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14. ABSTRACT Briefing Charts. A finite-element-based numerical model is employed to investigate the effect of propellant-insulation delaminations on the radial stress distribution at the bondline during the cooling of a solid rocket motor consisting of propellant, insulation, and casing. With the assumption of stress sensors evenly distributed along the propellant-insulation interface, the way that the debond angles, number of sensors, and sensor accuracy are related is established. Two approaches are proposed to evaluate the detectability of debonds based on the sensor readings. Furthermore, a quantitative mapping obtained between the debond angle and the sensor data is used to inversely estimate the delamination damage. It is demonstrated that the proposed methods can be used to detect delaminations in solid rocket motors.					
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DETECTABILITY OF DELAMINATIONS IN ROCKET MOTORS WITH EMBEDDED STRESS SENSORS

JANNAF S&MBS Meeting

30 April – 4 May 2012

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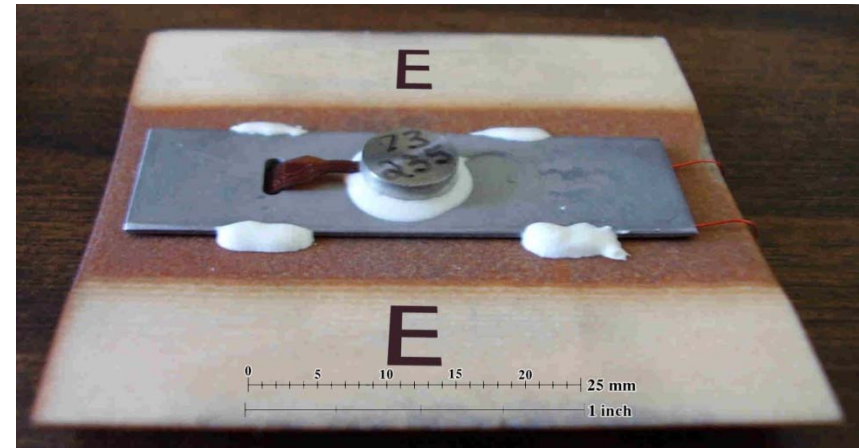
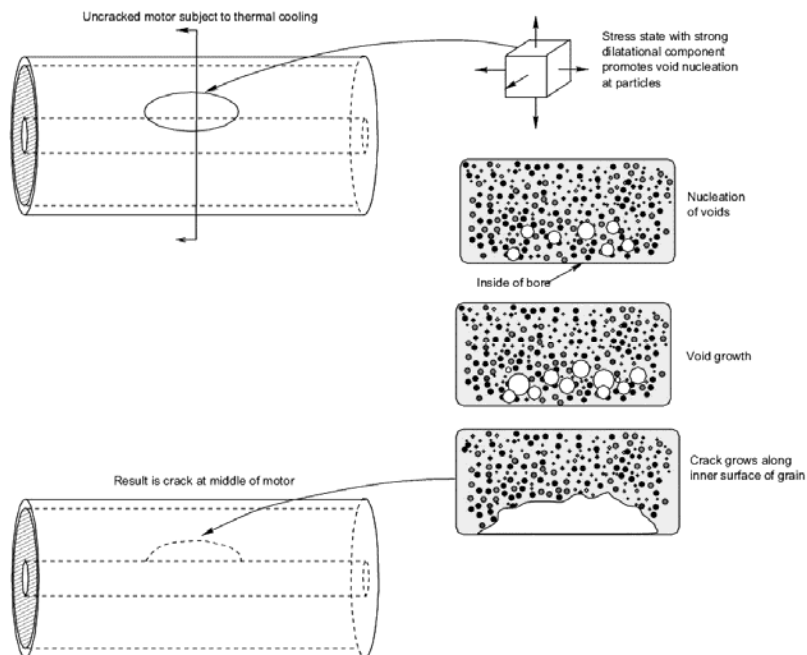
Air Force Research Laboratory, Edwards AFB, CA 93524



