Thermal Interface Material Tester Report

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Date

Introduction/Motivation

The Power Electronics Building Block (PEBB) is envisioned to be a replaceable unit in the Navy Integrated Power and Energy Corridor (NiPEC) [1]. To ensure heat is efficiently transferred out of the system a thermal interface material (TIM) must be used, one which can be easily installed onto the PEBB.

Pyrolytic Graphite Sheet (PGS) is a non-adhesive TIM, allowing users to easily replace it when installing PEBBs. TIMs generally have higher thermal conductivity when under greater pressure due to (give reason, read some stuff). There is known information on PGS at high pressures on its data sheet [2], however the PGS will be under low pressure, under 10 PSI, when in the NiPEC system. To determine the thermal properties of PGS at low pressures a TIM Tester was designed to test the thermal conductivity of the material under various amounts of pressure.

Background

The design of the TIM Tester was based on previous experimental testing rigs. Carlton determines the thermal properties of thermal paste, an adhesive TIM, by using an apparatus with two rods of known temperature gradients which compress the paste to a given pressure using a load cell and linear actuator [3].

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| Diagram  Description automatically generated |  |
| Figure 1: Diagram of Carltons conductivity tester setup and picture of physical test setup [3] | Figure 2: Rendering of our TIM Tester design (add labels and update image) |

Add discussion of the other paper you cited (Bulinski et al.). Also, look at ASTM D5470. Are there other pertinent standards?

Design

Our TIM Tester is closely modeled after Figure 1 using a vertically actuated load instead of a horizontal one as shown in Figure 2. The decision to make the apparatus vertical instead of horizontal was due to the intended material which will be tested. PGS is non-adhesive making it more difficult to mount the material to the compressing rods in a horizontal configuration.

The apparatus will consist of two aluminum rods which compress the PGS. The bottom rod will be mounted to a cold plate which will constantly transfer the heat out of the system. The top rod will have a heat cartridge placed inside of it, heating the rod to a constant temperature. Both rods will have 3 thermocouples embedded in them to read the temperature gradient across the system when compressing the PGS. The top rod will be mounted to balsa wood which will act as an insulating barrier between the rod and the load cell. The load cell will be mounted to an aluminum platform which will raise and lower using two lead screws. The lead screws will be driven by a pulley system using a singular stepper motor mounted at the top of the apparatus.

Please include annotated diagram of test rig and a list of parts/part numbers. The list can be in an appendix.

Please discuss thermal conductivity at interfaces.

(Create a Circuit Diagram to add) An Arduino Uno will be used to control the TIM Tester. The stepper motor needs a motor controller to communicate with the Uno. This motor controller will be used to tell the motor when to raise and lower the platform. The load cell will send force data to the Uno which will determine when the platform should stop given the desired pressure. The thermocouples will constantly send data to the Uno allowing the user to determine when the temperatures of the rods have reached equilibrium. This is when the temperature gradient will be used to calculate the thermal conductivity of the material. The goal is to have the software take a desired pressure as an input and output the thermal conductivity over time. There should also be an option allowing the user to cycle the pressure over time.

The TIM Tester is designed to calculate the thermal conductivity of material due to a given pressure. This will be done by taking the temperature gradient across the rods when the material is under the given load. This temperature gradient can be used to calculate thermal conductivity by (cite Carlton math). The system can also be used to test the material under cyclical loading. The final test that the system can perform is a compression test without using any thermal applications to determine material properties of the subject.

What pressure is the tester designed to achieve? How sensitive is the measurement of pressure and temperature? How do you calibrate the sensors? What are the challenges, difficulties, likely sources of error?

References

[1] Cooke, C. M., Chryssostomidis, C., and Chalfant, J., 2017, “Modular Integrated Power Corridor,” *2017 IEEE Electric Ship Technologies Symposium (ESTS)*, IEEE, Arlington, VA, USA, pp. 91–95.

[2] “Products Catalog,” p. 48.

[3] Carlton, H., Pense, D., and Huitink, D., 2020, “Thermomechanical Degradation of Thermal Interface Materials: Accelerated Test Development and Reliability Analysis,” Journal of Electronic Packaging, **142**(3), p. 031112.