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Innovative Bracket Design Concepts for the Installation of Aircraft Systems

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Abstract: *Following continually varying customer specific demands across the globe, aircraft design strategy is constantly changing. The manufacturers are focusing on finding ways to make the products more flexible thus meeting the several product variants with controlled manufacturing costs. Herein, the flexibility addresses the variety of needs with less product combinations through standardization/interchangeability while meeting all the requirements. Nowadays, the industry has also realized that the cost reduction has been one of the key driving factors to keep in the free-market competition. Therefore, it is imperative to find innovation methods across the manufacturing cycle of the aircraft keeping a close watch on cost control. The scope of innovation is extended to all areas of design encompassing its phases of all aircraft systems. The context of this paper is pertained to air conditioning and electrical systems, which are two areas where the routing of air ducts and electrical wires/cable bundles, respectively, need to be securely clamped to the structural elements. Brackets are extensively used for holding these ducts and cable bundles. It is found that, presently, several conventional clamping methods are used for holding the ducts and wire bundles individually. Hence, it is required to develop innovative brackets to hold combined both ducts and wire bundles wherever is possible. The new brackets impact potentially on weight and cost reduction in addition to substantial savings on assembly and maintenance time. The brackets thus designed have sufficient strength, low weight, and are easy to manufacture to be integrated with selected Air Transport Association systems. This paper aimed at describing the scope of the task, design requirements and best practices adopted while executing the project for an aerospace customer.*

Keywords: *Air ducts (ATA 21), Electrical cables (ATA 92), Mounting brackets, Wire bundles and insulation blankets.*

LIST OF ACRONYMS

A/C	Aircraft
ATA	Air Transportation Association
ABS	Acrylonitrile butadiene styrene
DT keys	Design time keys
ECS	Environmental Control Systems

INTRODUCTION

One of our strategic customers has approached us in developing innovative bracket design concepts for the installation of aircraft systems. Since the bracket installation zone is around the frame area (Fig. 1a, b) attached to fuselage structure, it is necessary to know about some basic structural elements through which the routing of air ducts and cable bundles takes place. The studied zone is extended on fuselage area covering its entire sections for the application of bracket installation.

Aircraft structures

Major airframe units are classified as (Chun-Yung, 1988): fuselage, wings, empennage (stabilizers, rudder, and elevators), flight control surfaces (aileron, spoilers, flaps, and slats), and 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. 2.

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 the

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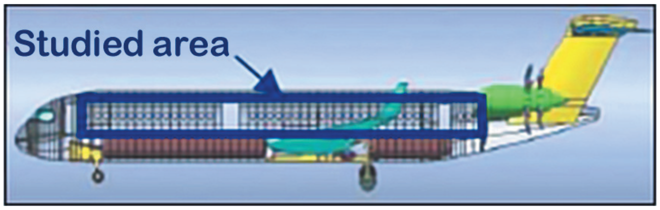
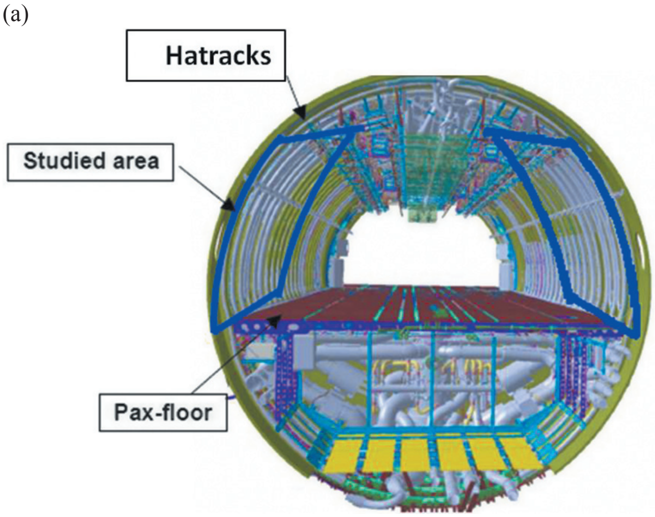


(a)



(b)

Figure 1. (a) Studied area; (b) Installation zone.

