University of Delaware

# HIGH STRUCTURAL INTEGRITY OF OPTICAL FIBER AT EXTREME TEMPERATURE WITH FIBERGLASS BRAID JACKETING TECHNIQUE

**N. H. Belal (MSECE), E. D. Wetzel (ARL) and K. Goossen**

University of Delaware . Center for Composite Materials . Department of Electrical and Computer Engineering

## Abstract

- A novel technique for protecting fiber-optic cable in case of extreme temperature is demonstrated.
- With fiberglass braid jacketing technique we have produced a robust optical fiber cable.
- The minimum bend radius (after burning off the plastic overcoat at 600°C) is reduced from 8.5 inches (for normal fiber) to 2.5 inches using fiberglass weave jacketing.
- The softening point of the fine fiberglass is 1056°C. Thus the jacketed fiberglass will give stronger structural integrity to the cable to survive extreme temperatures and from any kind of external impact without becoming excessively fragile.

## Acknowledgements

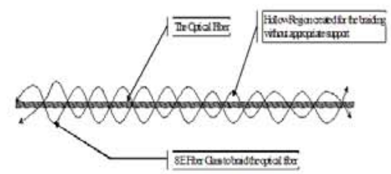
This work is supported by the Army Research Laboratory through the Composite Materials Research program.

## Objective

- Since the early 1990s, the oil and gas excavation industry has seen an increasing demand for highly heat-resistant optical fibers for sensor applications but the jacketing technique of the fiber optic is still not up to the target where it can survive extreme temperatures such as monitoring the structural integrity of steel (e.g. melting point of steel is 800-900°C)
- An example of this requirement is the monitoring of the architectural integrity of buildings, such as during the 9/11 disaster
- Our experiment demonstrated a technique of jacketing the optical fiber that overcomes this limitation.

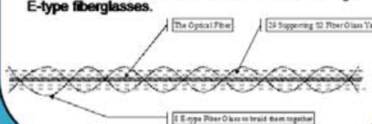
## Fabrication Approaches

- Firstly, scheme 1 was considered for fabrication where the optical fiber was braided with eight E-type fiberglasses.
- However, this created a hollow region between the braid and the optical fiber, which didn't give acceptable structural integrity to the fiber optic



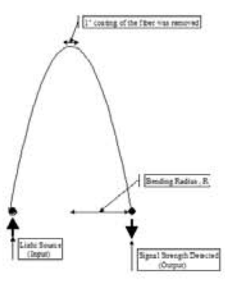

## Fabrication Approaches (Cont.)

- We designed scheme 2 where we used twenty-nine high strength *S-2 Glass* fiber bundles for supporting the optical fiber.
- A spool of 1 km glass yarn composed of the optical communication fiber and twenty nine *S-2 Glass* fiber bundles was obtained.
- A certain length of this yarn was braided with E-type fiberglass. A novel technique was used to braid as illustrated in the following Figure.
- The optical communication fiber was placed in the middle and the other *S-2 Glass* fiber bundles were placed all around it in such a way that it always stays in the middle. Then we braided this bundle with eight E-type fiberglasses.




## Procedure

- A 2 ft long length of the yarn was connectorized both sides, subjecting an inch section in the middle to 600°C for 45 seconds which was sufficient to burn off acrylate coating of the optical fiber.
- We performed the bending test by bending this yarn as shown in the Figure.
- A 1.3 μm wavelength laser light source was sent through one side; the other side of the fiber was connected to an optical power meter.
- For comparison, a standard cable (no fiberglass) was subjected to the same test (it only took 2-3 seconds to burn off the plastic in this case).
- We performed a similar bending test




## Results

- It was clearly observed from the first (the jacketed yarn) the second (standard cable) Tables that after the acrylate coating is burned off in high temperature, the braided yarn can survive much better than the standard optical fiber in terms of bending radius, which implies survivability to any kind of external impact.
- Technically, without the coating, the bare fiber optic is quite fragile after burning off the plastic.

| Bending Radius, R (Inch) | Signal Strength (dB) |
|---|---|
| 11.0 | 4.12 |
| 10.5 | 4.12 |
| 10.0 | 4.12 |
| 9.5 | 4.12 |
| 9.0 | 4.12 |
| 8.5 | 4.12 |
| 8.0 | 4.12 |
| 7.5 | 4.12 |
| 7.0 | 4.12 |
| 6.5 | 4.12 |
| 6.0 | 4.12 |
| 5.5 | 4.12 |
| 5.0 | 4.12 |
| 4.5 | 4.12 |
| 4.0 | 4.12 |
| 3.5 | 4.12 |
| 3.0 | 4.12 |
| 2.5 | 4.12 |
| 2.0 | 0.0 |

| Bending Radius, R (Inch) | Signal Strength (dB) |
|---|---|
| 11.0 | 4.12 |
| 10.5 | 4.12 |
| 10.0 | 4.12 |
| 9.5 | 4.12 |
| 9.0 | 4.12 |
| 8.5 | 4.12 |
| 8.0 | 0.0 |

## Conclusion

- From the plot here, we can see that when using the braided jacketed yarn, the minimum bend radius (after melting the plastic overcoat) is reduced from 8.5 inches to 2.5 inches (normal fiber with the plastic intact can go to about 1 inch.
- Braiding was with E-type fiberglass (softening point is 850°C); survivability to 600°C is shown.
- The softening point of the *S-2 Glass* fiber is 1056°C. Thus with the S-glass braid, we believe even higher temperatures are possible without becoming excessively fragile.