



Thermal loads of horizontal tail plane structure

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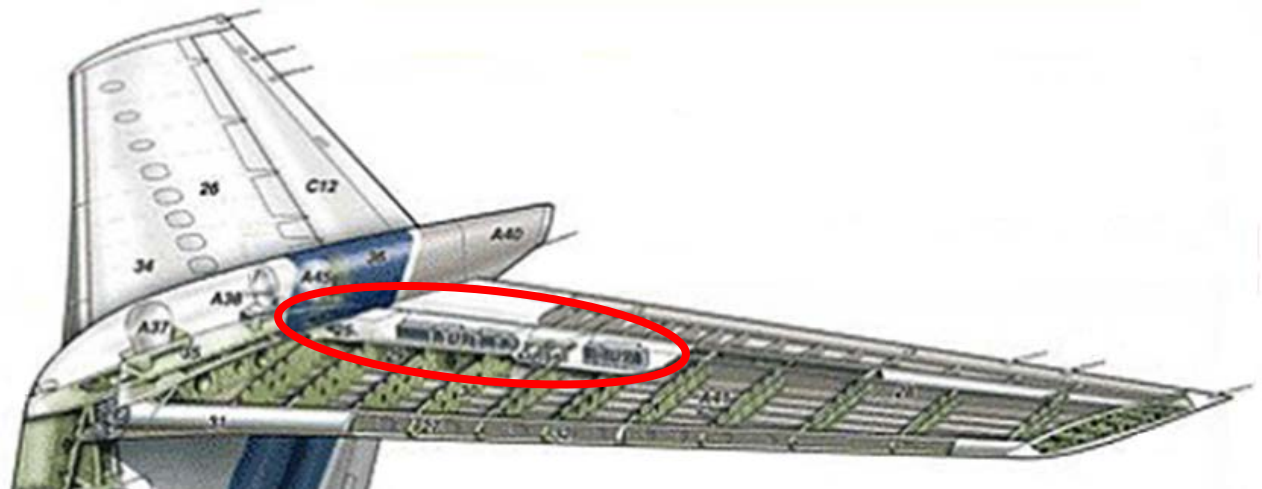
1. Introduction

- **One of the first projects with significant thermal loads in Fokker hybrid component**
- **Considerable effort:**
 - To design for FDT due to thermal loads
 - To conduct thermal tests for correlation with FEM strains
- **Successful FAA/EASA certification achieved**

2. Horizontal stabilizer structure sensitive to thermal loads

Hybrid primary structure:

- CFRP skins, front and rear beams
- Cres pivot fitting, aluminum center beam and ribs
- Especially long center beam attached to pivot fitting attracts thermal loads

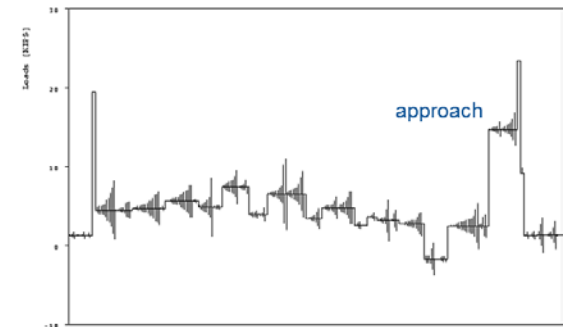


3. Temperature range for static loads

- **Structural temperature range for static load cases:**
- **-67 – +176 deg F / -55 – +80 deg C**
 - Air temperatures < -67 deg F (new text CMH-17, Vol. 1, D. Wilson) covered by aerodynamic heating at M=.85
 - 2D thermal model in following Fokker project: tropical conditions at noon, dark horizontal surface -> drop to +176 deg F in flight segment with relevant loads (due to forced convection)
- **OEM selection of static load cases based upon mechanical loads -> all load cases combined with both temperature extremes**

4. Temperature range for fatigue loads (design phase)

- **Structural temperatures for FDT (during design):**
 - In flight -> International Standard Atmosphere + aerodynamic heating based upon adiabatic equation $T_{\text{total}} = T_0 \left(1 + \frac{\gamma - 1}{2} e M_a^2 \right)$
 - Ground temperature +50 deg C (experience)
- **Good conductivity from boundary layer through CFRP skin and Al ribs and center beam -> little lag**
- **Cres pivot fitting has thermal inertia (also shielded from forced convection by the vertical tail plane and fairing)**
 -> In design phase: critical mechanical load of approach segment is combined with low temperature of previous flight segment



