Innovative Flexible Bracket Design and Simulation for Aircraft Mechanical Systems

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Abstract

Support brackets are extensively used for holding the ducts, cable bundles and high pressure and temperature fluid lines in aircraft mechanical systems such as in Environmental Control System (ECS) and electrical systems. Typically, the air conditioning system operates using engines bleed air and supplies controlled conditioned air to the passenger and the crew compartments. Refrigeration is produced by an air cycle system. Bleed air needs to be tapped from engine would experience a varying pressure load (up to 350 psi) and varying temperature (up to 600°C) at different operating conditions. This would obviously produce the expansion/contraction of pipes which will result in axial moment and angular displacement from their nominal positions. These movements should be compensated by means of providing suitable expansion joints/thermal compensators to avoid undesirable loads at the support points which may affect the overall functioning of the system. It is found that several methods such as braided flexible hoses with rigid support brackets are used in skewed pipe routing layouts. In this paper it is proposed to use flexible support brackets instead of rigid brackets. This methodology allows to introduce plain bellows (low cost & weight) with flexible brackets which allows the pipe assemblies for expansions/contractions. Further modular construction of the bracket allows movements either in linear or lateral directions with minor modification to the bracket, thus making it suitable for any pipe assembly lines carrying high pressure and temperature fluid. Simulation is carried out using CATIA V5 R20 DMU kinematics for a typical ECS-engine bleed air pipe routing of a transport aircraft where lateral/linear movement of the pipe is simulated in the model for different directions.

Keywords: Flexible, Bracket, Engine, Bleed Air, Kinematics, Simulation.

1 Introduction

There was a requirement for development of innovative flexible bracket design concepts for the installation of aircraft mechanical system. For the purpose flexible support bracket design concepts were studied and proposed against rigid bracket support design. Flexible support bracket are the structural substantiation for ducts in static and fatigue conditions. It ensures that all the components such as valves, bellows, gimbals etc., are being operated under their structural limitations and to optimize system support scheme (location, direction, free play) by minimizing reaction loads and number of degrees of freedom.Since the bracket installation zone is around the rear fuselage area Fig. (1&2) attached to pressure bulkhead of fuselage structure, it is necessary to know about some basic structural elements through which the routing of air ducts and cable bundles takes place.

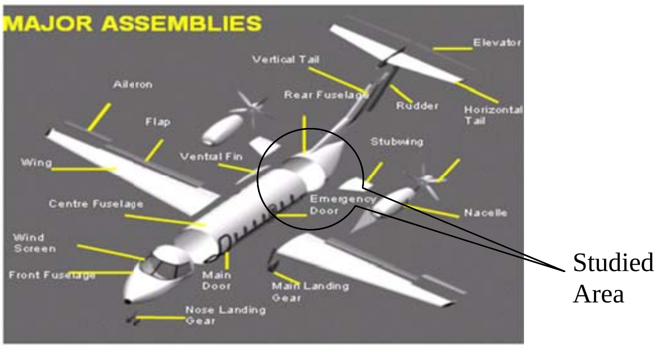

Figure 1: Studied area

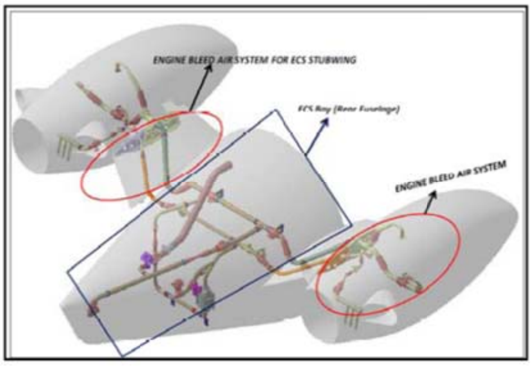

Figure 2: Installation zone

1.1 Aircraft structures

Major airframe units are classified as [1] fuselage, wings, empennage (stabilizers, rudder, and elevators), flight control surfaces (aileron, spoilers, flaps and slats), landing gear. Among these, fuselage is an essentially tubular structure, with the forward and rear ends formed as cones. The fuselage structure is divided into vertical (frames/rings, bulkhead) and longitudinal members (longerons, stringers), as can be seen in Fig. (3).

