Validation of Pressure Sensitive Adhesive as Alternative Accelerometer Attachment on Aluminum Alloy Jig under Vibration Test with Temperature and Axis Variation

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ABSTRACT

Validation of accelerometer attachments is performed on pressure sensitive adhesive to attach to the aluminum alloy jig. Conditions of the vibration test is 10Hz to 2000Hz with maximum acceleration value of 331m/s^2 for the 6-hour duration parallel to the vibration axis along x-axis and z-axis under temperature conditions 23˚C to 60˚C at a ramp rate of 1˚C every 6 minutes. The random vibration methodology follows the ISO 16750-3 under method 4.1.2.10.2.3 for maximum r.m.s. acceleration. Degradation of attachment was detected at about 60˚C starting at 500 Hz.

1. 0 INTRODUCTION

Vibration testing is an important reliability test to determine the mechanical strength of electronic assemblies. Accelerometers are attached to the device under test (DUT) and jig to monitor the vibration condition instantaneously. The fidelity of the detected signal is directly connected to the stiffness of the accelerator attachment. Commonly used mounting methods are cyano-acrylate adhesive or screw. Cyano-acrylate adhesives are difficult to remove from the surface of the accelerometer and the jig. Screw mounting creates permanent damages on the DUT that may affect its vibration behavior. An emerging alternative is the use of pressure sensitive adhesives. Previous paper attempted to validate the use of pressure sensitive adhesives at extreme vibration conditions along the z-axis. Adhesion between accelerometer and aluminum alloy-based jig will be tested using frequency and acceleration amplitude in severe test conditions based on ISO 16750. This paper attempts to determine the response of the adhesive in holding the accelerometer positioned at x-axis, z-axis under various temperatures.

2.0 REVIEW OF RELATED WORK

Adhesives are used to bond surfaces of two solid materials. Generally, the two kinds of adhesion are mechanical adhesion and chemical adhesion. Mechanical adhesion happens when the adhesive penetrates through the pores and crevices of the surface while in chemical adhesion, intermolecular forces are acting between the adhesive and the solid surface. The intermolecular forces can be covalent or Van der Waals. Double sided tapes are pressure sensitive adhesives (PSA) that can adhere to almost any surface. It contains tackifying resins that hold the surfaces together. The polymers used for pressure sensitive adhesives are acrylics, styrenic block copolymers and natural rubber[1].

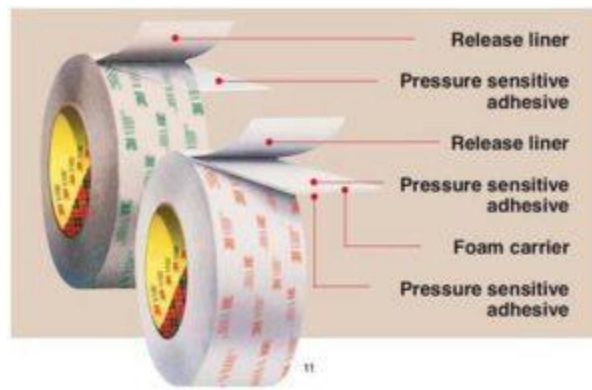

Fig. 1. Typical structure of pressure sensitive adhesives.[2]

Typically, there is a foam carrier where the adhesives are applied. A release liner is included to protect the adhesive from contaminants. Natural rubbers are formulated with tackifying resins, oils, and antioxidants.

Accelerometer is a piezoelectric device that is sensitive to vibration. A high sensitive charge accelerometer type 4383 specifically designed for general purpose high sensitivity vibration measurements. Frequency range covered is 0.1 Hz to 8400 Hz, and maximum operational level of 2000 g, where g is the acceleration due to gravity.

