ODiSI Fiber Optic Sensor Protection Methods for Improved Durability

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1. Introduction

Accidental damage to fiber optic strain sensors can occur in a variety of ways. As an example, in the instrumentation of large test articles such as an aircraft wing, the low sensor profile makes it easy for its presence to be overlooked. It then becomes possible for the sensor to be unintentionally stepped on, or for tools to be dropped on it, resulting in a broken sensor. In other instances, test articles are instrumented in the instrumentation lab before being transported to the test location, resulting in possible rough handling in transit. In these instances, users will want to apply additional protection to the fiber sensors. This Technical Note demonstrates the protective options available to preserve the integrity of both the bonded fiber sensor sections as well as the sensor lead and connector.

2. Protecting Bonded Strain Sensors

The strain transfer epoxy used to bond strain sensors provides some level of protection to the fiber sensors, though this is minimal as only a thin epoxy layer is applied. An additional sealant can then be applied over the epoxy layer, providing both a visual and physical protective barrier to maintain sensor longevity. This additional layer would also provide resistance to moisture intrusion, which can be a factor in long term bond strength degradation in an outdoor installation.

Three different types of sealants were evaluated for performance comparison. These sealants all require an overnight cure which continues to 'develop' over the next few days into a rubbery finish with good elongation capabilities. They also have excellent waterproofing capabilities. A summary of some properties are listed in Table 1.

Table 1: Sealant properties

Name	**M-Coat JA**[1]	**RTV 3145**[2]	**Marine sealant 3M 5200**[3]
Manufacturer	Vishay	Vishay	3M
Chemical composition	2-part polysulfide liquid polymer compound	Polydimethylsiloxane adhesive	One part polyurethane
Shelf life	At least 9 months when stored between 40°F to 80°F in original unopened containers	Minimum 6 months at 75°F (24°C)	
Pot life	Mixed pot life 120 mins at 77°F (25°C)		
Waterproof?	Excellent	Good short-term	Excellent
Solvent-proof?	Good resistance	Resists many chemicals	
Short term operating temperature	-65°F to 360°F (-54°C to 182°C)	-49°F to 392°F (-45°C to 200°C)	-40°F to 190°F (-40°C to 88°C)
Color	Black	Clear or gray	Black/white

2.1. Effect of Protective Coating on Measurement Accuracy

In order to evaluate the effect of the protective coating on strain measurement accuracy, a strain sensor was bonded to a fiberglass coupon using the protocol outlined in Luna's Installation Guide[4]. It was clamped on one end and repeatedly loaded in bending by hanging weights from the tip. The measurement data was compared between a coupon with and without each type of protective coating applied. This test was carried out for both the high definition (HD) sensor as well as the Continuous Fiber Grating (CFG) sensor.

2.1.1. Test Setup

The sensor layout is as shown in Figure 1 (top) where a single 2 m strain sensor is bonded in 4 pairs of straight passes along the length of a fiberglass coupon 1" wide and 12" long. M-Bond 200 was used as the epoxy. Different weights (2, 4, 5 lb) were applied sequentially to the tip of the coupon in a bending configuration (Figure 1 bottom) and measurements were repeated 3 times. After the first round of load application, protective coatings were applied as shown in Figure 1 (middle) and left to cure for a week. The loading sequence was repeated at the end of the week.

