Root causes were searched for with 5-why and Ishikawa methods. Increased friction between pistons and bushings resulting in damage of sliding surfaces and eventual stop of operation remained the biggest challenge as the root cause was not found whereas for the other failures root causes were successfully identified.

# 3. TESTING

For leakage, solution focused on improving clean room workspace. For noise, preload of bearings and reduction of gaps in bearings were identified as a way forward. The greatest effort was put in better understanding and solving of failures between pistons and bushings. On a design level, different bearing arrangements were investigated. Next, a bearing testing unit was made to evaluate bearing performance independently from the cooler. Further on, measurements of vibrations and induced forces were done and axial displacements of a shaft were measured. On a lower level, geometry of pistons and bushings was analyzed and series of tribological test were done. Samples with different hard coatings were obtained and they were tested on a pin-on-disc tribometer. Several coatings were identified as promising candidates for prototypes.

# 4. PROTOTYPES

Based on previous testing and analyses, several design changes were proposed for a design of





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an improved cryocooler. Benefits were weighted against weaknesses for selection in the final design. However, considering bearing lubrication and hard coating, amount of information was not sufficient to make a single decision so several design variants were proposed. At the end, three variants were selected for prototypes:

A – ball bearings with phenolic cage impregnated with vacuum oil and DLC hard coating on pistons,

B – ball bearings lubricated with vacuum grease and DLC hard coating on pistons,

C – ball bearings lubricated with vacuum grease and TiN hard coating on pistons.

Two prototypes of each variant were built. Measurements of cooling performance showed no specific difference between variants. Cooling performance also remained at the same level as in standard cryocoolers for ground applications over the whole range of operating temperatures from -40 to +71°C.

# 5. KEY NEXT STEPS

Prototypes built during the project will be put on a life test as a part of LE-TEHNIKA internal project. In this way, variants will be compared on the basis of achieved lifetimes and the one with the highest lifetime will be selected for the final design. Expected duration of the life test which already includes some acceleration is around 2 years. During that time, LE-TEHNIKA aims to develop electronics of the cryocooler suitable for space and a solution for a waste heat dissipation in vacuum. For this, another project with ESA will be proposed, it cost is estimated to 570.000€ which includes development to TRL6 and improvements in production to increase reliability.

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