Use of Factorial Design for Temperature, Humidity, and Strain, for Characterization of FBGs

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Abstract

Factorial design can be used when treatments are combination of the levels of two or more factors that vary simultaneously. It provides the maximum amount of information with the minimum number of experiments. Factorial design allows estimation of sensitivity for each factor and also the effect of interaction between different factors. It is applicable in scientific and industrial researches. We report on the application of 3 variables 2 levels factorial design for simultaneous temperature, humidity, and strain sensing by using fiber Bragg gratings inscribed in standard optical fiber.

Factorial Design for 3 factors with two levels

- Use of Factorial Design to decrease the number of experiments in compare with Classical measurements
- k factors and n levels for every factor: n^k measurement points
- Data to be collected at the vertices of a hypercube in k-dimensions
- Cover all experimental domain

\[ y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_{12} x_1 x_2 + a_{13} x_1 x_3 + a_{23} x_2 x_3 + a_{123} x_1 x_2 x_3 \]

Trials Temperature Humidity Strain

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<tr>
<th>Temperature</th>
<th>Humidity</th>
<th>Strain</th>
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<tr>
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Number of experiments: 2^3 all combination of levels for 3 factors
- 8 measurements: 8 equations; 8 unknowns
- Linear response of FBGs to the factors in the range of levels of factors in this experiment, \( y = \lambda \) 

Fiber Bragg grating sensor

- Three uniform gratings, 4mm long, were inscribed in a standard optical fiber by a double frequency fiber laser emitting at 244 nm, by interferometric technique (Lloyd mirror set-up)
- Tow gratings were coated, one by Polyimide (PI2525), another one by Acrylate (DSM 950-200), third one remained bare

Experimental Set-up

- Climate Chamber

Results

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<tr>
<th>Factor</th>
<th>Low level</th>
<th>High level</th>
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<tr>
<td>X1 (°C)</td>
<td>25</td>
<td>65</td>
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<tr>
<td>X2 (%RH)</td>
<td>30</td>
<td>70</td>
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<td>X3 (µµ)</td>
<td>45.594</td>
<td>235.141</td>
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Effect of different levels of humidity on temperature sensing

- Increasing humidity modifies temperature sensitivity for polyimide recoated FBG, while not effects on bare FBG

Cross interaction between 2 by 2 factors

- Modification of temperature not effects strain sensing, as well as for cross interaction between strain modification and humidity, in all gratings

Conclusion

- In conclusion, factorial design is a powerful tool for FBGs characterization. In this study, we used factorial design to characterize FBGs cascaded in standard optical fiber Draka and obtain temperature, humidity, and strain sensitivities. In addition cross interaction coefficients between 2 by 2 and 3 by 3 factors were calculated.
- Temperature sensitivities of acrylate and bare FBGs are in agreement with classical measurements.
- Strain sensitivities of all FBGs are in good range.
- There is an increasing in temperature sensitivity due to polyimide coating.

References


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