Uses of Experimentation in the Engineering of Thermal Management

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Why Perform Experiments?

- Investigate New Phenomenon
- Obtain Engineering Design Information
- Perform a Feasibility Study
- Calibrate Analytical Models
- Product Verification and Testing

Investigation of New Phenomena

- Classic research project – *basic* Research, as opposed to *applied* research
- Goal is to learn, not to produce a product
- Procedures and instrumentation may be developed as part of the project.
- Few companies do this kind of basic research

Obtaining Design Data (1)

Examples:

- Fan curves, loss coefficients
- Thermal resistance of heat sinks
- Thermal resistance of interface materials

Nature of Data:

- Collect data over full range of operating parameters
- Collect data at sufficiently fine increments to capture shape of performance curve
- Results are sufficient for a meaningful curve fit

Hardware:

- Device under test should be as close as possible to final design
- Test apparatus should be stable, and reusable in subsequent tests. The apparatus should be designed to allow repeatable measurements.

Role of Uncertainty:

- Uncertainty provides an estimate of accuracy for the engineer who needs to use this data.

Feasibility Study (1)

Some organizations call this "Risk Reduction".

Examples:

- Development of a new type of product
- Assess advantages of a major design change

Nature of Data:

- Collect only enough data necessary to verify concept
- Trends in performance should be identified
- Sensitivity to key parameters is documented
- Boundaries of useful, safe, and reliable operation are delineated
- Effort may benefit from formal design of experiments

Feasibility Study (2)

Hardware:

- A mock-up of the system is likely to be sufficient
- Apparatus may be an existing product with modification

Role of Uncertainty:

- How confident are you that you have proven the concept?
- Is data accurate enough to remove risk in subsequent product development?

Design of Experiments Approach

- Use DOE to determine sensitivity of response to parameters that can be controlled by the device design.
- DOE reduces number of experiments necessary to characterize the system.

Calibration of Analytical Models (1)

Does an analytical model predict performance of a real system? Can the measured data be used to tune the model so that the model can be used to optimize a design? What are the values of the adjustable coefficients in the tuned model?

Examples:

- Validation of a numerical or analytical model
- Obtain correlation parameters in formulas used in hand calculations

Nature of Data:

- Sensors should be located where they give the most information
- Physical position of sensors need to be known with good precision.
- Measurement should be done with highest accuracy that is affordable. Sloppy work is likely give data that will not allow the model to be accurately tuned.
- If possible, sensor/system interaction should be built into the model, e.g., in a CFD model, include significant blockages due to placement of probes in the flow.

Calibration of Analytical Models (2)

Hardware:

- Design of apparatus should match analytical model as closely as possible
- Apparatus might be idealized (simplified) in order to make the comparison a true test of the analytical model.

Role of Uncertainty:

- Allows you to conclude whether the analytical model is correct. Is the disagreement between the model and the experimental results within the experimental uncertainty?

Product Validation (1)

Product validation or certification studies imply that the performance specification is already defined. Standards for some products exist, see, e.g., JEDEC (`www.jedec.org`), NIST (`www.nist.org`), Underwriter Laboratories (`www.ul.com`).

Many corporations have their own testing procedures and specifications.

Product certification may involve the generation of engineering design data for your customers.

Examples:

- Verification that product meets specification(s)
- Provide customers with engineering data, e.g., fan curves, heat sink performance, material property data.

Nature of Data:

- Data collection and procedures are defined by product specification or performance standard.

Product Validation (2)

Hardware:

- Product should be a final production sample.
- Test apparatus is dictated by the performance specification, and should be well maintained (reused).
- Test equipment should be calibrated against known standards.
- Instrumentation should have up-to-date calibration certificates.

Role of Uncertainty:

- Defined by specification
- Device should exceed the specification by at least the measured uncertainty.