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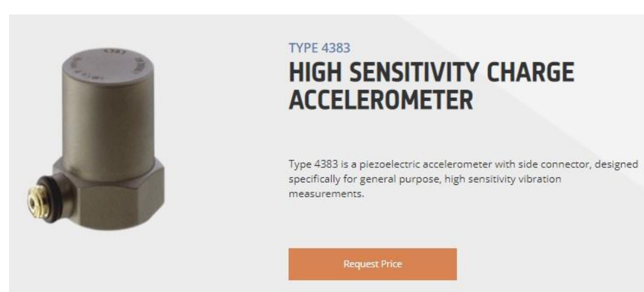


Fig. 2. Sample of a High Sensitivity Accelerometer.[3]

The adhesives used for PSA Tapes are rubber, acrylic, and silicone. Rubber adhesives which are based on natural or synthetic rubbers and formulated with tackifying resins, oils, and antioxidants. Rubber is the most cost-effective PSA and offers quick stick capability. Rubber adhesive is not recommended for high heat applications. Acrylic adhesives formulated with acrylic polymers and generally have a better long-term aging and more resistance to solvents and environmental factors. Acrylic adhesives typically develop a stronger bond than the traditional Rubber adhesive and can take higher temperatures. Silicone is formulated with Silicone polymers and the only adhesive that will bond well with silicone substrates. Silicone adhesives are relatively expensive and have a very low initial tack but can withstand higher temperatures than both rubber and acrylic adhesive[2].

2.0 EXPERIMENTAL SETUP

PSA brand B is tested at various conditions since it exhibited the highest pull strength[3]. Two accelerometers are mounted on the jig at *x*-axis and *z*-axis using PSA brand B and stud. Previous paper reported that no detachment of accelerometer occurred during the *z*-axis vibration at ambient temperature[3]. Table 1 shows the test conditions to validate the PSA.

Table 1. Accelerometer mounted using PSA brand B and stud along x-axis and z-axis

Mounting Material	*x*-axis	*z*-axis
Stud	Ambient to 100˚C at a rate of 1˚C every 6 min	Ambient to 100˚C at a rate of 1˚C every 6 min
PSA Brand B	Ambient to 100˚C at a rate of 1˚C every 6 min	Ambient to 100˚C at a rate of 1˚C every 6 min

As a test, the experiment requires an opposing force (accelerometer sensor) of mass *m* to be attached to the jig via the pressure sensitive tape. The mechanical movement of the attached (accelerometer sensor) mass will act as an opposing force whose magnitude is equivalent to the force of adhesion of pressure sensitive adhesive. Refer to Figure 3 for the diagram of these opposing forces.

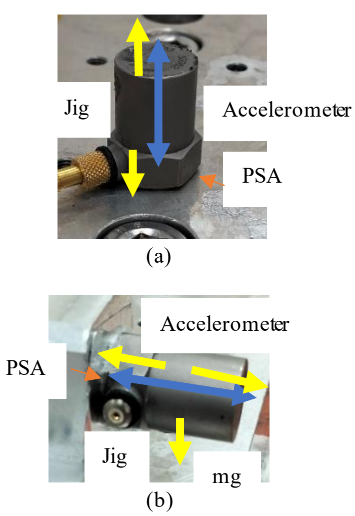


Fig. 3. The direction of the opposing forces in yellow arrow. Vibration direction along the (a) *z*-axis and (b) *x*-axis in blue arrow. The downward force *mg* is orthogonal to the vibration direction along the *x*-axis and is parallel in the vibration direction along the *z*-axis.

2.1 Materials

The PSA material used in the experiment is shown in Fig. 4 while the associated accelerometer is available in Table 2.

Fig. 4. Pressure sensitive adhesive for accelerometer attachment

Table 2. The accelerometer 4383 and associated weight

Accelerometer Part ID	Weight			Average
4383-A	17.6	17.6	17.7	17.63
4383-B	17.7	17.6	17.6	17.63

2.2 Equipment

The equipment to be used in the experiment is a vibration system consisting of three (3) the main units: Vibration controller (computer with signal and filter banks), Power amplifier and the Vibration Generator (shaker). The computer applies the required signal parameters. These signals are amplified through the Power amplifier before going into the electrical-to-mechanical conversion via vibration generator. In this set-up, a control feedback accelerometer is attached to the vibration generator. The stud mounted accelerometer is used as the feedback accelerometer and a reference point in the experiment. Detachment of the stud mounted accelerometer is unlikely to happen throughout the experiment.