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Introduction



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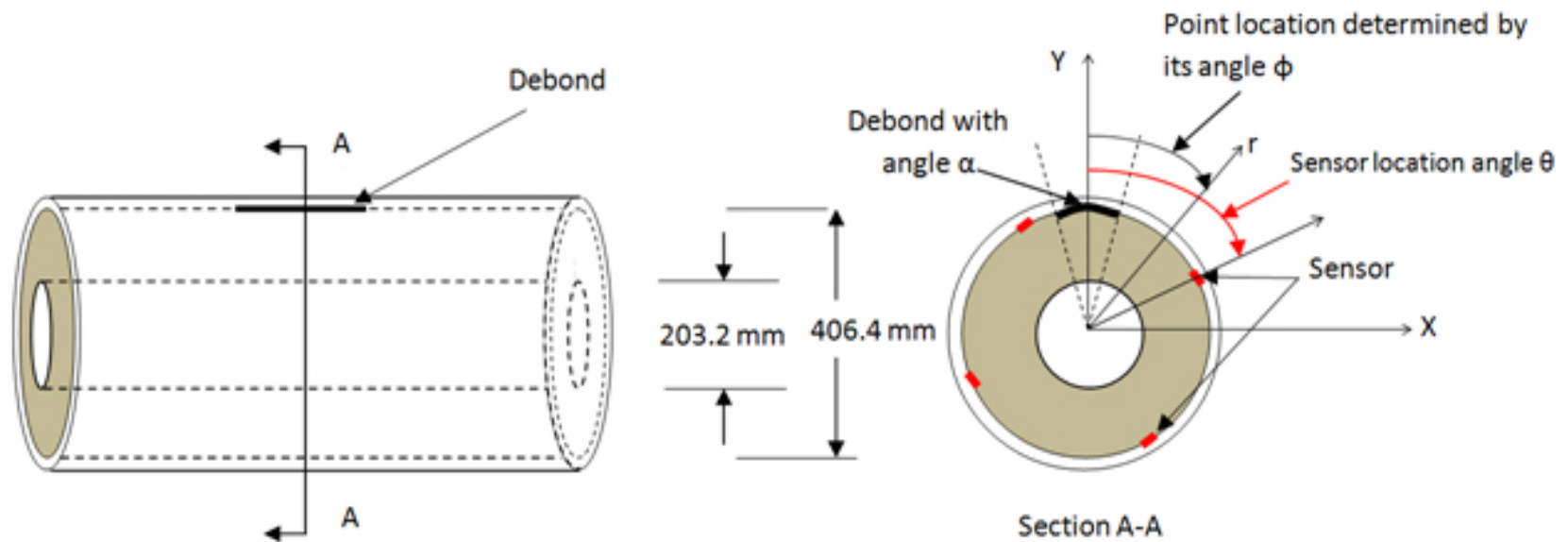
Introduction (Continued)



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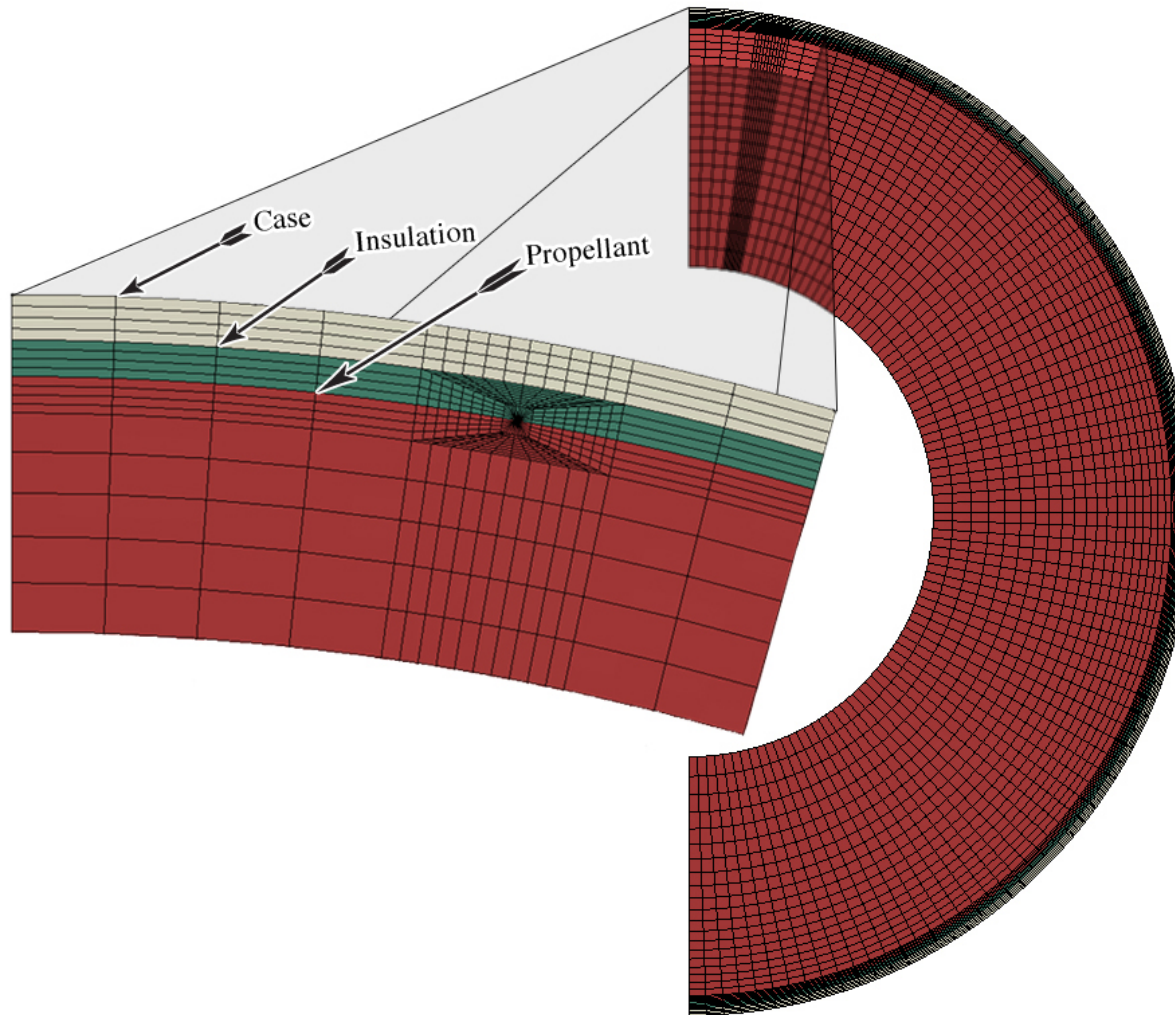
Finite Element Model Details



