Flexible Thermal Link for Space Based Cryocooler: A Review

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Abstract— Flexible Thermal Link plays very crucial role in the cryogenic component for transfer the heat. The purpose of these links is to provide a means of transfer the heat from a hot surface of cryocooler to the cold reservoir. Because of high heat dissipation component in cryocooler, skin temperature of cryocooler increases and it can be reason for lowering performance and reduce its life during work in satellite. Therefore flexible thermal link should be good in thermal performance in other low thermal resistance and also should have enough flexibility. This could maintain skin temperature of cryocooler and resist the vibration which comes on the cryocooler in satellite. Also flexible thermal link should have its flexibility, durability, and mass constraints. The present states of developments of flexible Thermal Links for space based cryocooler are reviewed in this paper. In the past years new research on these flexible thermal links has developed to vitally improve them and make suitable for even more applications.

Key words: Flexible Thermal Link, Encapsulate, Thermal conductivity

I. INTRODUCTION

In recent years cryocoolers are being used to cool the electronic components in satellite. Because of high heat dissipation, temperature of crocooler's skin temperature increases which is the reason for reduction in performance and life of cryocooler in space. Here, flexible thermal link can be beneficial for removing heat from skin of cryocooler. A flexible thermal link can be made under various circumstances. A flexible thermal link should have some specific properties which turns it into a good heat transfer device. When flexible thermal link is designed then important factor is material selection. There are many material which has good thermal conductivity, low thermal resistance, enough flexible. Materials like Graphite sheet, Aluminum, copper, Carbon fiber etc. They have good properties which are listed in table [1], and comparison between Al and copper shown in table 1[6] but weight matters in space application. So according to application material can be selected. Second factor is, which form of link can be provide flexibility so C shape, S shape [2] straight long [1] can be better idea for it. And also with together two material can be used by encapsulated method [1]. After selection of material and shape of the flexible thermal link. Third vital thing is connection of both side of link with end block. Link and block should have highly in contact which can give better heat transfer. So for that soldering is one method but there are some disadvantages which cannot be used in space [2].Another method is swaged method [2]. After the fabrication and assembly of flexible thermal link, it needs to be tested for thermal performance, flexibility, vibration qualification test. Testing setup of thermal testing can be set in different ways [2] and flexible testing setup [2].Many author shown result in terms of thermal conductance, resistance and stiffness.

II. DESIGN OF FLEXIBLE THERMAL LINK

The main aspect is design, many author have taken their own design in papers. An author has used carbon fiber type K1100 which has thermal conductivity 1000W/°C at 300K and 292W/°C at 100K in fiber axis [5]. In figure.1 [5], a sample of carbon fiber have been manufactured and tested to proved feasibility of proposed design. And finally design has been selected by author where feature of design is six carbon fiber bundles with free 60mm length and 43mm core diameter. About 2 million fibers have been used with 10 micron diameter. Here, a Mylar foil wrapped around the link to eliminate the potential contamination of environment due to carbon fiber particles.

Fig. 1: Carbon fibre sample [5]

Another author has designed, fabricated, and tested an aluminum foil thermal link. Design requirements and achieved performance characteristics are in below table 1.

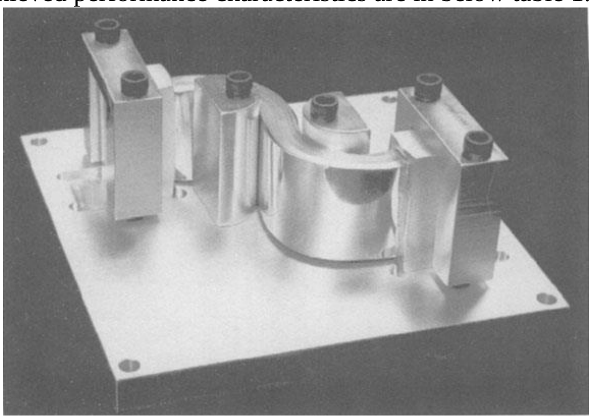


Fig. 2: Photograph of the completed aluminum foil thermal link [2]

Specification	Design Required	Achieved
Thermal Resistance	2.2 K/W @ 77 K	1.9 K/W
Mass	< 100 g	63 g
Diameter	< 50.8 mm	achieved
Flexibility X axis	< 50.8 mm	1.85N
Flexibility Y axis	7 mm deflection	0.8N
Flexibility Z axis	per axis	0.75N

Table 1: Design Requirements and Performance Characteristics of Aluminum Foil Link [2]

Author of K Technology Corporation has designed Encapsulated APG thermal strap. The specification included, in part, the mounting configuration, thermal conductance and structural requirements. A thermal strap was designed to satisfy this specification. The strap consists of 3 encapsulated APG foils terminated at each end by machined aluminum bulkheads.

