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CECAM

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CECAM featured project

"Thermal Modeling for Composite Airframe Structures"

Overview:

General aviation aircraft structures can reach extremely high temperature levels while parked on the ground. These temperature levels depend on ambient conditions (e.g., temperature and solar radiation) and airframe construction (e.g., material types, geometry and paint color).This is an area of concern for composite airframe structures because composite material capabilities are dependent on airframe temperature. Maximum temperature levels are used in design for determining the maximum operating limit (MOL) temperature of the structural elements.

THERMOD is a computer modeling code that determines the MOL temperature for aircraft depending on the paint scheme. The THERMOD computer code, developed by Nathan Govindarajoo, Ph.D., calculates airframe temperatures based on a comprehensive range of factors and predicts steady-state and transient airframe temperature distributions.

Although, limited evaluations have taken place, there is high confidence in the results from THERMOD. Wichita State University wind tunnel experiments evaluating THERMOD convective cooling capabilities show the predictions are reasonable and conservative (typically within 10°C). Wichita State also conducted exposure tests on panels with different paint schemes to validate THERMOD's capability in predicting panel thermal profiles. THERMOD was slightly un-conservative in these tests as it assumes a 10 mph wind to be present, which provides a cooling effect.

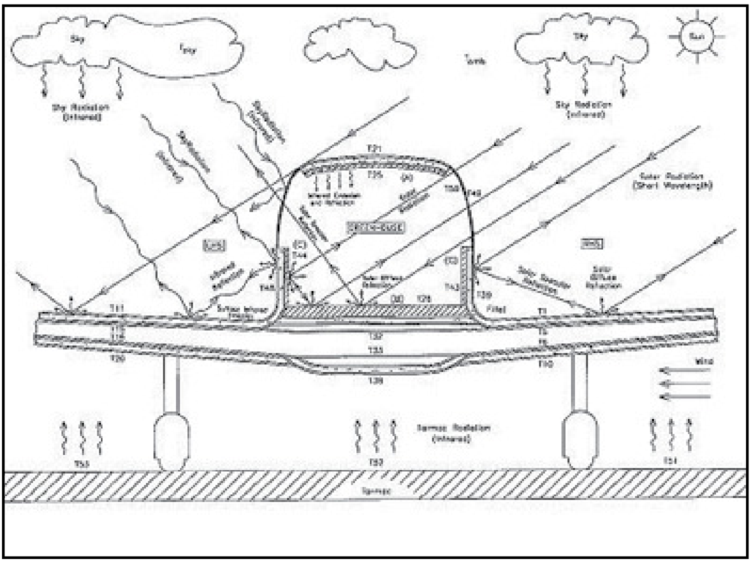
Objective:

THERMOD considers the effects of radiation, convection and conduction to determine MOL temperature. The radiation sources considered include direct solar, infrared sky, tarmac reflected solar and infrared emission from the surrounding structures, including the tarmac, wings, fuselage and their interactions. Convection due to the wind and turbulent convection in the cabin is simulated; one-dimensional conduction through the cabin wall is also simulated. The model incorporates the effect of fairings at the wing-fuselage junction and considers the greenhouse effect in the cabin. It also models the effect of shade underneath the wing. These considerations allow for realistic modeling of the thermal environment.

The program predicts the maximum temperatures of an aircraft from steady-state assumptions, which give conservative steady-state temperatures. Because limit loads generally occur during flight conditions, a transient (unsteady-state) thermal analysis simulates the thermal conditions. This simulates the aircraft executing: taxi, take-off, climb, and cruise, in addition to cooling of the cabin by opening the door. This simulates a realistic thermal environment for predicting the MOL temperature.

THERMOD formulates 67 independent nonlinear equations. The nonlinearity is introduced through radiation effects and convective properties modeled as temperature dependent. The program uses the Newton-Raphson iteration technique to solve this system of equations.

An enhanced, Windows-style version of THERMOD was developed after addressing original issues such as the impact of input variable uncertainties, the accuracy of THERMOD in predicting steady-state or initial temperatures, and improving THERMOD's ease of use. Program enhancements included development of an alternate implicit finite difference method. This method for solving the transient problem is unconditionally stable over the time and spatial domain compared to the original explicit forward finite difference method. Numerical validation of THERMOD was made with finite element methods and good correlation was found.



Above: Schematic representation of THERMOD.

Additional Documentation:

Extensive background information and details on the objectives and summary of results of the project are available in a series of reports. They range from the validation of THERMOD analyses with test data, to a user's manual for using the program. The reports and the THERMOD software are available for download at the website.

Next Featured Project:

"Evaluation of Friction Stir Weld Process and Properties for Aircraft Application"