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Finite Element Model Details (Continued)



Case: Graphite-epoxy motor case, quasi-isotropic, linear elastic

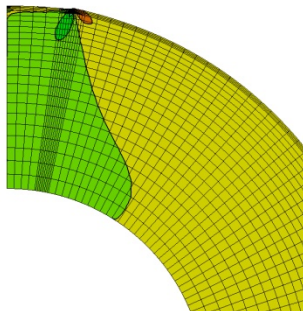
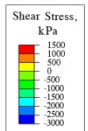
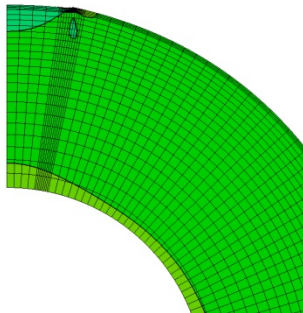
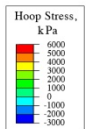
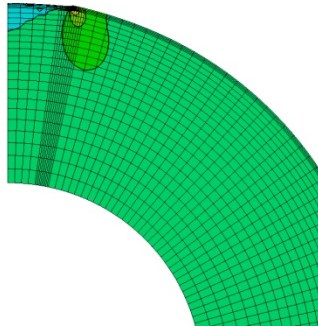
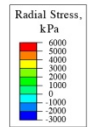
Insulation: EPDM, temperature-dependent linear elastic

Grain: HTPB, temperature-dependent linear elastic

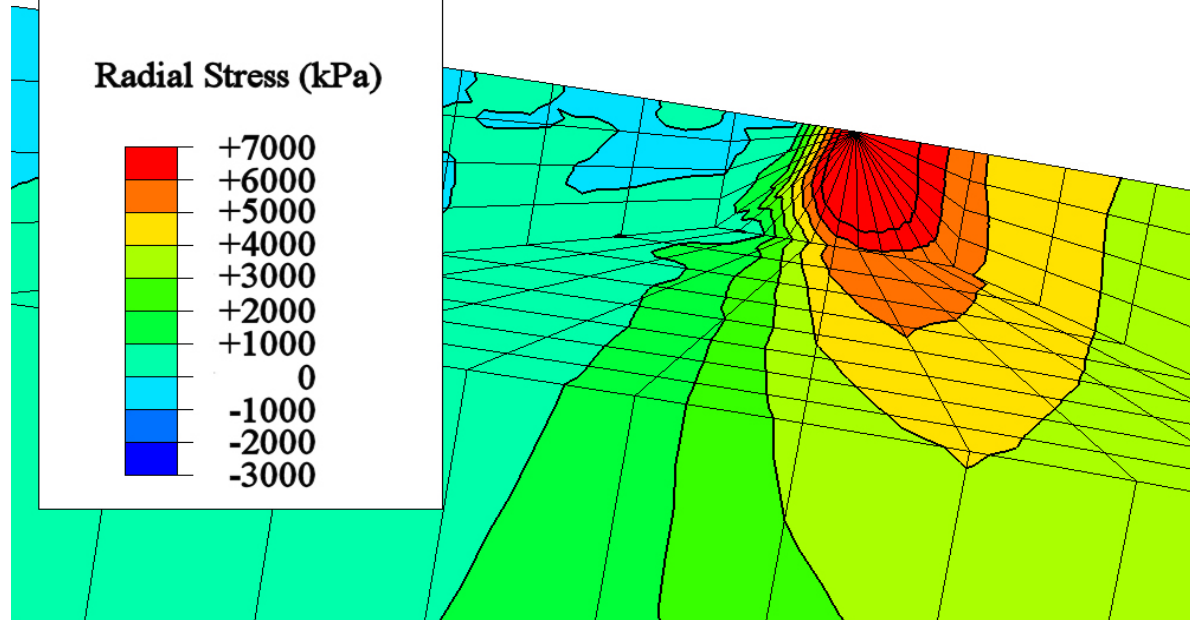
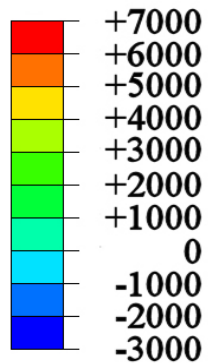


Results and Discussion

Contour Plots



Radial Stress (kPa)