Fig. 5. IMV vibration machine setup installed in IMI-ATC

2.3 Procedure

A single aluminum alloy jig is used to mount each accelerometer. Each individual accelerometer is attached to the jig as shown in Fig. 6.

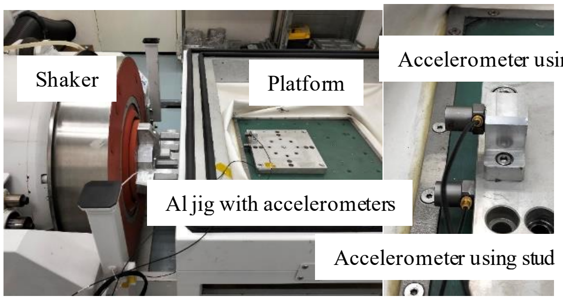


Figure 6. Pressure sensitive adhesive evaluation set-up along the x-axis.

Figure 7. Thermal chamber covered the platform.

Figure 7 illustrates the platform covered with thermal chamber to facilitate temperature control while vibrating. Accelerometer mounted in PSA brand B are each attached at their respective location such as in Fig 8.

Fig. 8. Accelerometer and PSA attachment configuration.

The vibration levels for the experiment are shown in Fig. 9. These are taken form the ISO 16750-3 under method 4.1.2.10.2.3. Table 3 indicates the frequency versus PSD according to ISO 16750-3.

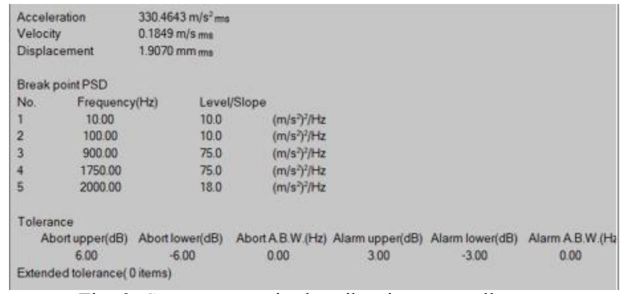


Fig. 9. Set-up screen in the vibration controller.

Table 3. ISO 16750-3 random vibration method 4.1.2.10.23[4]

Frequency (Hz)	PSD [$(m/s^2)^2/Hz$]
10	10
100	10
900	75
1750	75
2000	18

3.0 RESULTS AND DISCUSSION

Each of the of the down points results are recorded at periodic intervals to detect signs of detachment. No signs of detachment were noted until about 60˚C. Refer to Table 4.

Table 4. Summary of results observed at selected time and temperature interval.

Mounting/Axis	**Result @ 23℃**	**Result @ ~40℃**	**Result @ ~60℃**
Stud/ x-axis	No detachment	No detachment	No detachment
Brand B/ x-axis	No Detachment	No Detachment	Onset of detachment
Stud/z-axis	No detachment	No detachment	No detachment
Brand B/z-axis	No Detachment	No Detachment	Onset of detachment

The temperature in the chamber is increasing at a rate of 1˚C every 6 minutes while undergoing random vibration as shown in Fig. 10.

