BLEED SYSTEM STRESS ANALYSIS: AN APPLICATION OF FINITE ELEMENT ANALYSIS

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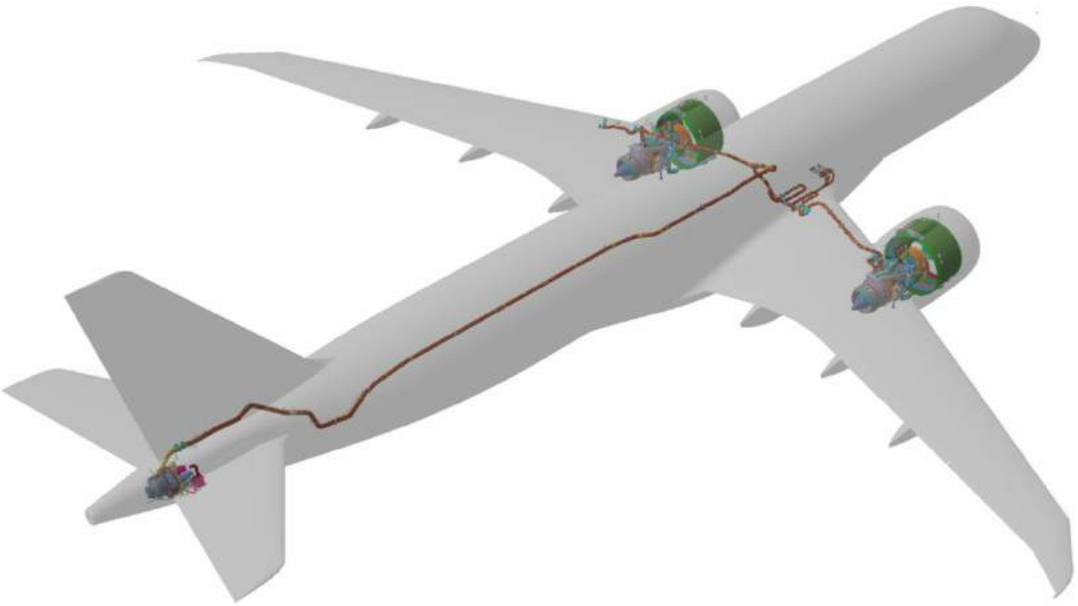
Objective

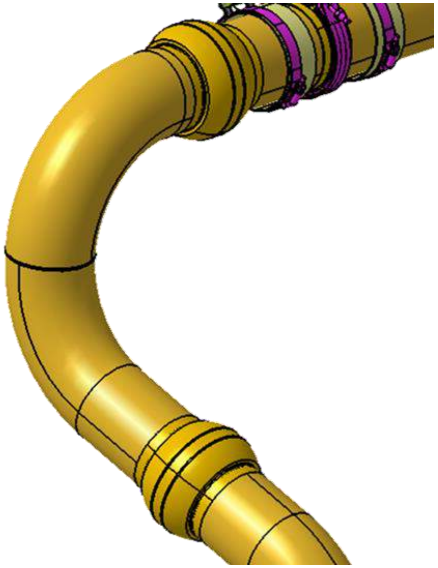
The objective of this presentation is to show the methodology for design of bleed system by using FEA analysis.

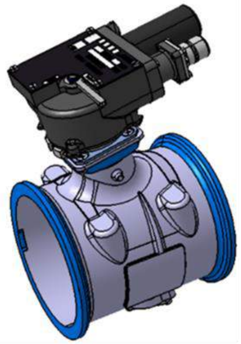


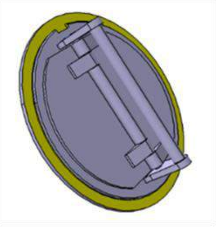
Bleed Air System

In the general the Bleed Air System (BAS) it's composed by:

- Ducts of different materials: Titanium, Aluminum, Inconel, Stainless Steel.
- Valves:
  - Flow Control Valves (FCV);
  - Check Valves (CV);
  - Wing Anti-Ice Valve (WAIV);
  - Ground High Pressure Connection Valve (GHPCV);
  - Etc.
- Couplings:
  - Bellows Ball Joints;
  - Rigid Joints;
  - Hydraflow Joints.