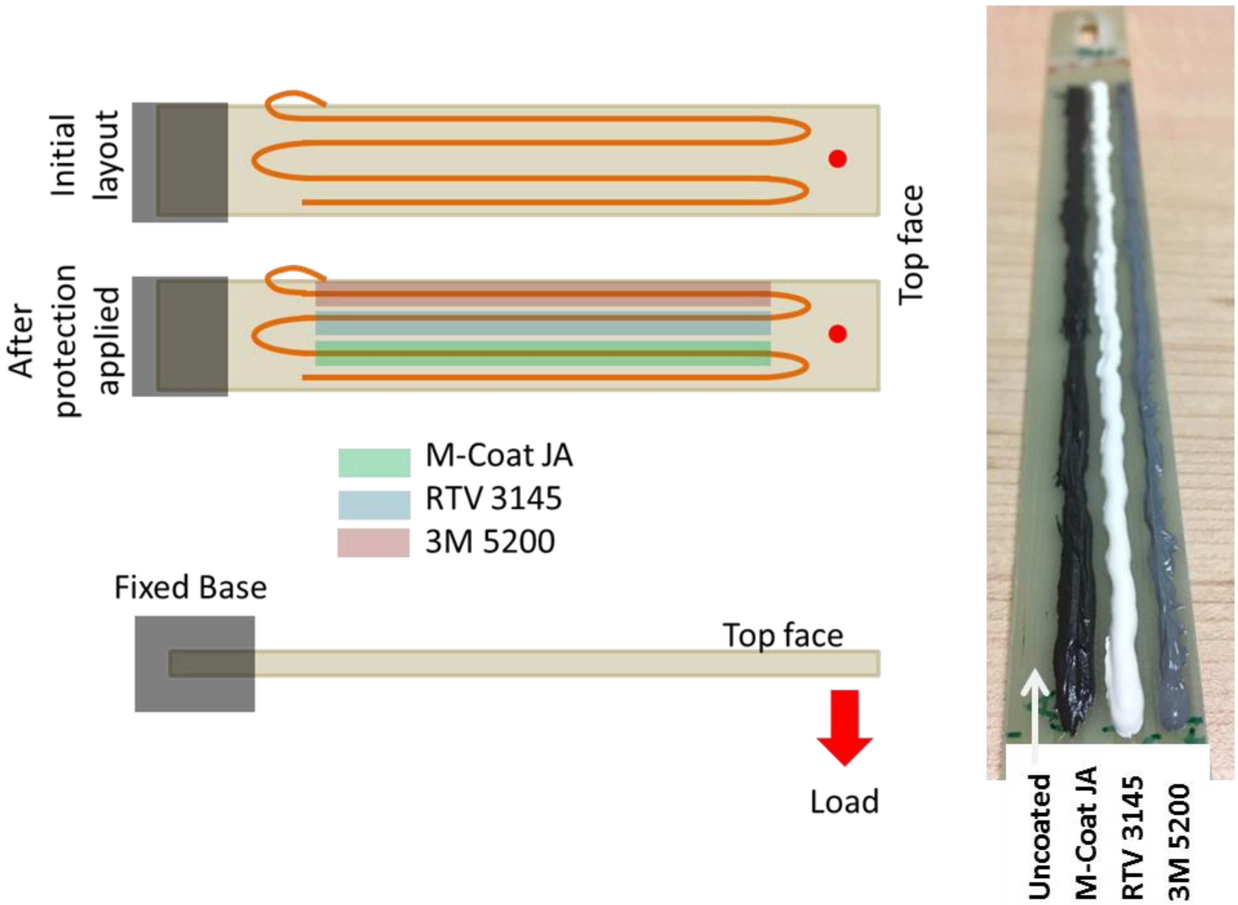

Figure 1: Fiberglass coupon instrumented with a 2 m strain sensor and loaded in bending.

2.1.2. Results

The strain distribution along the sensor length is shown in Figure 2A. For each bonded pass, the strain profile linearly decays from the root to the tip of the coupon. Measurement comparisons were then carried out between the strain distribution at maximum load, before and after a protective coating is applied (Figure 2B). As can be seen from this figure, using the unprotected sensor path as a reference, there is no appreciable difference between measurements obtained before and after a protective coating was applied over the epoxy.

