DEFORMATION CONTOUR MEASUREMENT WITH FIBER-OPTIC SENSOR TECHNOLOGY

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INTRODUCTION

Many applications in biomechanical research desire to monitor the changing shape of a locally deforming contour. Current contour measuring devices, such as the External Peripheral Instrument for Deformation Measurement (EPIDM), or chestband, uses an array of strain gauge bridges to measure local curvature at discrete intervals (Eppinger, 1989). These curvatures are then integrated to determine local contours in an impact environment. Though widely used to monitor thoracic contours during a frontal crash test, this instrument is bulky and has limited durability and accuracy in severe impact situations (Bass et al, 2000; Shaw et al, 2000).

Alternative measurement technology has been developed to address these issues. Shape Tape, designed by Measurand Inc., relies on fiber optic sensing loops, which are treated to lose light proportional to bending. These loops are arranged in sensor pairs, which are adhered to the top and bottom surface of a metal substrate. The prototype band contains eight sensors, each spaced an inch apart. This array is enclosed in a protective metal casing, shown in figure 1.

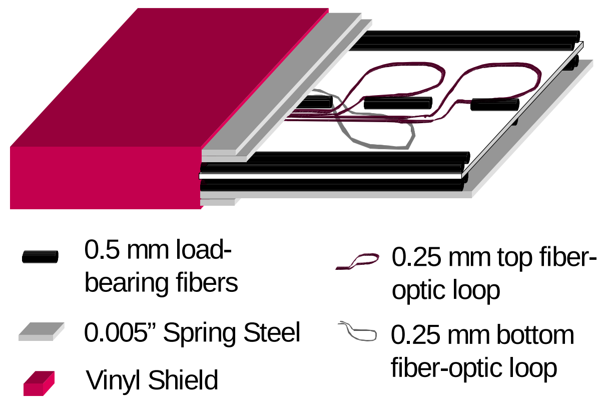

Figure 1: Shape tape Components

EVALUATION METHODS

Several tests were conducted to evaluate the effectiveness of Shape Tape. A calibration test was performed to investigate the linearity of the sensors. The band was wrapped around mandrels of varying diameters. The recorded signal voltages were compared to the mandrel curvatures to determine their relationship. The repeatability and durability of the sensor band was determined by adhering it to a linkage system driven by a motor. This cycled the band in a serpentine fashion for approximately 1000 cycles. Data was taken with the band lying flat just prior to, and immediately after this experiment. Pressure tests were conducted by subjecting the tape to a compressive load in a Tinius-Olsen Universal Testing Machine. Loads up to 1000 N were applied locally and uniformly on the band while sensor data were continually recorded. The band was also heated from 22C to 86C to determine its sensitivity to environmental temperature changes.

RESULTS AND DISCUSSION

Calibration results showed that the sensor pairs were linear, with R^2 values of 0.995 or better. A representative signal performance is shown in figure 2. This compares favorably to the chestband, which has a

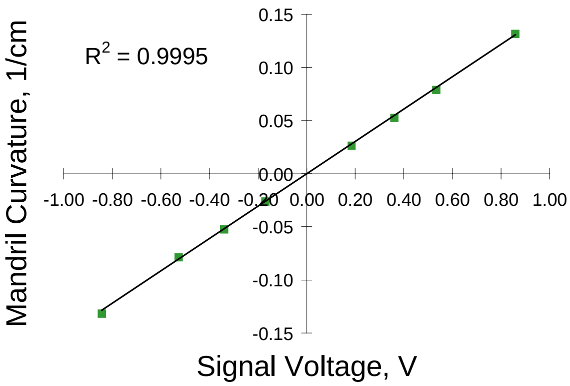

Figure 2: Representative signal calibration performance (signal pair 2)

typical linearity to about 3 percent of the full-scale measurement of 0.4 1/cm. The sensor values were repeatable to within 2 percent of full scale after 1000 cycles. The fiber-optic signals changed less than 2 percent of full scale. Localized pressure produced signal differences less than 9 percent of full scale. This resulting apparent radius of curvature, approximately 33 cm, is likely the result of the shape tape conforming locally to the underlying aluminum beam. The rounded edges of the indentor most likely caused the unloaded portions of the band to bend locally, resulting in additional curvature at these sensor locations. The pressure sensitivity test results are shown in figure 3. Signal changes to temperature changes were approximately negligible (0.5% of full scale).

CONCLUSIONS

Shape Tape measurement accuracy is comparable to that of the predominantly

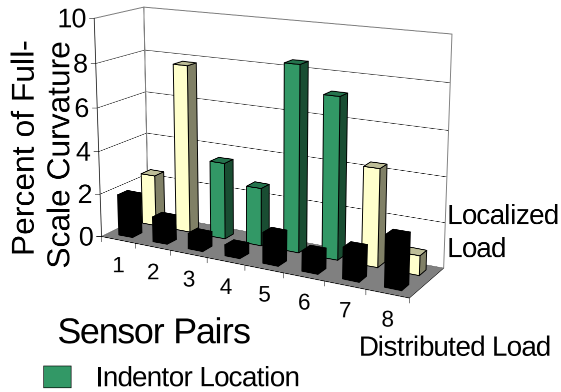

Figure 3: Shape tape pressure sensitivity

used chestband technology, but the Shape Tape has distinct advantages. Its small size (1.4 cm x 0.3 cm) enables it to be used in many testing situations for which other similar instruments would be poorly suited, such as determining local ribcage contours beneath subcutaneous tissue in thoracic impact experiments. Further testing will confirm its performance in characterizing dynamic deformation contours in controlled impact tests.

REFERENCES

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