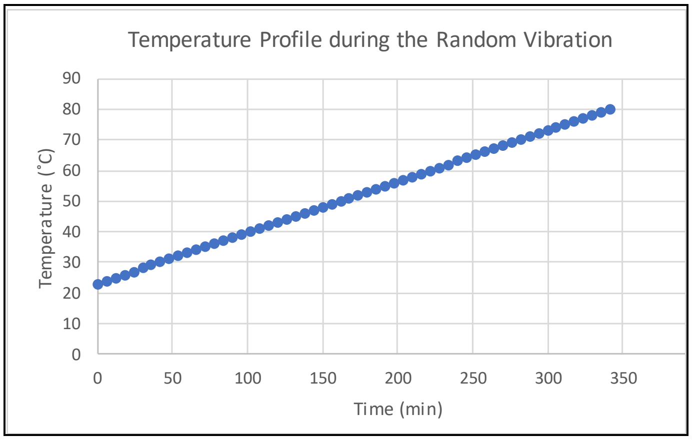
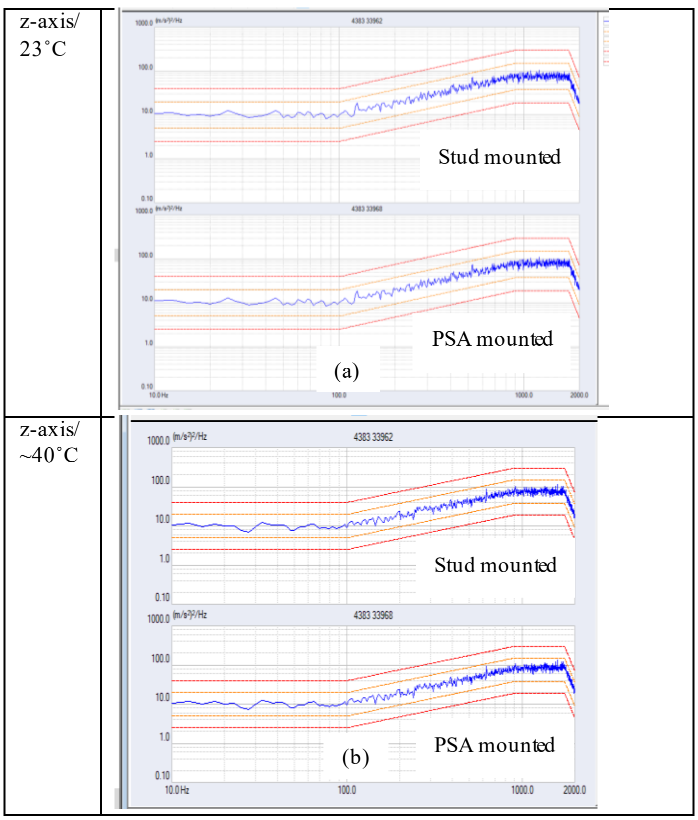


Fig. 10. Temperature profile inside the chamber during random vibration. Rate is 1˚C every 6 minutes.

Validation of waveform and response along the *z*-axis is comparable to the stud mounted response up to about 40˚C. The PSA mounted graph declined at about 60˚C, 500 Hz. On the other hand, waveform and response along the *x*-axis are not comparable initially. The difference is attributed to the gravitational force. Slight variation of the PSA mounted graph was observed at 60˚C. Figure 11 illustrates the evolution of the graph with respect to temperature.