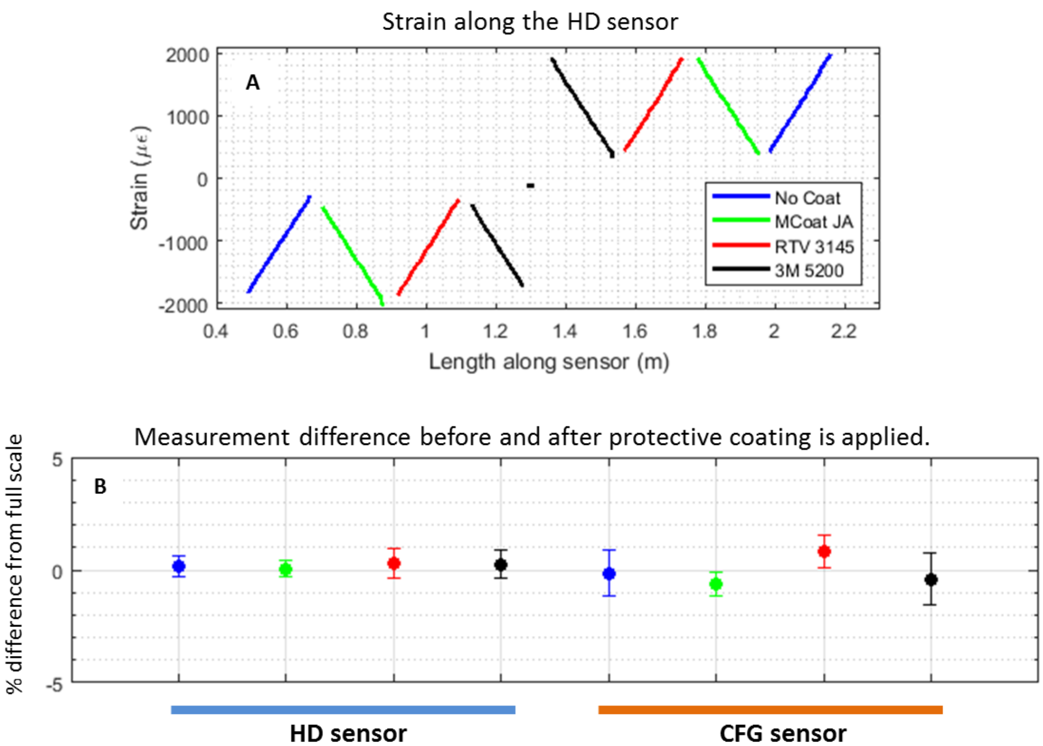

Figure 2: A. Strain distribution along the length of a HD sensor. B. Measurement difference before and after a protective coating is applied.

2.2. Effect of Protective Coating on Sensor Durability

In order to impart a quantifiable and controlled impact to each of the protected fiber passes, a drop style impact tester was used, in accordance to ASTM D7136. A 0.9 g mass with a 10 mm spherical tip diameter was dropped from increasing heights to determine the amount of impact energy that could be withstood by the protected sensor (Figure 3). Using this method, it was determined that this mass could be dropped from a maximum height of 15 cm (1.29 J impact energy) with no visible damage to either the protective coating, nor damage to the fiber sensor as evidenced by the lack of degradation or loss of data quality from the ODiSI interrogator. This would be equivalent to dropping a 150 g wrench from waist-height onto an instrumented surface.

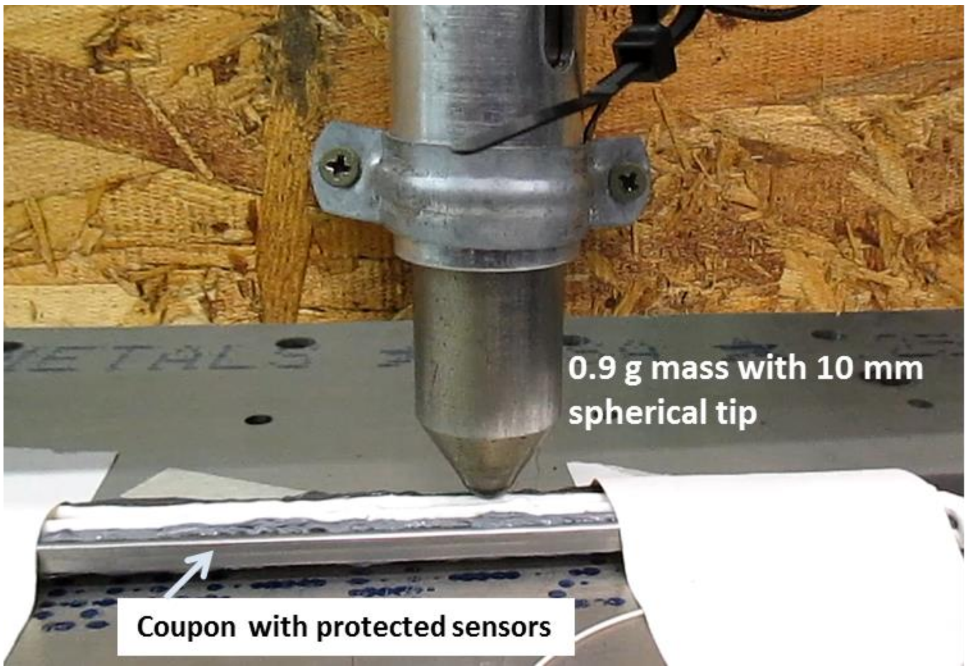

Figure 3: The protected sensors survived an impact from a 0.9 g mass with a 10 mm spherical tip diameter.