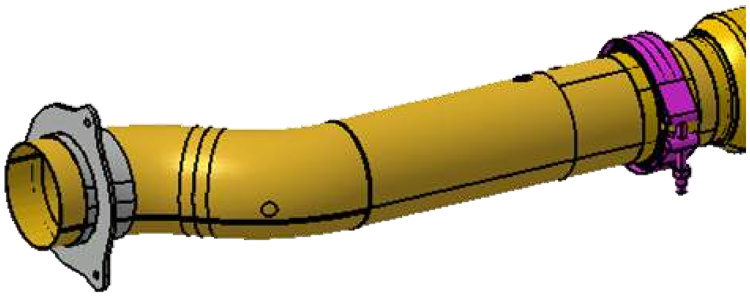


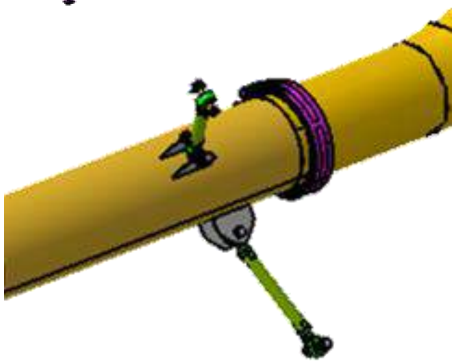


Bleed Air System

In the general the Bleed Air System (BAS) it's composed by:

- Brackets/Supports:
  - Sliding Support;
  - Flanges;
  - Ribs;
  - Plate Supports;
  - Rods.
- Optional Components:
  - Ozone Converter;
  - Molecular Separation;