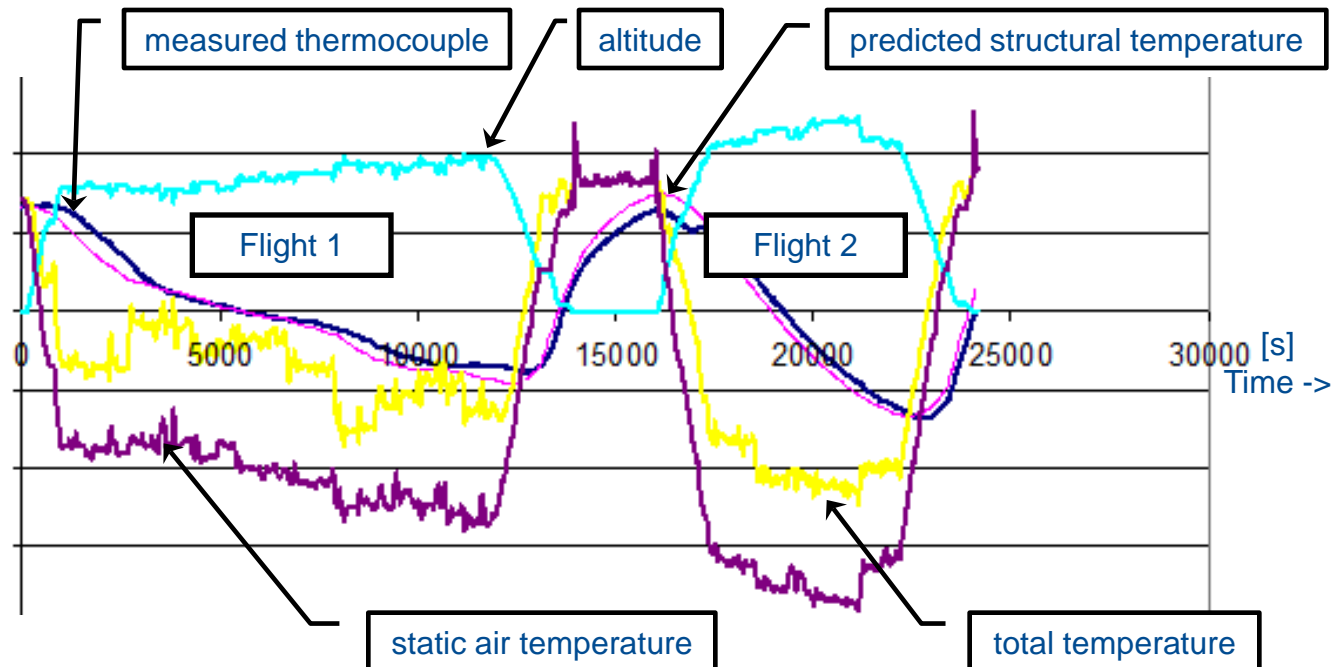
5. OEM ground and flight temperature measurements for FDT (certification)

Structural temperatures measured on ground for a hot day (ISA + 31 deg F plus solar heating) and on typical flights with thermocouples on flight test aircraft

- **Confirmed that (ribs and) center beam show fast response to OML temperature**
- **Static air temperatures in flight lower than International Standard Atmosphere -> adapted**
- **Thermal inertia (and shielding from convection) measured on beam web of pivot fitting
-> temperature model correlated**