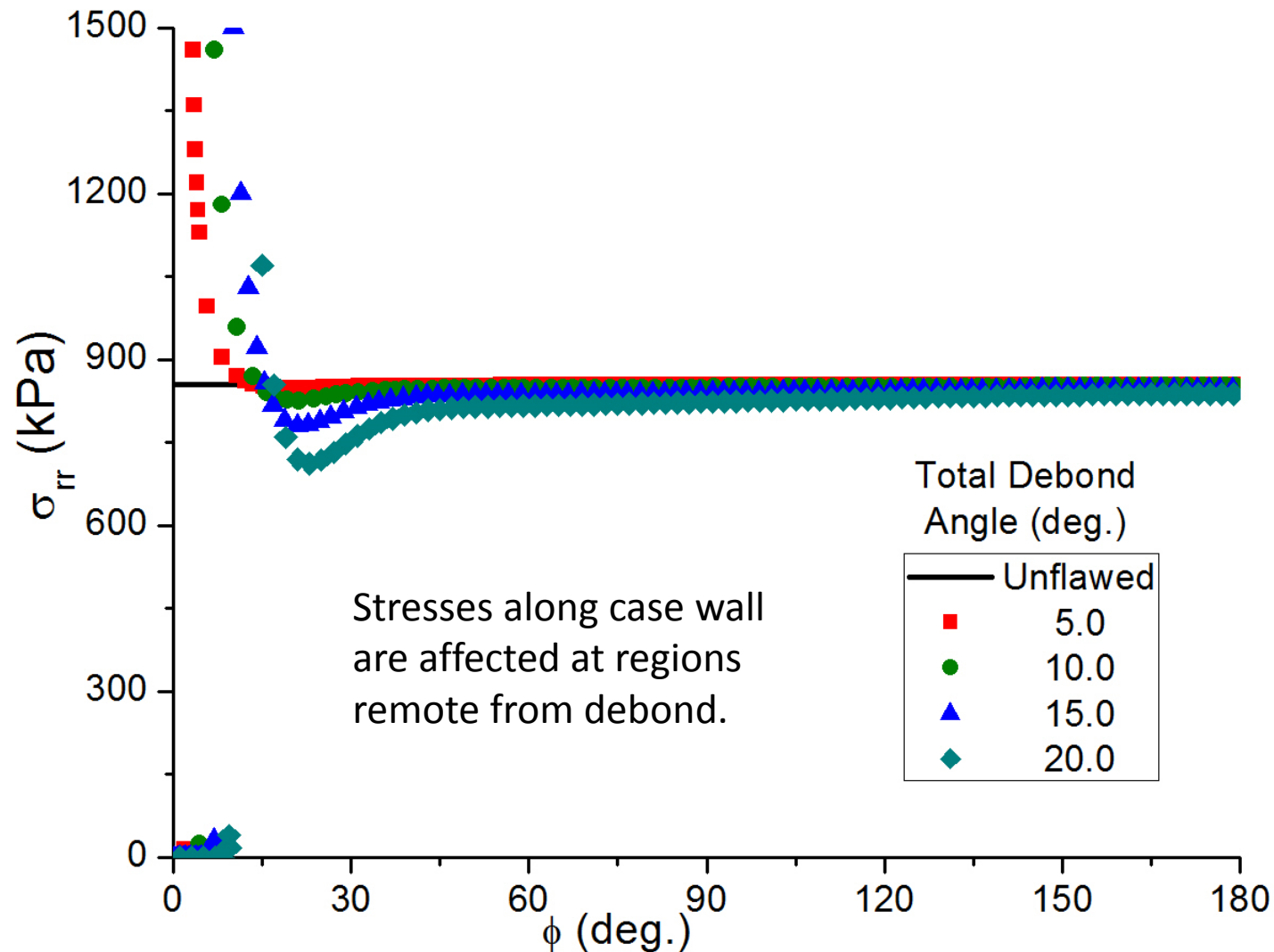


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Results and Discussion

Case-Wall Radial Stresses

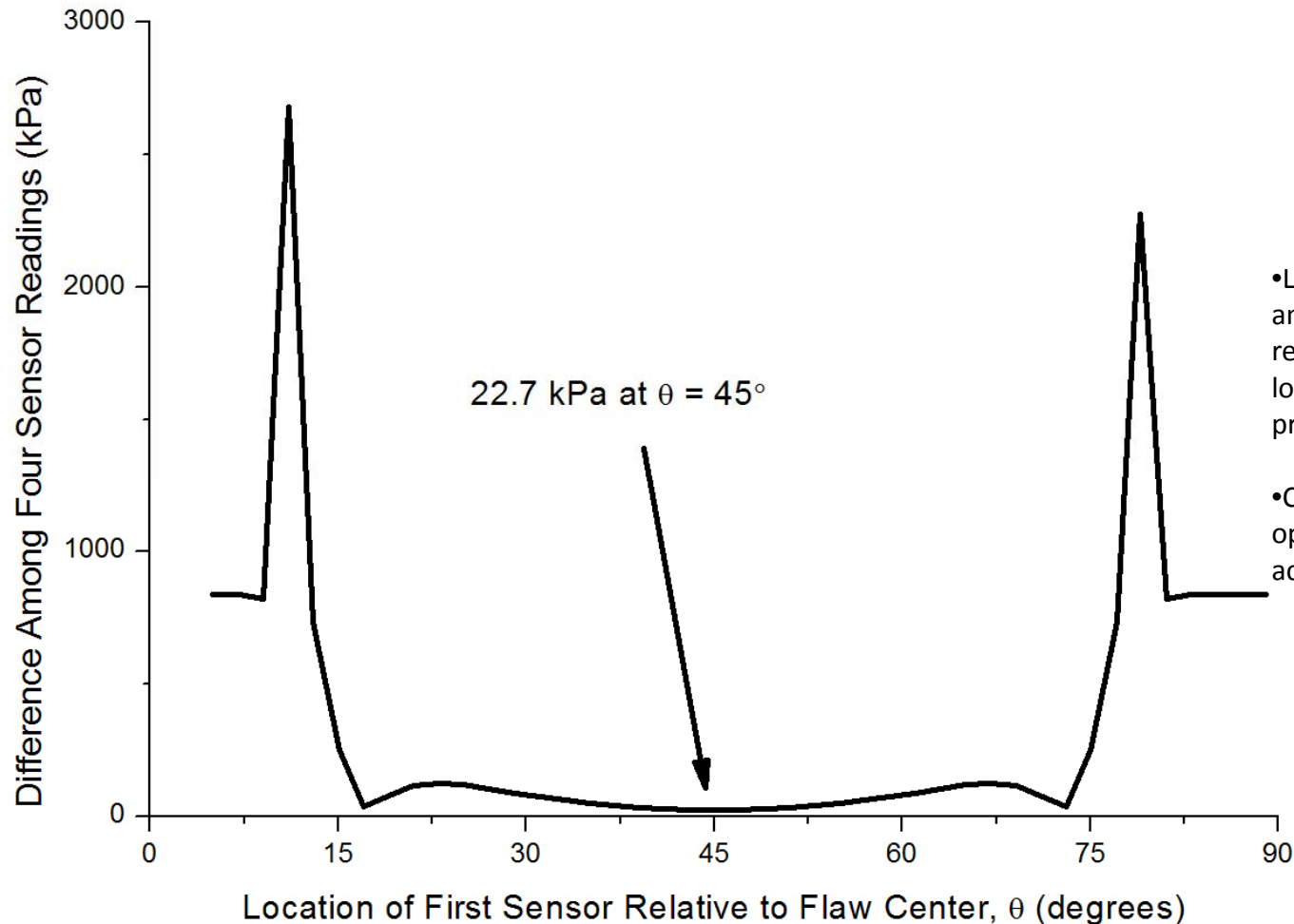


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Results and Discussion