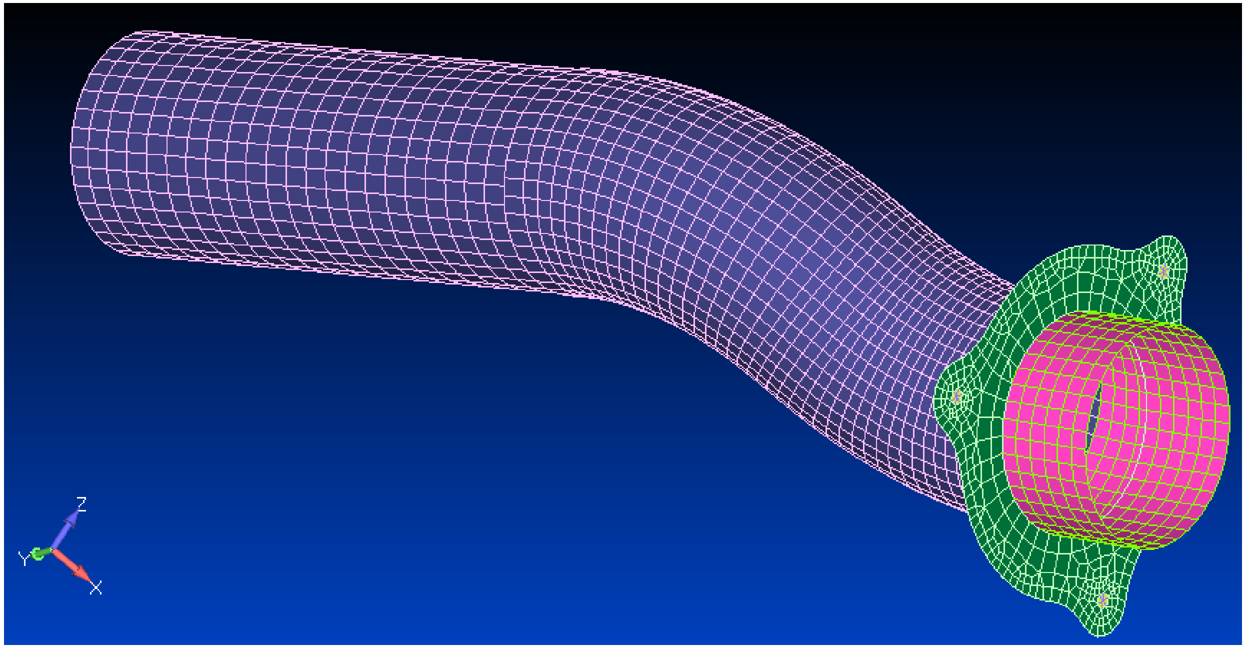




Structural Modeling Definition

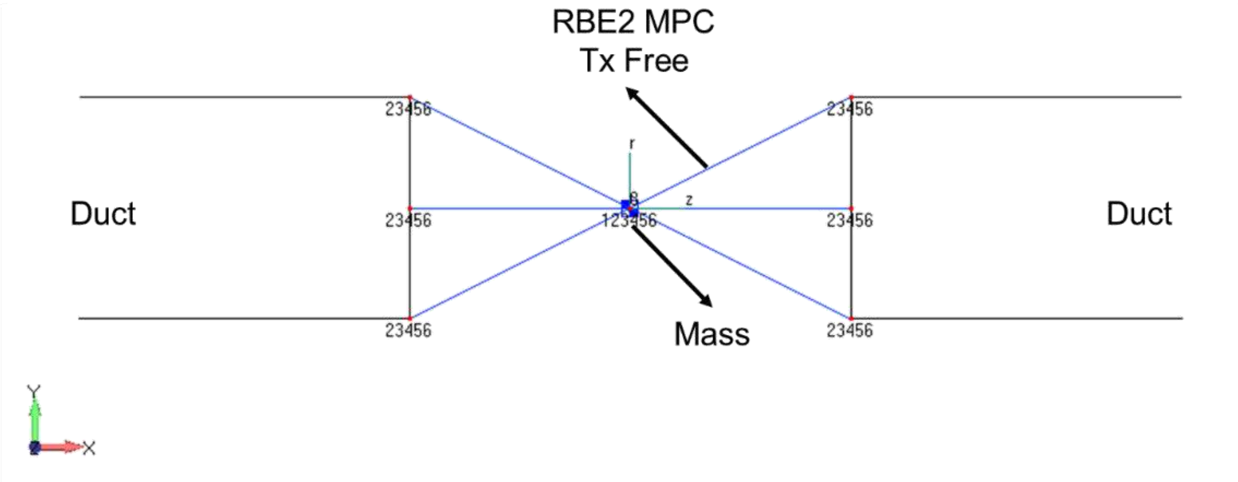
For all components in BAS, it’s can be modeled using elements of plate, spring, rigid, rod and mass:

- **Ducts:** modeled with plate element and the shape used in this case is tree-noded triangle and four-noded quadrilateral and the properties associated to this element are the thickness and the material.

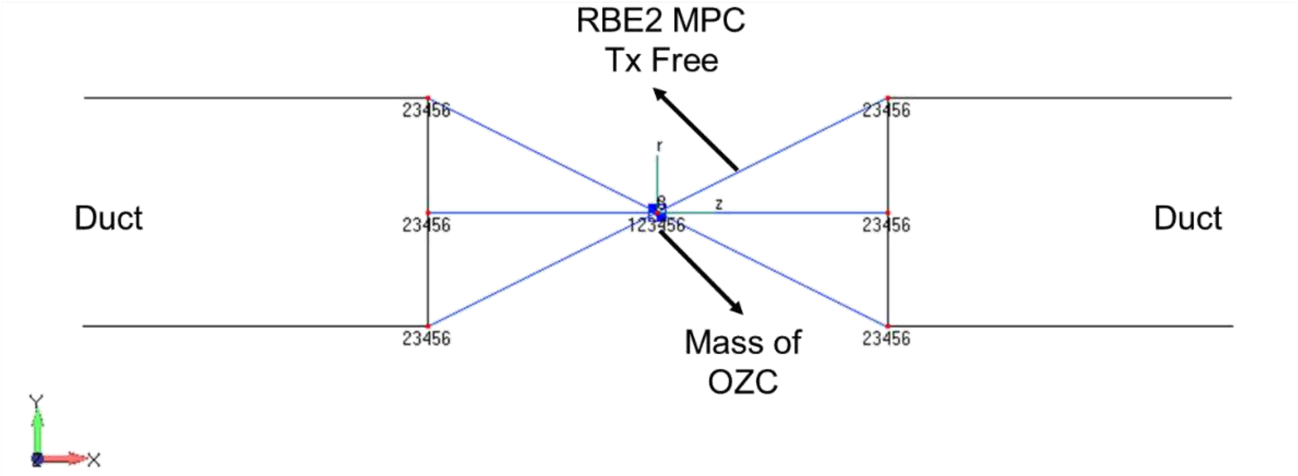


Structural Modeling Definition

- **Valves:** modeled with rigid elements and mass element.