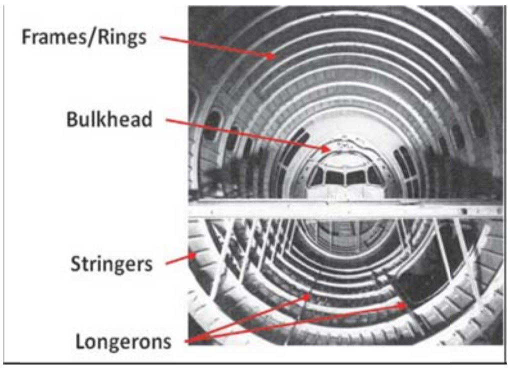

Figure 3: Fuselage cross section

The external skins are made from sheets, suitably formed to follow the aerodynamic shape by rolling or stretching form. They are secured to the longitudinal and transverse supporting structure by riveting. The largest single item of the fuselage structure is the skin Fig. (3) and its stiffeners. It is also themost critical structure since it carries all the primary loads due to fuselage bending, shear, torsion, and cabin pressure [2].Frames Fig. (3) are relatively light structural elements, which are generally made up of rolled or stretch formed sheet or extruded sections. The fuselage longitudinal members pass through cut outs in the frames and are attached by cleats to the frames webs. The longitudinal members terminate at the forward and rear faces of the major bulkheads.The longerons are of relatively heavy sections compared to the stringers. Both of them were made up of rolled or extractedsections, suitably formed to follow the skin contours by forming on press brakes or stretch forming presses.Bulkheads Fig. (3) are the major load carrying members of the fuselage.

1.2 Environmental control system

In a typical Light Transport Aircraft (LTA), the air conditioning system operates using engine bleed air and supplies controlled conditioned air to the passenger and the crew compartments. Refrigeration is produced by a single bootstrap air cycle system. The temperature control functions are accomplished automatically by an electronic controller in conjunction with an electro-pneumatic Temperature Control Valve. Re-circulated cabin air is mixed with sub-zero air conditioning pack outlet air to achieve the required cabin conditioning airflow with minimum engine bleed airflow. The conveyance of air is through pipe routings.These pipe routings are hot lines that tap the bleed air from the engine and pass through the ejector system. The hot air passing through these lines would be cooledand subsequently used for ECS of the aircraft. ECS pipe routing design for a typical LTA is shown in Fig. (2).The bleed air pipes that tap the air from engine would experience a varying pressure load (as high as140psi) and varying temperature (as high as 340°C) at different segments. This would obviously produce the expansion/contraction of pipes which would result in axial moment and swaying of pipelines from their nominal configuration. These movements if unaccounted, by not introducing of expansion joints, would lead to undesirable loads at the support points affecting the overall functioning of the system. With the limited anchoring points available in the aircraft structure and also fixed ECS configuration, the routing of pipes (skewness, length) to suitably accommodate the joints becomes an arduous task. The skewness of pipe in both planes adds to the complexity of the design.

2 Bracket design

The structural elements considered, while designing the brackets, are skin, stringers, clips, and frames Fig. (3). Bracket is a small fitting or support used to attach system parts as duct, fluid pipes, cable and blanket keeping them in the intended positions. Generally, the brackets are made from steel sheet strip slit and are cut to size before configured to the required shape by bending operation. The brackets are heat-treated to obtain the desired surface properties.

2.1 Types of brackets

Fig. (4) Provides the following basic types of brackets:

- A-bracket is directly attached to the primary structure with permanent fasteners.
- B-bracket is a removable bracket attached on to A-brackets or directly on to the structures.
- C-bracket is attached to either A or B ones; usually they are attached to the A and B brackets.