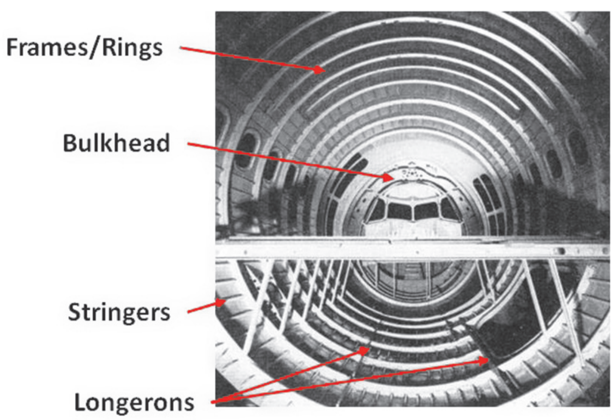


Figure 2. Fuselage cross-section

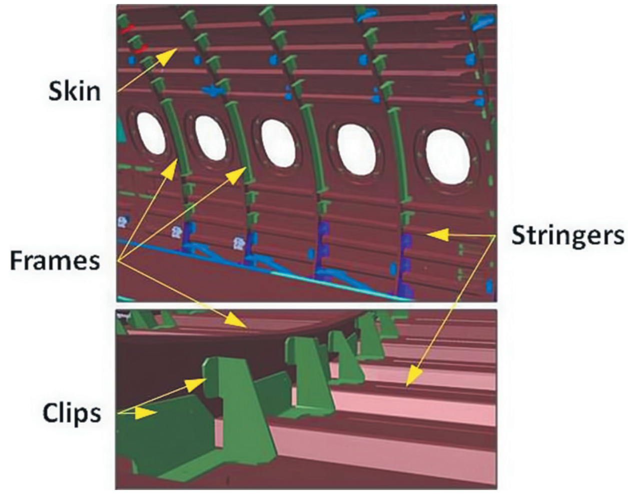


Figure 3. Fuselage elements

most critical structure since it carries all the primary loads due to fuselage bending, shear, torsion, and cabin pressure (Ganapathi, 1993).

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 cutouts 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 extracted sections, suitably formed to follow the skin contours by forming on press brakes or stretch forming presses. Bulkheads (Fig. 2) are the major load carrying members of the fuselage.

Stringers (Fig. 3) when rolled from strip stock are limited in length by manufacturing techniques. Since the skin and stringers are working together, they are spliced at the same location, maintaining the relative stiffness of the skin/stringer combination.

The purpose of stringer clips (Fig. 3) are to transfer skin panel normal pressure loads to frame; to help break up excessive column stringer length; to provide some degree of compressive strength of frame inner chord; and to act as a frame web panel stiffener.

Air Transport Association chapters

The aircraft systems are provided with several ATA chapter numbers (Wikipedia, 2012), which are common referencing standards for all commercial aircraft documentation. This standardization allows greater ease of learning and understanding for all technical stakeholders of the aircraft, such as pilots, aircraft maintenance technicians, and engineers. The standard numbering system is controlled and published by the ATA.

The aircraft cabin environment (Fig. 4a) is controlled by the air conditioning system (Fig. 4b), which is referred to ATA-21 chapter. The air conditioning system is composed of units and components, which furnish means of pressurizing, heating, cooling, moisture controlling, filtering and treating the air used to ventilate the areas of the fuselage within the pressure seals. The system includes cabin supercharger, equipment cooling, heater, heater fuel system, expansion turbine, valves, scoops, ducts, and so on.