2.3. Rough Handling Tests

The bonded coupons were also roughly handled to examine robustness. A coupon was laid on a cement floor and stepped on as well as jumped on. The same coupon was also laid on an asphalt road and driven across multiple times by a vehicle, averaging 530 kg load on the coupon, with no evidence of degradation or loss of data quality from the ODiSI interrogator.

Figure 4: Fiber sensor with protective coating applied, being stepped on and driven across, with no degradation of data quality.

3. Sensor Bulkhead Mount

Once a strain sensor is bonded down to the test article, a sensor bulkhead mount should be used to protect the sensor connector, and the sensor lead should be secured to the part. The bulkhead mount available from Luna is shown in Figure 5. This facilitates ease of transport to the test facility, and handling when mounting the part into the test fixture.

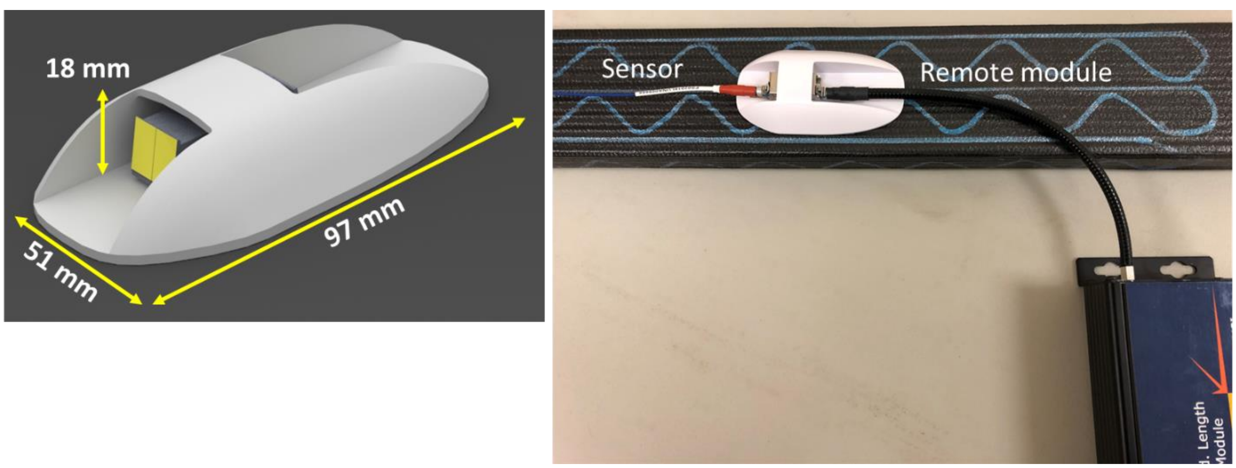

Figure 5: Sensor bulkhead mount.

For further information on the various methods discussed here for protecting strain sensors, contact Luna's Customer Support at solutions@lunainc.com or call 540.961.5190.

4. References

1. http://www.vishaypg.com/micro-measurements/list/product-11032/
2. http://www.vishaypg.com/micro-measurements/list/product-11035/
3. https://www.3m.com/3M/en_US/company-us/all-3m-products/~/3M-Marine-Adhesive-Sealant-5200-Fast-Cure/?N=5002385+3293241048&rt=rud
4. https://lunainc.com/wp-content/uploads/2017/01/TN_Applying-Strain-Sensors_RevB_v1.pdf

Product Support Contact Information

Headquarters:	3155 State Street Blacksburg, VA 24060
Main Phone:	1.540.961.5190
Toll-Free Support:	1.866.586.2682
Fax:	1.540.961.5191
Email:	solutions@lunainc.com
Website:	www.lunainc.com

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