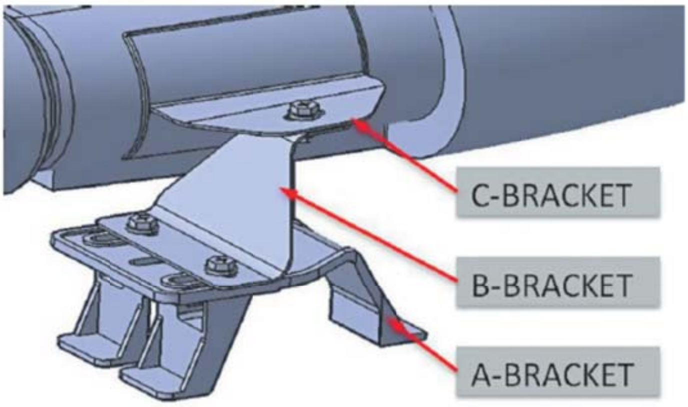

Figure 4: Types of brackets

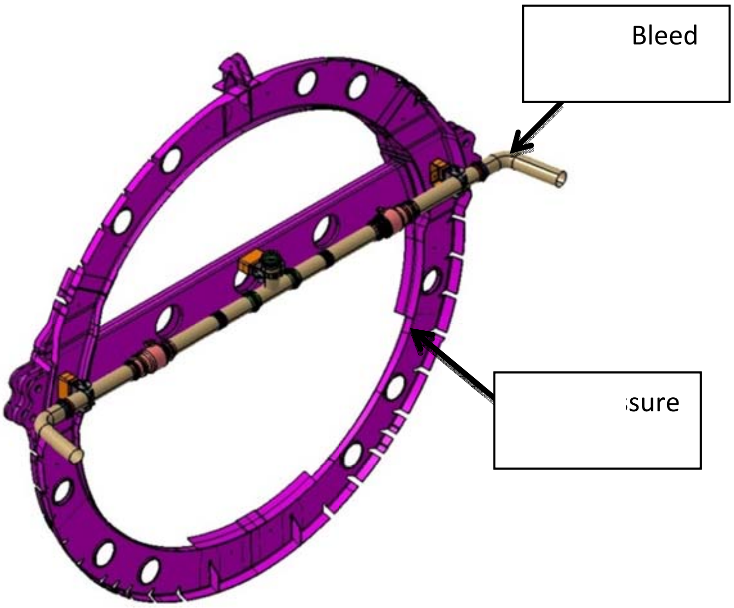

Figure 5: Installation design environment

2.2 Bracket design requirements

Fig. (5). shows the bracket installation environment. The brackets are to be designed such that they will not damage system, structure and insulation brackets during the life span of aircraft. Their weight shall be minimized as much as possible thus reducing the overall aircraft weight leading to indirect cost savings. Brackets are designed for their intended use within the operating temperature of the aircraft. The unique feature of the brackets is that they shall be easy to install with a quick-fix mechanism by one technician thus, saving phenomenal time for the installation and disassembly.The number of feature elements constituting the brackets shall be minimized optimally. While designing the brackets, care shall be taken on the manufacturing aspects, such as ease of production, machining, tolerances, and manufacturing cost.

2.3 Design features of flexible support bracket

The design shall be adapted to the structural elements shape such as frame section and respective interfaces. Fig. (6). shows the main features of the flexible support bracket. Bracket was designed and simulation was carried out for different assembly conditions using CATIA V5 R20 commercial software. The expansion/contraction of pipes which result in axial moment and angular displacement from their nominal positions are compensated by means of providing suitable expansion joints/thermal compensators to avoid undesirable loads at the support points which may affect the overall functioning of the system. It was found that several methods such as braided flexible hoses with rigid support brackets are used in skewed pipe routing layouts. However, in comparison with plain bellows braided flexible bellows are relatively complex in construction and costly. Thus, the proposed flexible support bracket allows using simpler low cost and low weight plain bellows with the combination of flexible brackets which allows the pipe assemblies for expansions/contractions. Modular construction of the bracket allows movements either in linear or lateral directions with minor modification to the bracket, thus making it suitable for any pipe assembly lines carrying high pressure and temperature fluid. Fig. (7). Show the different orientations of the support bracket which can be used according to the anticipated direction of thermal compensation requirement.

3 Simulation

Simulation was carried out using CATIA V5 R20 kinematics for a typical ECS-engine bleed air pipe routing of a transport aircraft where lateral/linear movement of the pipe is simulated in the model for different directions. Fig. (8 & 9) shows the position of the engine bleed line for lateral movements.