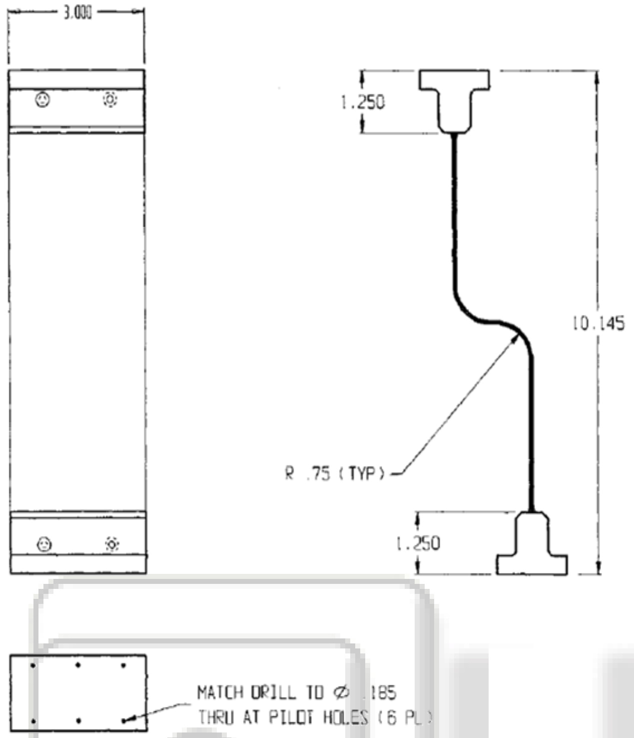


Fig. 3: Encapsulated APG thermal strap schematic [1]

Based upon the measured thermal properties and the observed flexibility of the test coupons, a thickness of 0.020 inch was selected for the encapsulated APG panels for the thermal strap design. A schematic of the thermal strap is shown in Figure 6.The 12" long strap has a designed conductance of 0.43 W/°C. [1]

Thermal strap can be designed and fabricated .It formed by fibers or foils and comprising a flexible middle section (10) and two rigid end parts (12). The fibers or foils are embedded in a rigid matrix material thus forming the rigid end parts (12). [7]

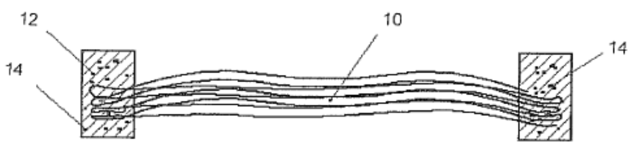
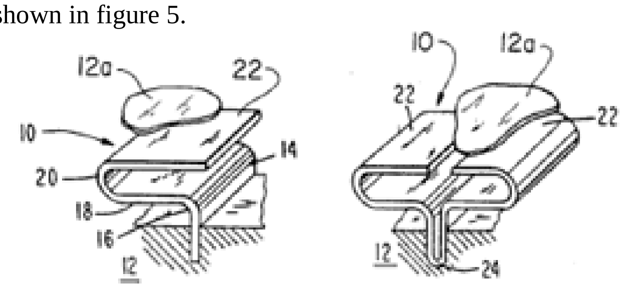


Fig. 4: Flexible Thermal strap [7]

Some of authors have also used these shapes for better flexibility as well as thermal conductivity which are shown in figure 5.



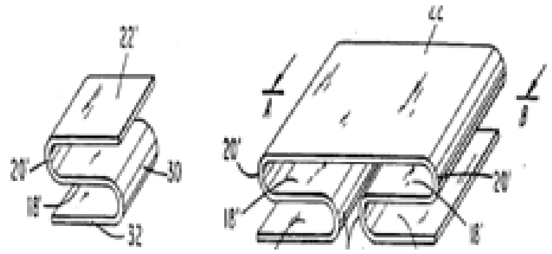


Fig. 5: Different type of shapes and design of thermal link [8]