Differential Method

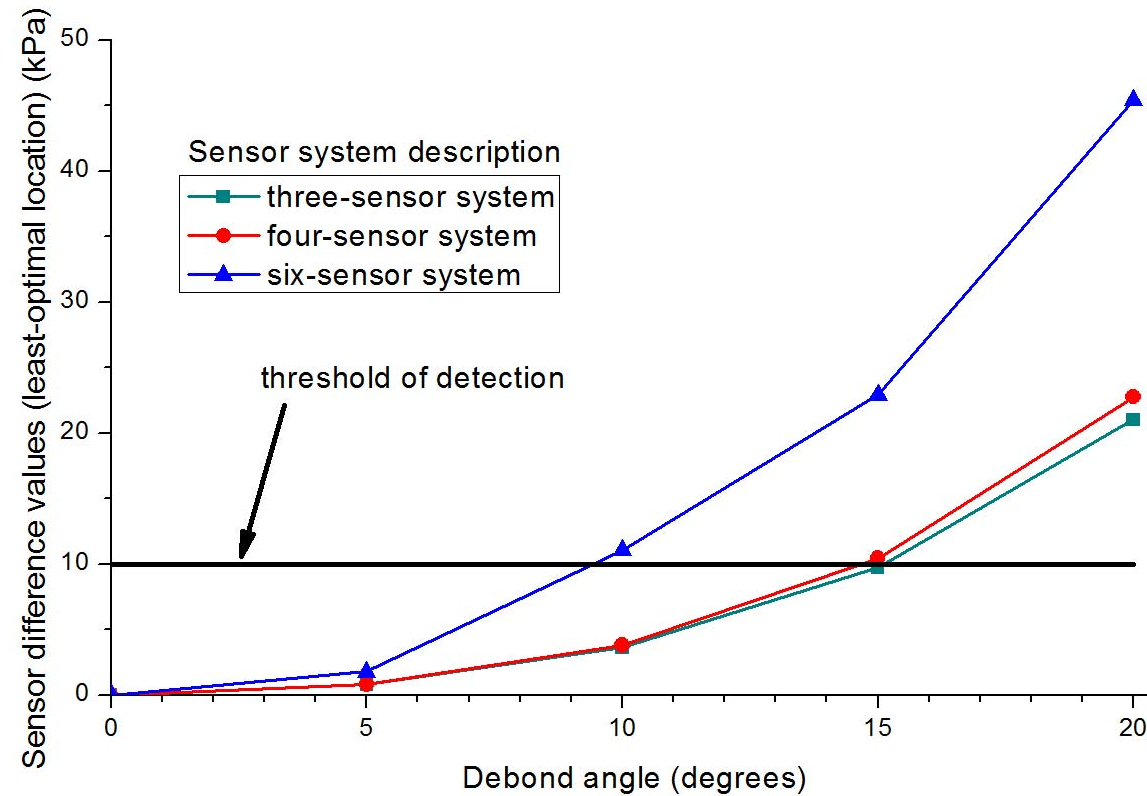


- Looking at the difference among the (four) sensor readings at “least-optimal” location gives conservative prediction of detectability.
- Compare reading at “least-optimal” location with sensor accuracy (10 kPa or less)