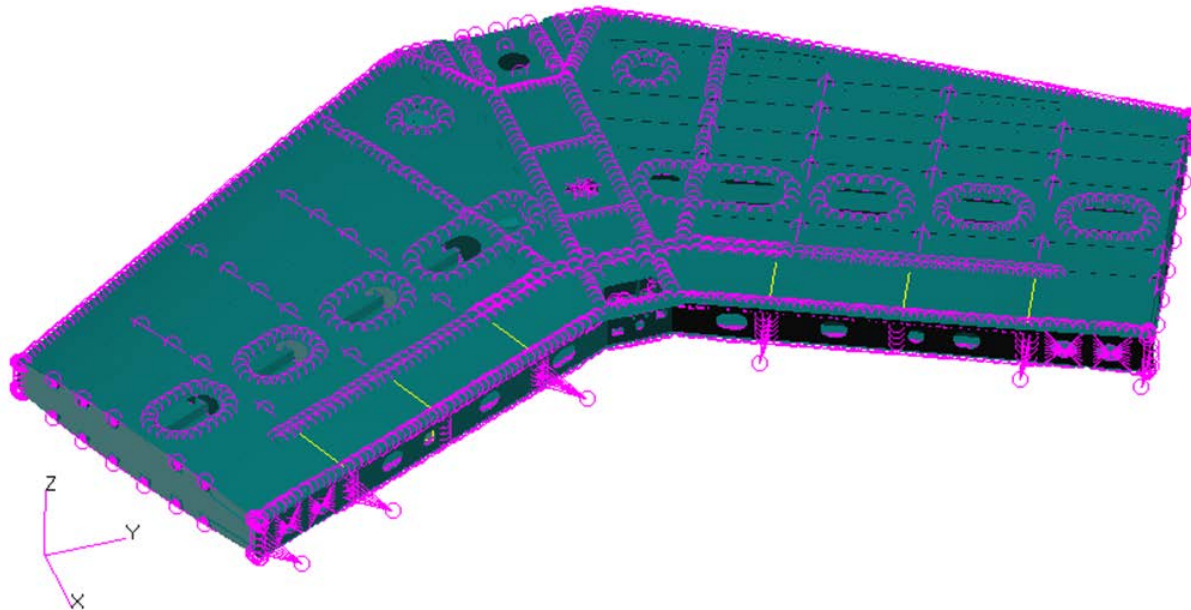
5. OEM flight and ground temperature measurements for FDT (*cont'd*)

- OEM temperature model for analysis shows good correlation also for pivot fitting with thermal inertia, shielded from forced convection by the vertical tail plane and fairing



6. Modelling joints in fine-grid FEM model

- Fine grid FEM model for analysis of composite structure and mainly FDT analysis of metal structure
- Combination of mechanical and thermal loads
- Joints modeled per bolt (infinite stiffness -> Huth)



7. Correlation of thermal loads in FEM and tests

Validation of the thermal loads in thermal tests:

- Instrumented HT component test article in autoclave at Fokker (higher temperatures)
- OEM Test aircraft at Eglin Air Force Base (both lower and higher temperature)

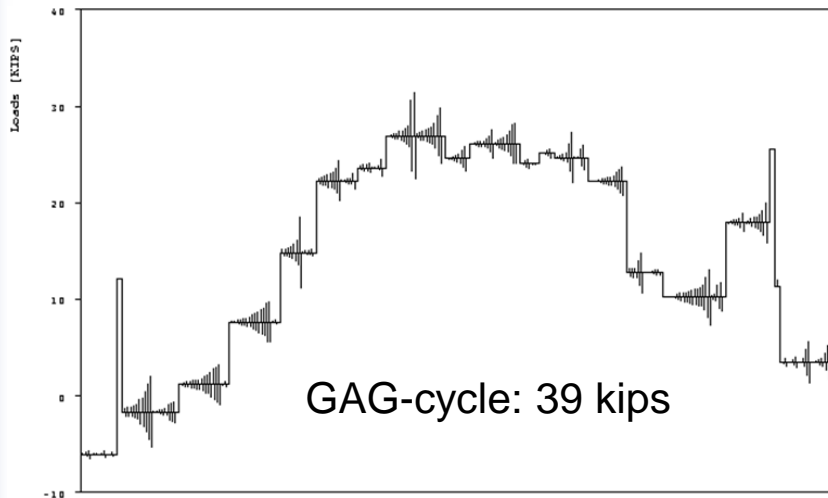
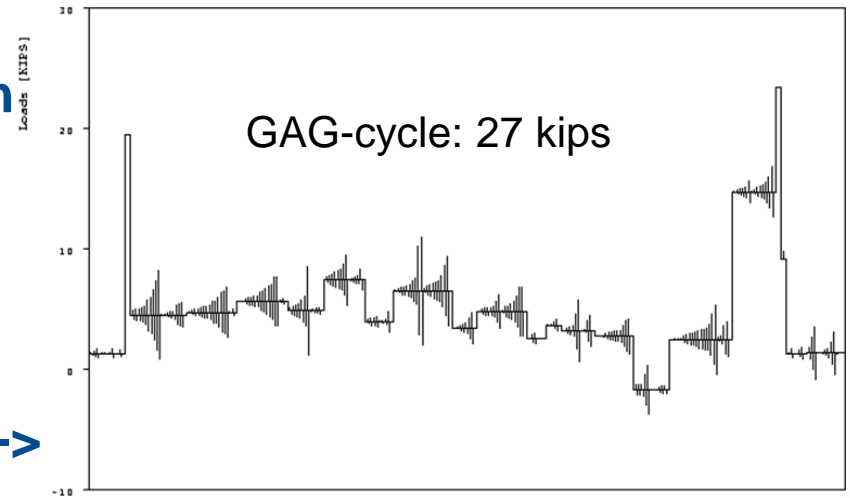
-> FEM modelling
especially of joints
validated by
correlation of strains