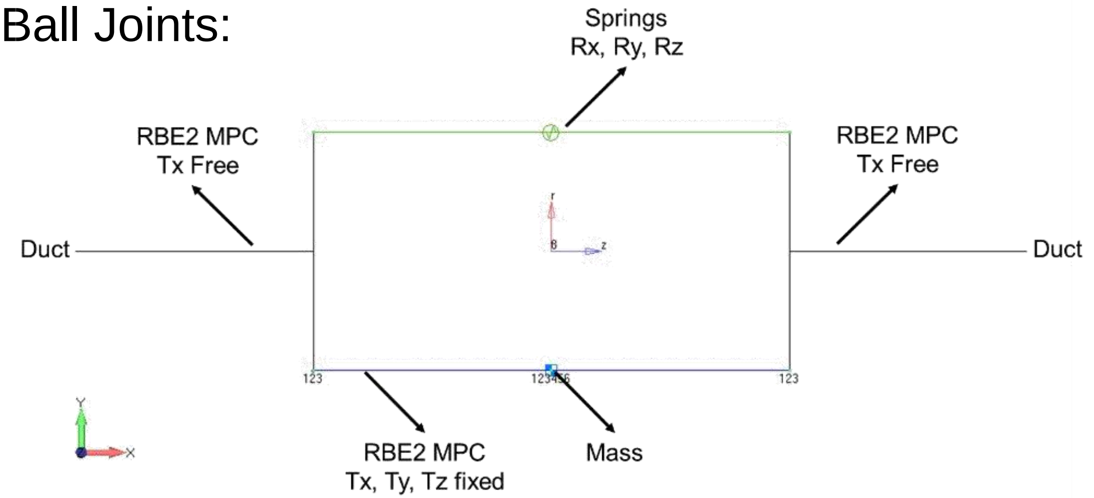


- **Optional Components:** Ozone Converter

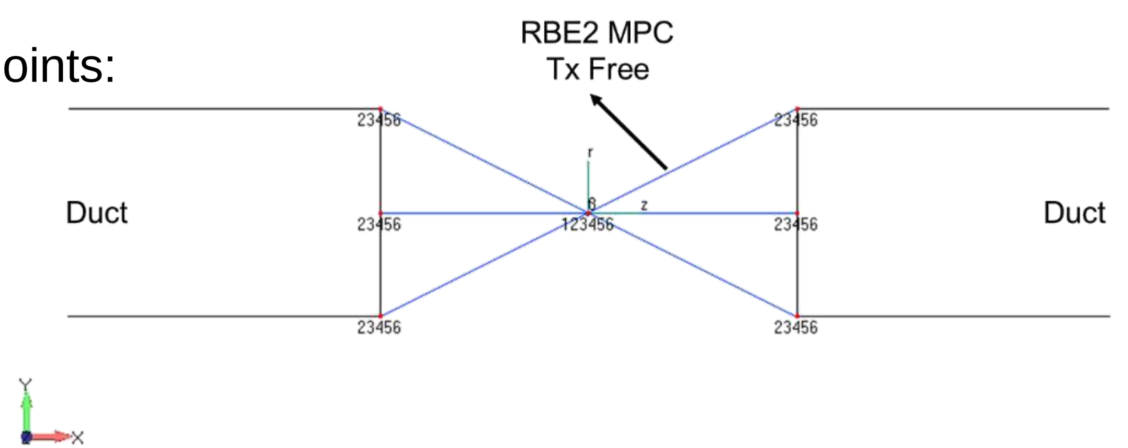


Structural Modeling Definition

- **Couplings:** modeled with elements of mass, spring and rigid.
  - Bellows Ball Joints:

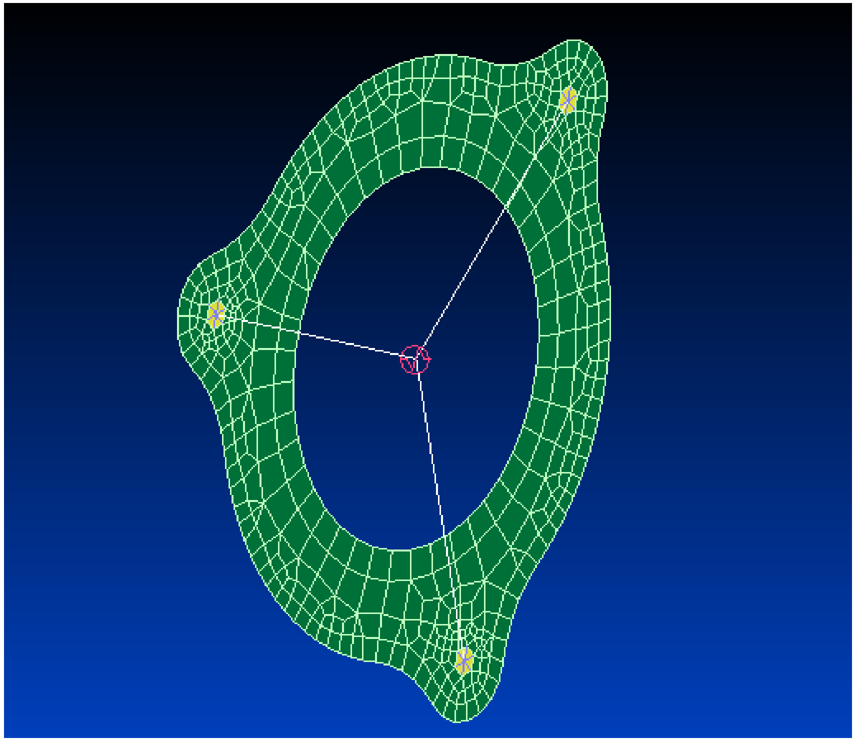


  - Rigid Joints:

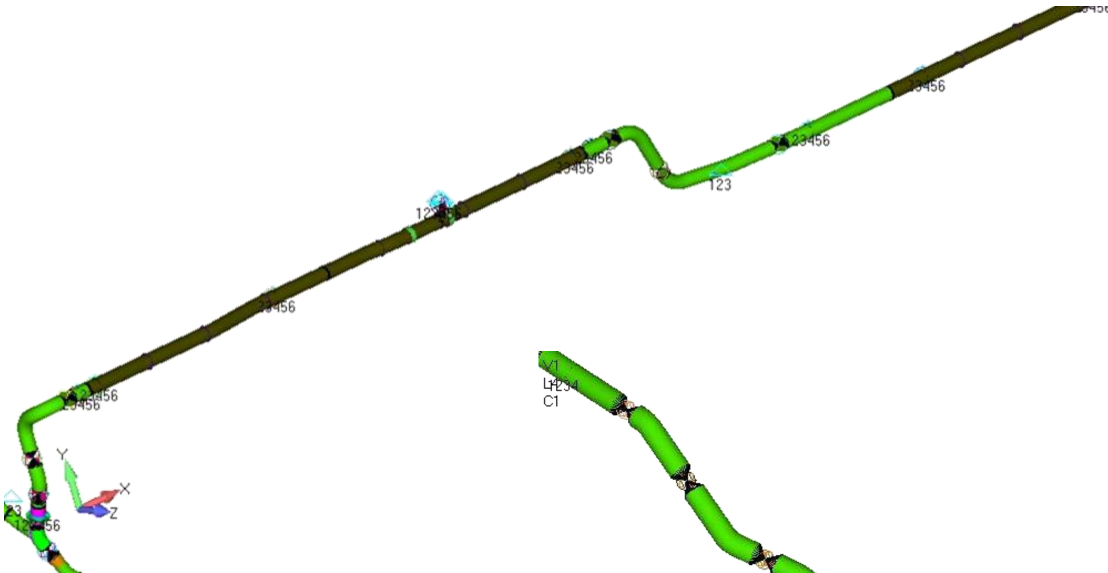


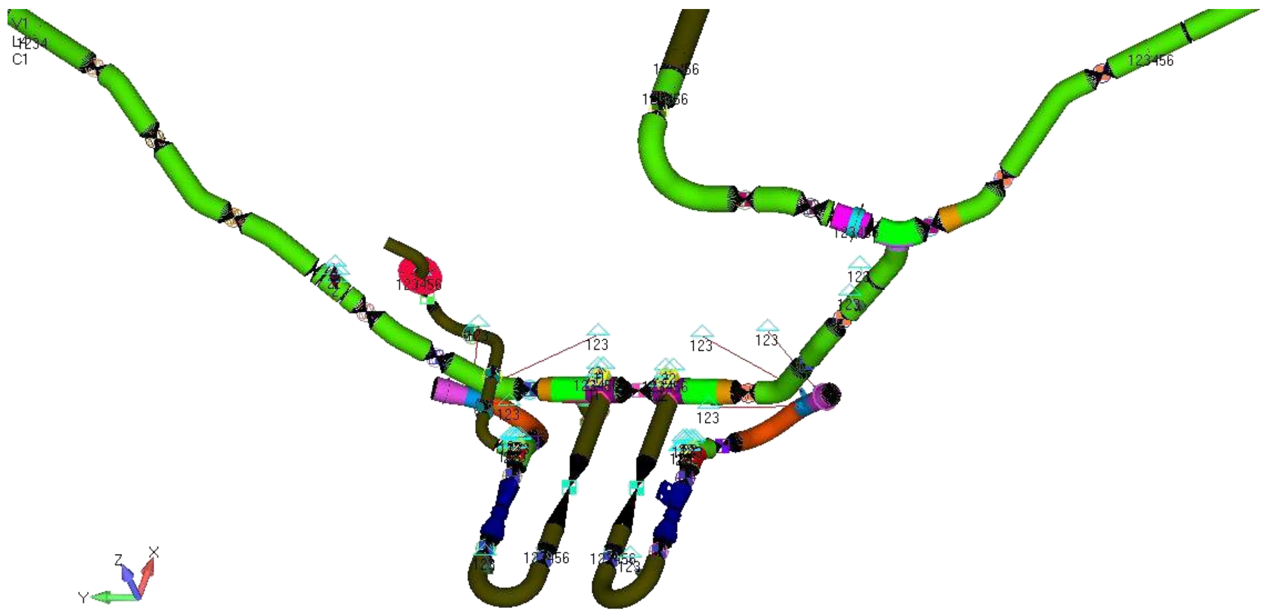
Structural Modeling Definition

- **Brackets/Supports:** modeled with elements of mass, spring, rigid and plate.
  - For each type of bracket it's associate a structural stiffness.