Results and Discussion

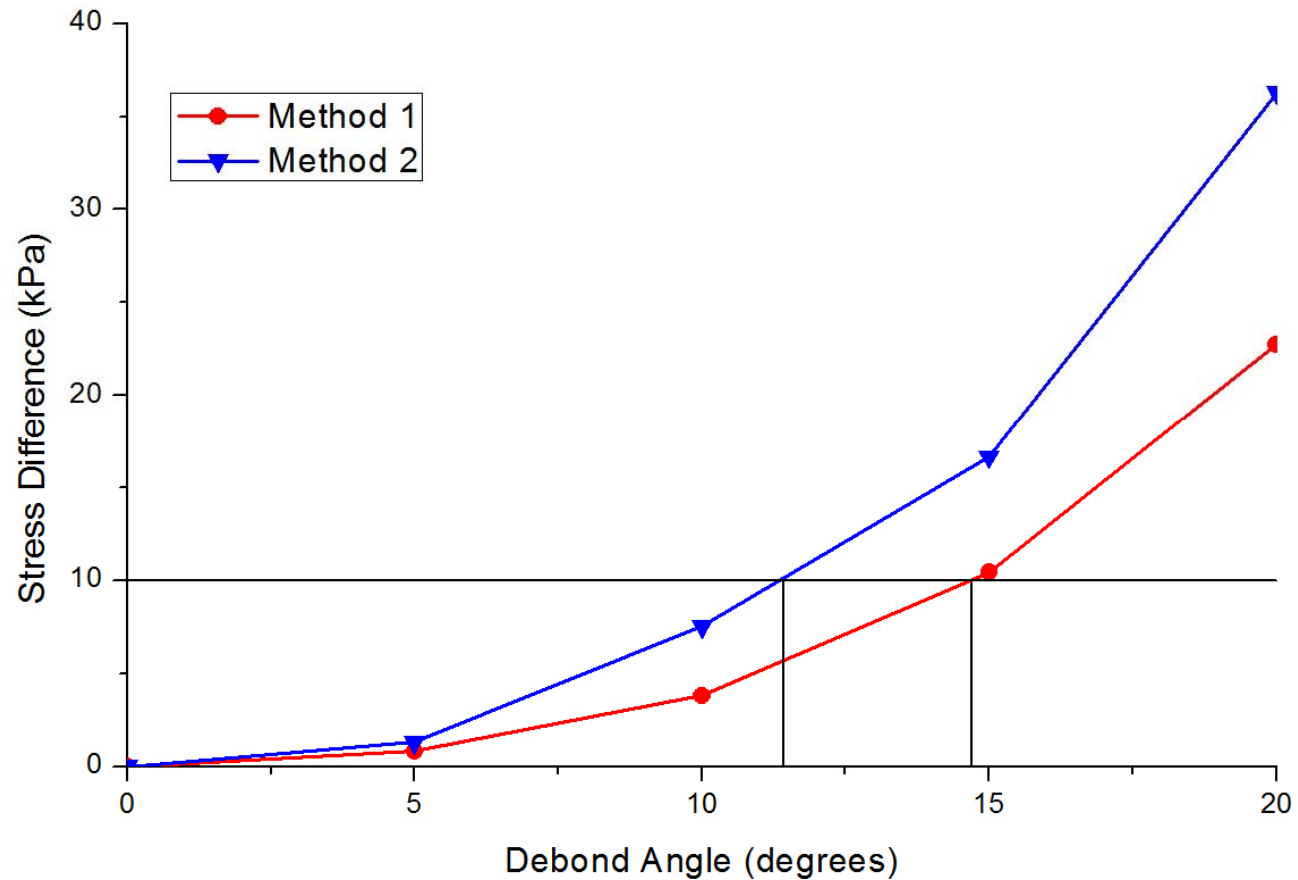
Differential Method





Results and Discussion

Baseline Method

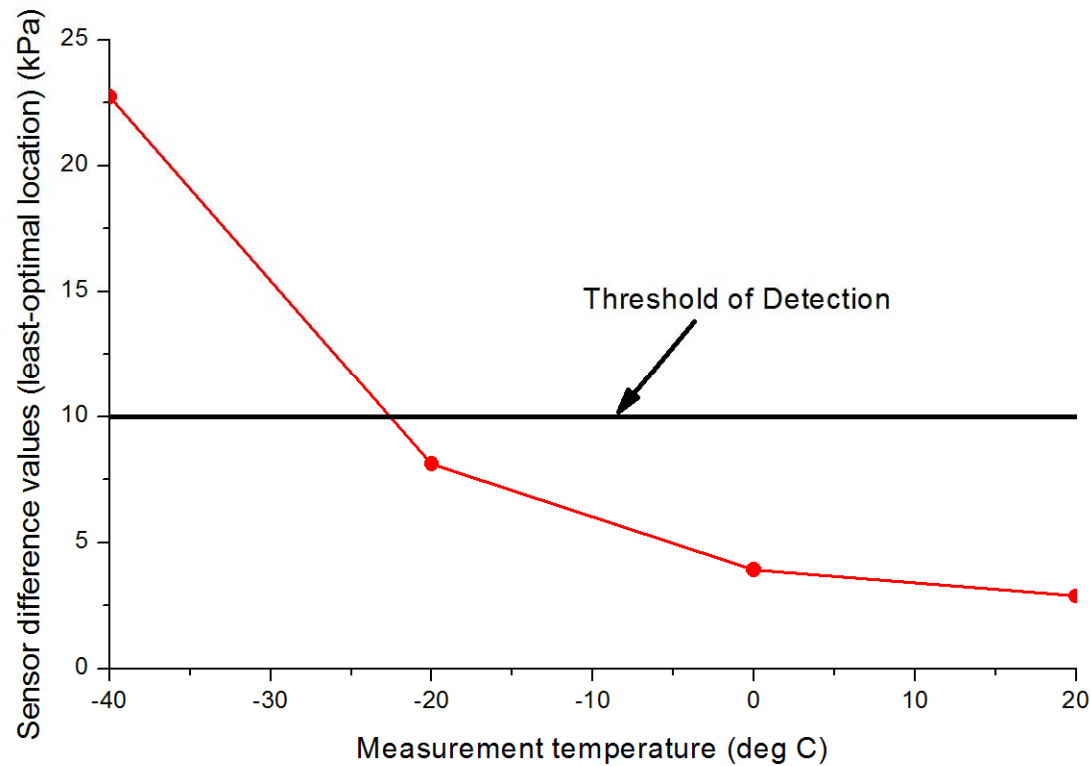


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Results and Discussion

Effect of Test Temperature

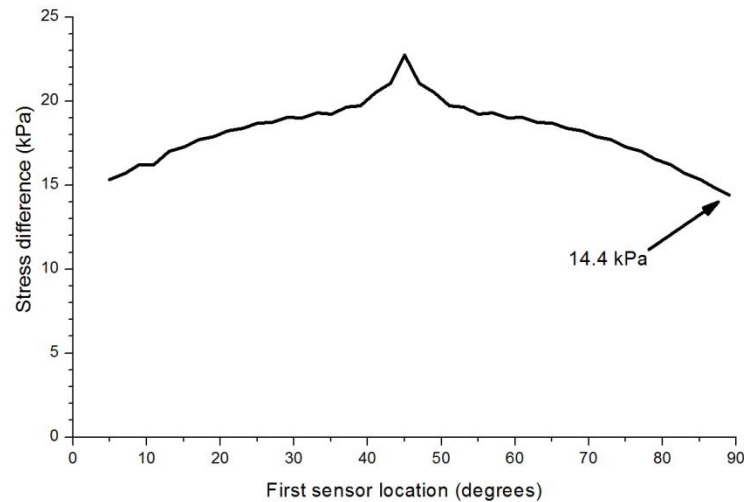