An author has tested fabricated link is placed inside a cryogenic vacuum test Dewar (see Figure 6) for Thermal evaluation. One end of the link is then attached to the dewar's cold finger and the other is suspended from the top of the dewar by a piece of Kevlar 49 thread which acts as a thermal isolator so negligible amounts of conductive parasitic heat load make it into the link on the end opposite of the cold finger, a small electrical resistance heater is attached to simulate an instrument heat load. The entire thermal link is then insulated with multilayer insulation (MLI) to minimize undesired radiative loads or losses. The power source for the electrical heater is turned on and set to a predetermined value as measured by digital voltage and current meters (refer to Figure 6). Once steady-state is achieved, the temperatures at each end of the link are recorded. This procedure is then repeated for several different electrical power levels. [2]

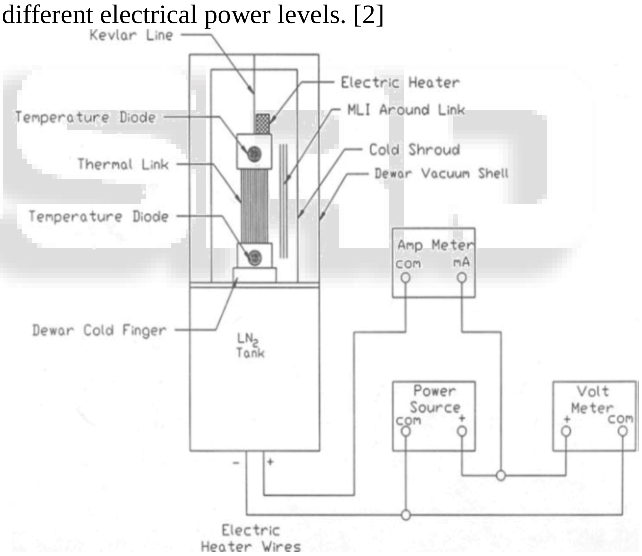


Fig. 6: Schematic diagram of thermal conductivity test setup including wiring schematic heater Power supply and digital volt meters [2]

Many authors use this kind of setup to check thermal performance of thermal link.

III. FLEXIBILITY TEST

A static flexibility test is performed on the link to determine the force required to displace the link a given amount in the x, y, or z direction. Depending on the application, the test procedure is as follows: the link is placed in a testing fixture, known as a "flex jig" (see Figure 3 for a schematic); one side of the link is bolted down to the jig and the other to a precision scale capable of milligram measurements. The plate of the flex jig in which the link is attached is displaced the desired amount, as measured by a dial indicator. Once the plate has been moved, the new reading on the scale is compared to the zero displacement reading; this difference is the weight required to move the end of the link and can easily be converted to Newton of force. This process is repeated for a negative deflection. [2]

Since the flexibility of the link is desired in all three axes, and the flex jig only moves in the one direction, the link must be rotated and the scale placement adjusted to measure the other two directions.

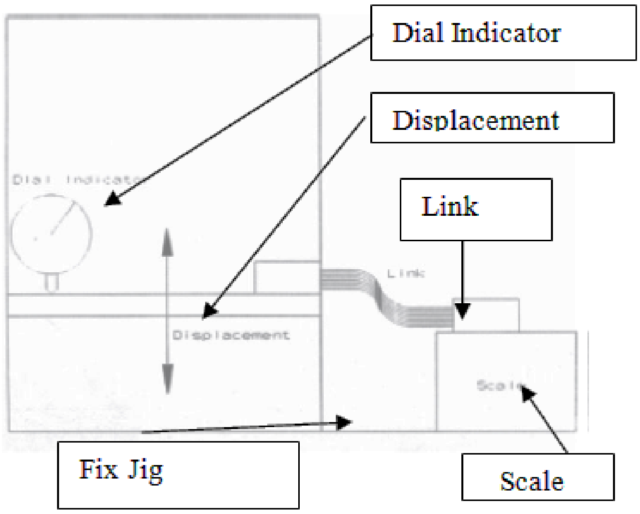


Fig. 7: Schematic of test setup for flexibility measurement. [2]

IV. CONCLUSION

Flexible thermal link maximize Thermal conductance Dynamic/mechanical flexibility and provide high performance affordable solutions. Also it eliminates joining materials including solder, internal contact resistance, wicking into braid/foil out gassing.

Pyrolectic graphite sheet, aluminium, copper are generally used as thermal link because of its high thermal conductivity.From the review of published study, the patented APG Configuration encapsulation technique creates a gliding contact between the APG core and the encapsulate. The high in-plane along with the low through the thickness strength of APG result in a material with little bending stiffness. This property combined with the thin flexible foil encapsulates yields a highly conductive flexible material ideally suited for the stated application.

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