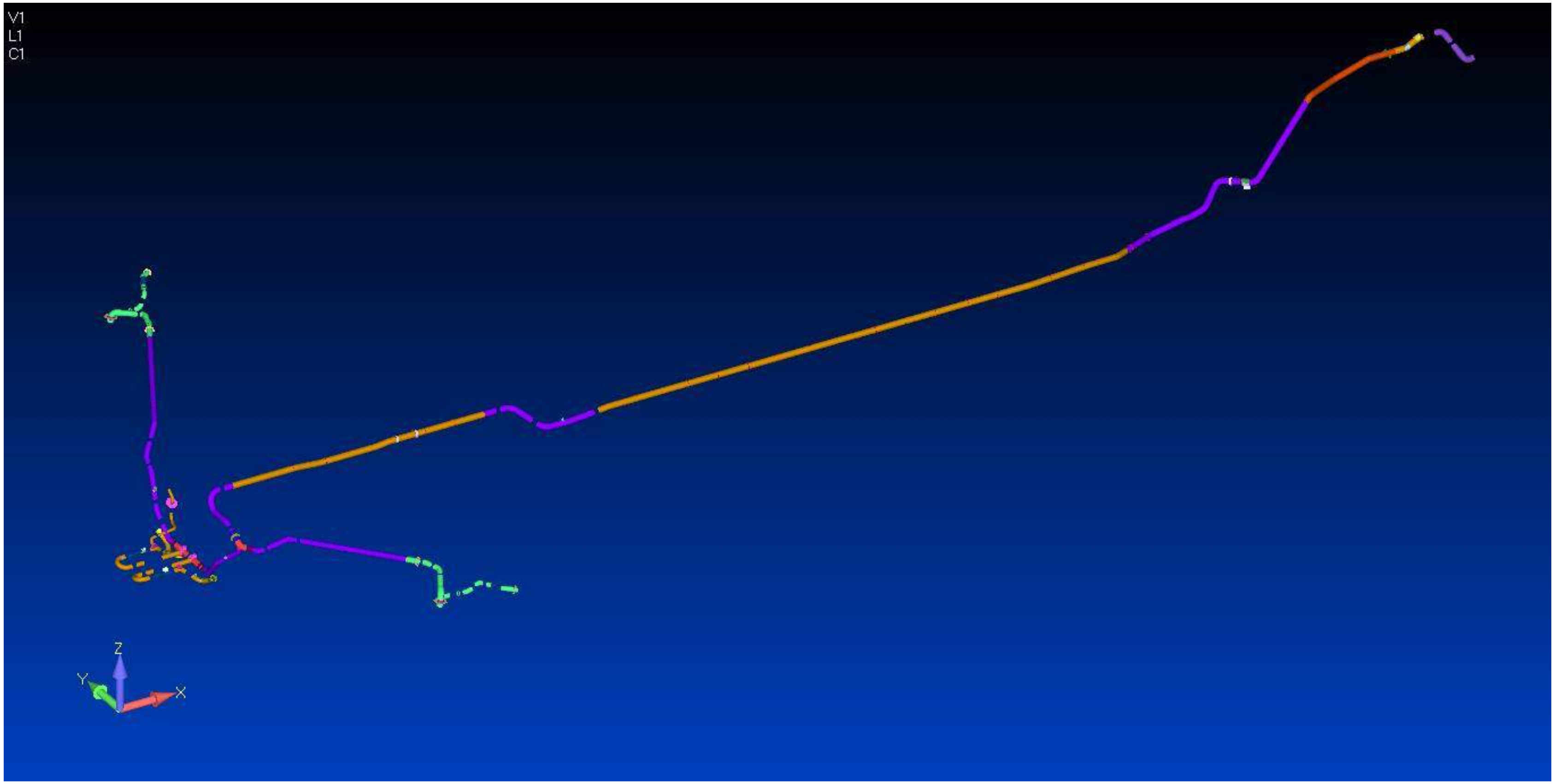


Finite Element Model Overview



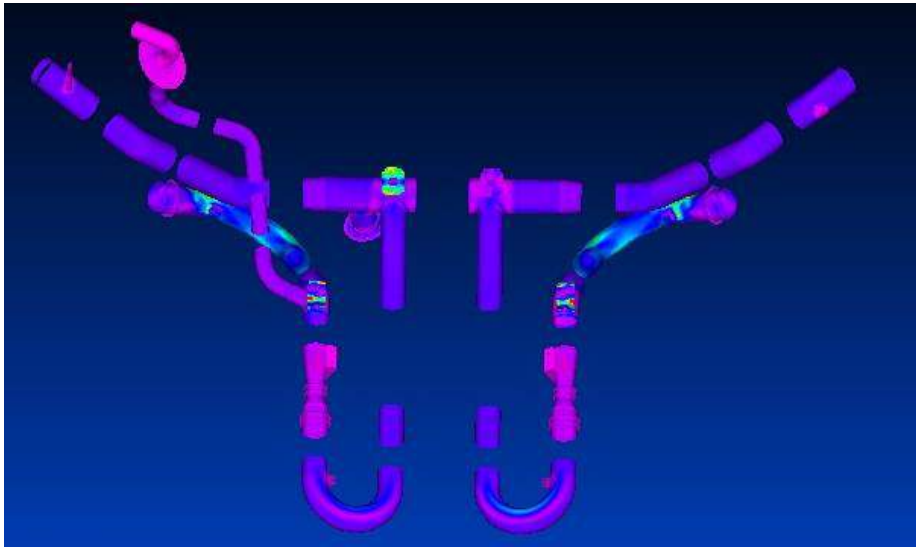


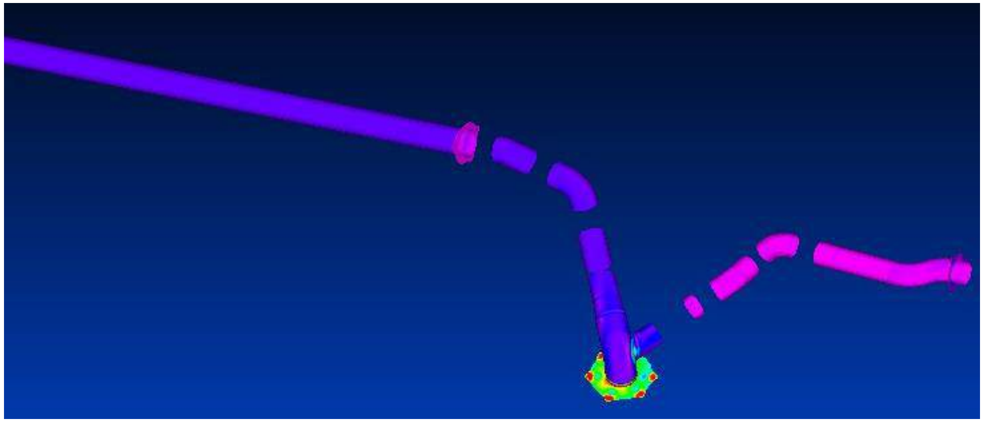
Finite Element Model Overview



Analysis Cases

- **After modeled all parts/components of the BAS, a several type of analysis could be done:**
  - Modal Analysis
  - Static Analysis
  - Frequency Response





Loads Cases

- **Requirements:**
  - § FAR 25.1438 Pressurization and pneumatic systems.
    - (a) Pressurization system elements must be burst pressure tested to 2.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure.
    - (b) Pneumatic system elements must be burst pressure tested to 3.0 times, and proof pressure tested to 1.5 times, the maximum normal operating pressure.
    - (c) An analysis, or a combination of analysis and test, may be substituted for any test required by paragraph (a) or (b) of this section if the Administrator finds it equivalent to the required test.