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Results and Discussion

Effects of Sensor Failure



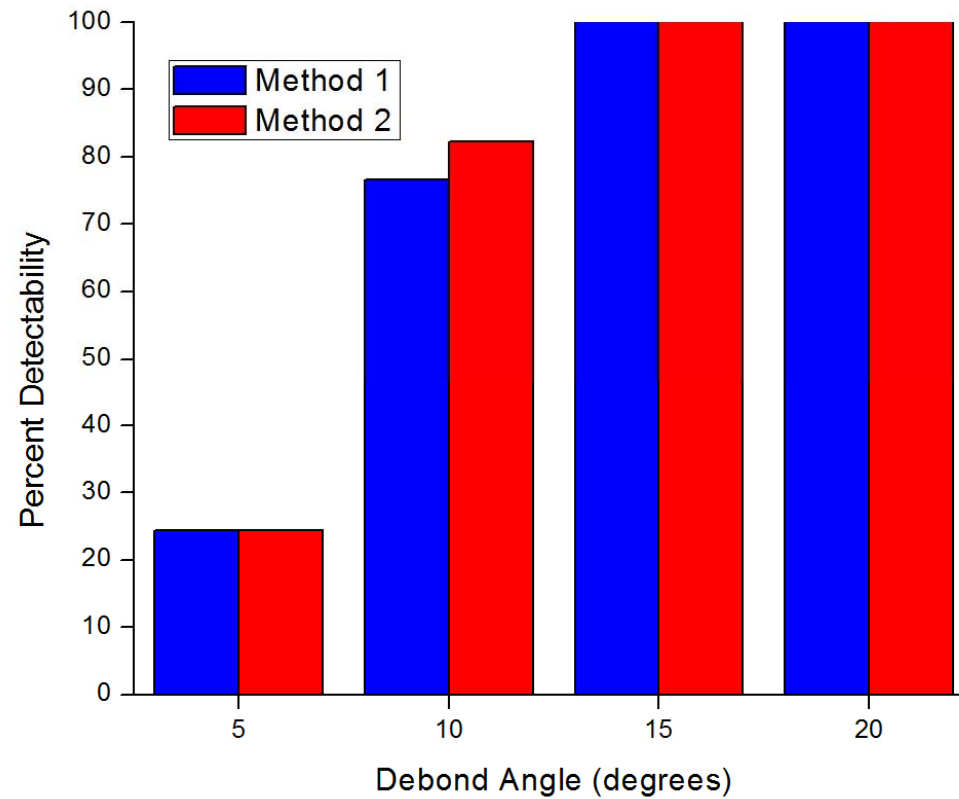
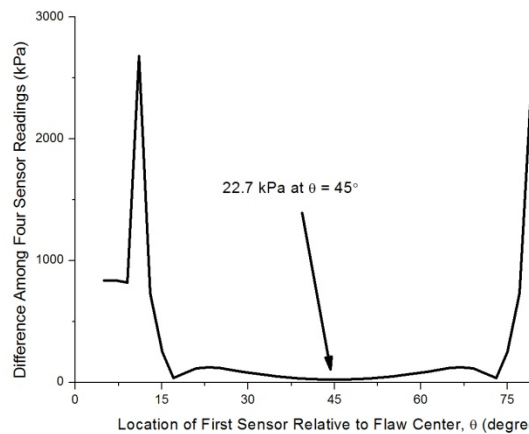
Four-sensor system with one failure:
Stress difference at “least-optimal”
location = 14.4 kPa