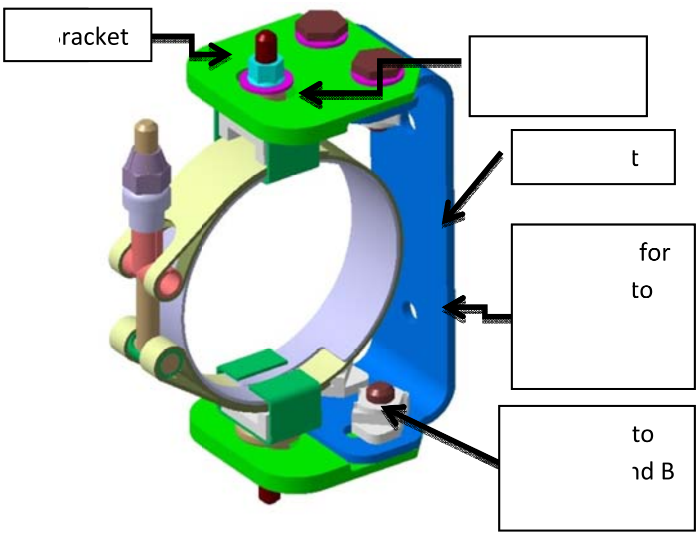

Figure 6: Flexible bracket features

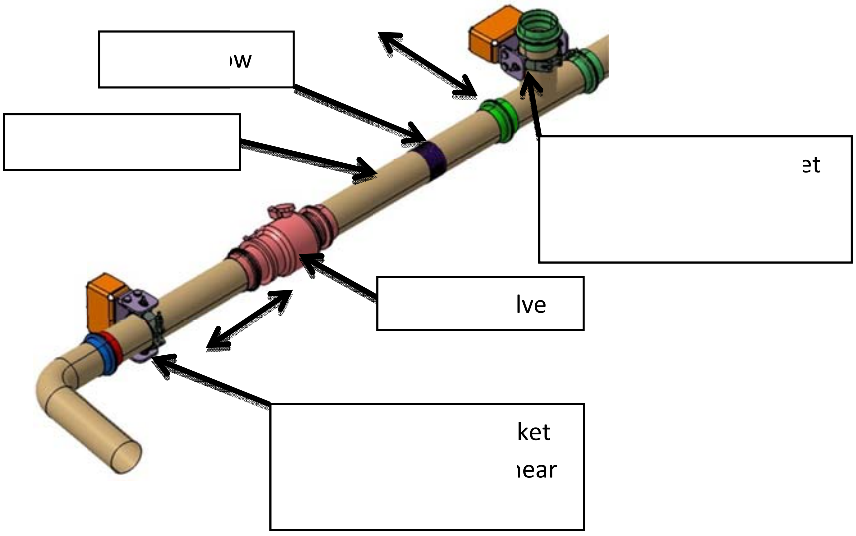

Figure 7: Clamping of engine bleed line

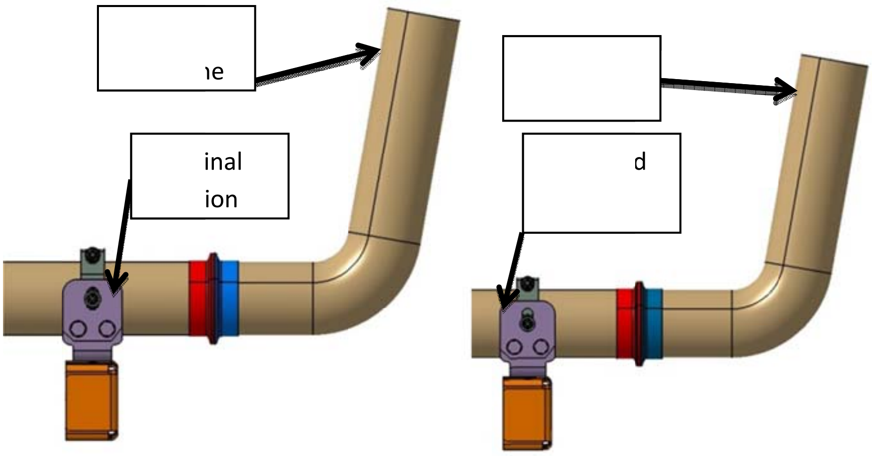

Figure 8: Lateral direction compensation

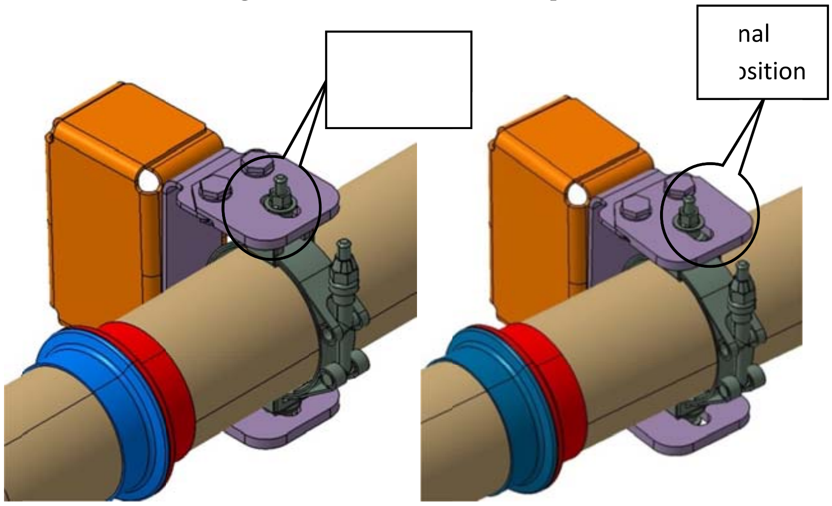

Figure 9: Simulation result

4 Conclusion

Proposed flexible support bracket simulation results have indicated that the expansion/contraction generated by the plain bellows due to thermal and structural loads are compensated successfully by the innovative feature employed in the bracket. Thus reducing the reaction loads on the support bracket. Use of flexible support brackets allows to introduce plain bellows which is cost effective. Modular construction of the bracket allows movements either in linear or lateral directions with minor modification to the bracket, thus making it suitable for any pipe assembly lines carrying high pressure and temperature fluid. In summary this paper provides the new concept of bracket design which can be adopted for similar applications with minor modifications.

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