[Amdt. 25-41, 42 FR 36971, July 18, 1977]

Loads Cases

- **Requirements:**

  - § CS 25.1438 Pressurisation and low pressure pneumatic systems
  - Pneumatic systems (ducting and components) served by bleed air, such as engine bleed air, air conditioning, pressurisation, engine starting and hotair ice-protection systems, which are essential for the safe operation of the aeroplane or whose failure may adversely affect any essential or critical part of the aeroplane or the safety of the occupants, must be so designed and installed as to comply the CS 25.1309 In particular account must be taken of bursting or excessive leakage. (See AMC 25.1438 paragraph 1 for strength and AMC 25.1438 paragraph 2 for testing.)

Loads Cases

- **Requirements:**
  - § AMC 25.1438
  - Pressurisation and Low Pressure Pneumatic Systems
  - 1 Strength
  - 1.1 Compliance with CS 25.1309(b) in relation to leakage in ducts and components will be achieved if it is shown that no hazardous effect will result from any single burst or excessive leakage.
  - 1.2 Each element (ducting and components) of a system, the failure of which is likely to endanger the aeroplane or its occupants, should satisfy the most critical conditions of Table 1
  - 1.3 After being subjected to the conditions given in column 1 of Table 1, and on normal operating conditions being restored, the element should operate normally and there should be no detrimental permanent distortion.
  - 1.4 The element should be capable of withstanding the conditions given in column 2 of Table 1 without bursting or excessive leakage. On normal operating conditions being restored, correct functioning of the element is not required.
  - 1.5 The element should be capable of withstanding, simultaneously with the loads resulting from the temperatures and pressures given in the Table, the loads resulting from –
    a. Any distortion between each element of the system and its supporting structures.
    b. Environmental conditions such as vibration, acceleration and deformation.
  - 1.6 The system should be designed to have sufficient strength to withstand the handling likely to occur in operation (including maintenance operations).

Loads Cases

- **Table 1:**

Conditions 1	Conditions 2
1·5 P_1 at T_1	3·0 P_1 at T_1
1·33 P_2 at T_2	2·66 P_2 at T_2
1·0 P_3 at T_3	2·0 P_3 at T_3
–	1·0 P_4 at T_4

- P1 = the most critical value of pressure encountered during **normal functioning**.
- T1 = the combination of internal and external temperatures which can be encountered in association with pressure P1.
- P2 = the most critical value of pressure corresponding to a probability of occurrence **'reasonably probable'.**
- T2 = the combination of internal and external temperatures which can be encountered in association with pressure P2.
- P3 = the most critical value of pressure corresponding to a probability of occurrence **'remote'.**
- T3 = the combination of internal and external temperatures which can be encountered in association with pressure P3.
- P4 = the most critical value of pressure corresponding to a probability of **occurrence 'extremely remote'.**
- T4 = the combination of internal and external temperatures which can be encountered in association with pressure P4.

Loads Cases

- **Requirements:**
  - 2 Tests
  - 2.1 Static tests. Each element examined under 1.2 should be static-tested to show that it can withstand the most severe conditions derived from consideration of the temperatures and pressures given in the Table. In addition, when necessary, sub-systems should be tested to the most severe conditions of 1.2 and 1.5. The test facility should be as representative as possible of the aircraft installation in respect of these conditions.
  - 2.2 Endurance tests. When failures can result in hazardous conditions, elements and/or sub-systems should be fatigue-tested under representative operating conditions that simulate complete flights to establish their lives.

Loads Cases

- **Approach:**
  - Use AMC 25.1438 to select most conservative proof case from TABLE 1
  - Do that for each part of the system downstream of each valve
  - Apply maneuver loads by selecting the highest G loads in X, Y, Z directions separately
  - Apply fuselage, wing and pylon maximum displacements
  - Result: extremely conservative analysis that reflects directly in system weight and complexity.

Loads Cases

- **Questions:**
  - Result: extremely conservative analysis
  - Question 1: is this loads cases definition applicable only for testing separate components in laboratory benches?
  - Question 2: why will one simulate the entire complete coupled system with same load cases adopted for separated components?
  - Question 3: proof cases are defined in order to over predict behavior and have big margin of safety (“margin of ignorance”) for separated/isolated parts. Will not the complete coupled analysis be able to decrease the margin of safety?
  - Question 4: Why do not use same margin of safety of other aircraft structures if the complete coupled analysis is done?

THANK YOU !

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