Three-sensor system with one failure:
Stress difference at “least-optimal”
location = 0.2 kPa



Results and Discussion

Probability of Detection

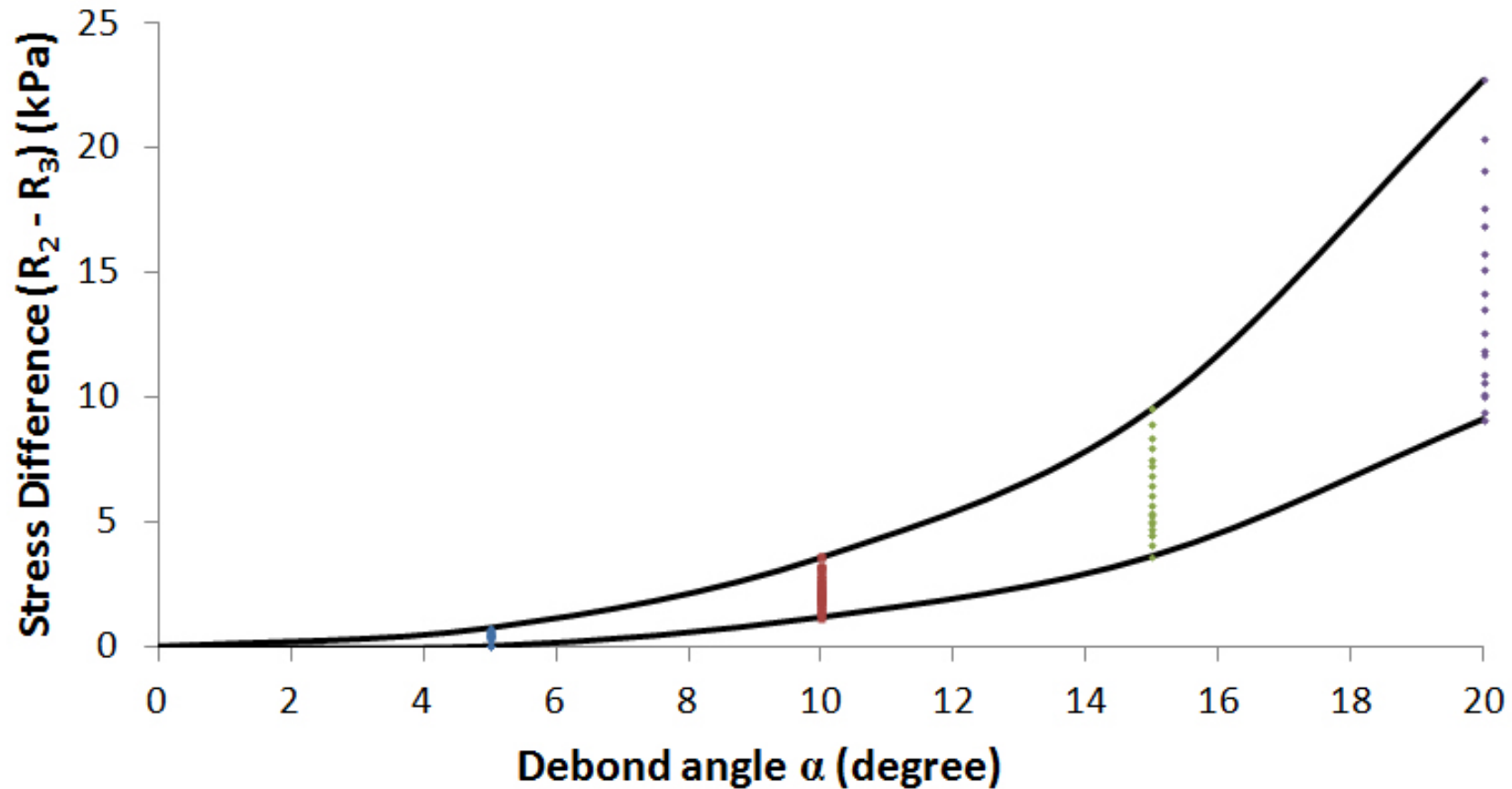


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Results and Discussion

Estimation of Total Debond Angle



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Conclusions

- **FEA analysis shows that debonds can be detected with pressure sensors at the case wall. Methodology is described, including:**
 - Differential and baseline methods
 - Effects of test temperature
 - Effects of sensor failure
 - Probability of detection
 - Method to estimate debond size