8. Thermal loads and mechanical loads in spectrum

Example of long flight with significant thermal loads at aluminum center beam upper cap:

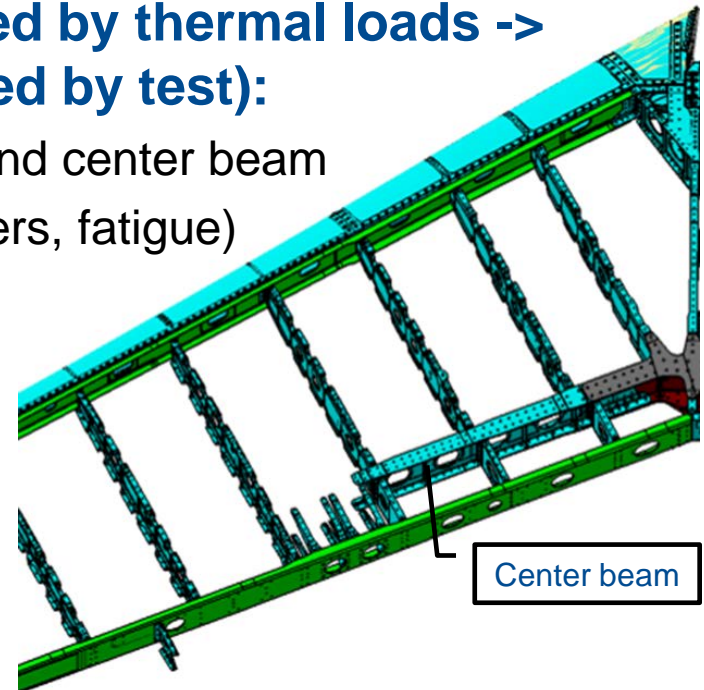
Mechanical loads only ->



<- Same flight with thermal loads added to 1-g mechanical loads

9. Structure covered by analysis (supported by test)

- Thermal loads cannot be covered in full-scale tests (unless by over-loads)
- Especially the following metal structure and composite structure attached to it affected by thermal loads -> covered by analysis (supported by test):
 - Long load path of pivot fitting and center beam
 - Ribs (static analysis joints/girders, fatigue)
 - Leading edge joints
- Based upon correlation: static analysis with factor of safety $j=1$ for thermal loads



10. Compensating for missing thermal loads in DT test

- **Critical inspection interval of multi-element metal joint with directed inspection - affected by thermal loads
-> analysis was to be validated by test**
- **Metal structure is tested in dedicated FDT airframe test
-> thermal loads not covered**
- **HT component test for the composite portion has LEF=1.15 -> enveloped the predicted fatigue damage using analysis that included thermal stresses (test period slightly elongated)**

11. Conclusions

- Depending on design - thermal loads can yield a significant contribution to static and fatigue loads
-> not possible to cover in a full-scale test
- Aerodynamic heating for FDT of aluminum structure attached to skins (especially cruise) can be predicted by equation for recovery temperature at skin surface
- Temperature of heavy/shielded pivot fitting had to be measured
- Ground temperature had to be computed or measured
- Modelling of joints in FEM was validated by thermal tests
- Sufficient correlation to accept factor of safety $j=1$ for static thermal loads
- Critical DT interval affected by thermal loads may still be covered by full-scale test spectrum with LEF for CFRP