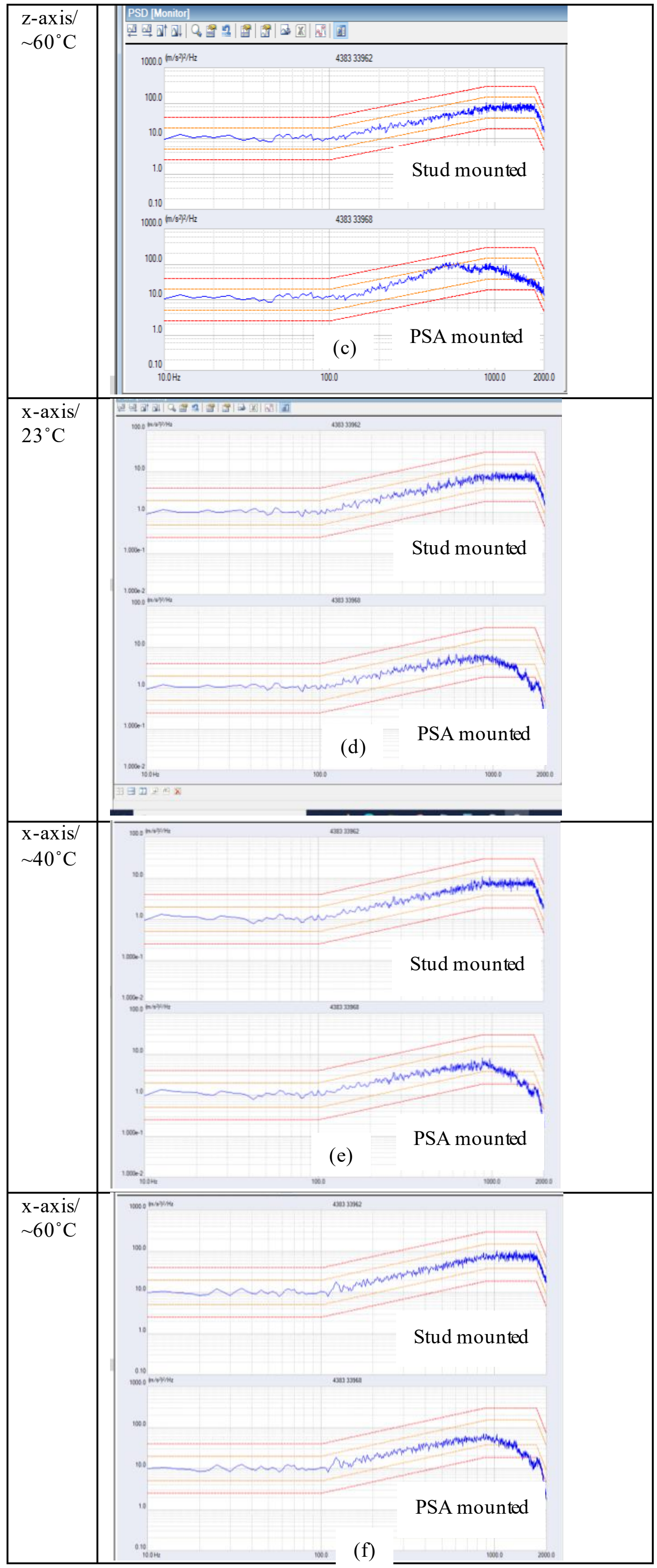


Fig. 10. Random vibration waveform results of (a) z-axis, 23˚C, (b) z-axis, ~40˚C, (c) z-axis, 60˚C, (d) x-axis, 23˚C, (e) x-axis, ~40˚C, (f) x-axis, 60˚C.

4.0 CONCLUSION

The signals obtained from the accelerometer mounted using stud and PSA along *z*-axis are comparable with each other, initially. However, a deviation is observed between stud mounted and PSA mounted accelerometer at initial stage. After about 6 hours of random vibration from 10 Hz to 2000 Hz, and PSD ranging from 10 (m/s2)2/Hz to 75 (m/s2)2/Hz, along the *z*-axis and *x*-axis, the accelerometers mounted using PSA brand B exhibited deterioration of attachment at about 60˚C. The tests validate the limit of PSA mounted accelerometer.

5.0 RECOMMENDATIONS

The limitation demonstrated by PSA brand B suggests a further search of higher grade PSA technology that will enable to surpass the performance of PSA brand B.

6.0 ACKNOWLEDGMENT

The vibration machine installed in IMI-ATC is critical in simulating the rugged mechanical condition of various products produced by IMI. Therefore, this is to acknowledge IMI's commitment to produce quality products based on international standards by investing in this vibration machine. Moreover, the support given by Joseph M. Garfin, Global Head of ATC, is invaluable to this endeavor.

7.0 REFERENCES

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