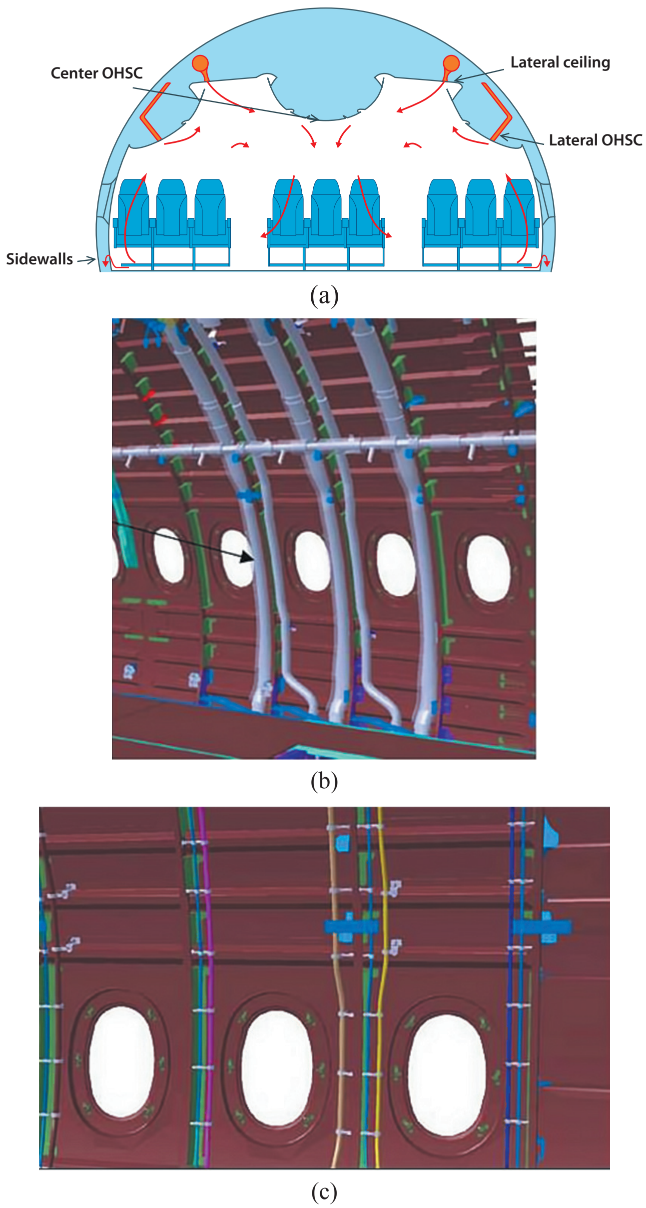


Figure 4. (a) Cabin air distribution; (b) ATA-21, air ducting; (c) ATA-92, electrical cabling.

The ATA 92 (Fig. 4c) chapter refers to harness routing, assembly drawing, space allocation, and bracket installation. It is composed of electrical cables and bundles attached to the structure.

Conventional wire bundle clamping methods

The conventional method of clamping (Fig. 5) the electrical cables and air duct bundles is a painstaking process and consumes huge installation time, which demands skilled labor (Federal Aviation Administration, 1998). Loop and square are the two most common types used for wire bundle clamping with

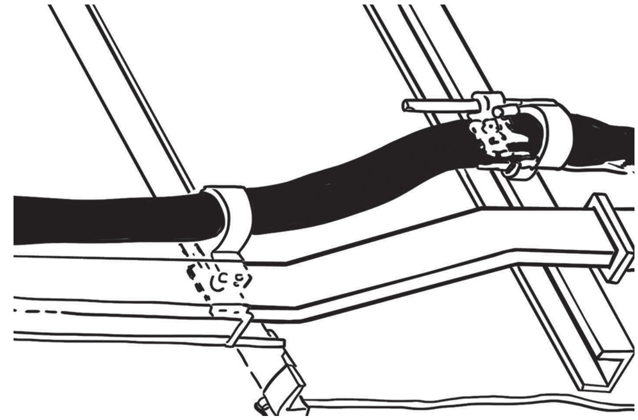


Figure 5. Wire bundle installation to the structure

tailpiece for fastening on to the structure (Blake, 1975). These clamps are made of metallic strip with a rubber cushion at the wiremating surface in order to avoid the pinching of crushing the wires. The clamps are mounted to the structural elements in several directions following the wire bundle positions.

The innovative design concepts aim at configuring specialized attachment brackets with special features. The special brackets thus designed have less installation time and are easy to maintain. Standardization of brackets incorporates features for quicker clamping, avoiding the use of standard assembly/service tools. Thus, only one kind of bracket is used on all the zones with provisions to hold different systems (ATA 92 and 21). The bracket systems also avoid impacts like puncturing of insulation blanket and drilling holes on the supporting structure.

BRACKET DESIGN

The structural elements considered, while designing the brackets, are skin, stringers, clips, and frames (Fig. 2). Bracket is a small fitting or support used to attach system parts as duct, bundle, 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.

Types of brackets

Figure 6 provides the following types of brackets:

- A-bracket is attached directly to the primary structure with permanent fasteners;
- B-bracket is a removable bracket attached on to A-brackets or directly on to the structure;

- C-bracket is attached to either A or B ones; usually they are glued on to the A and B brackets.

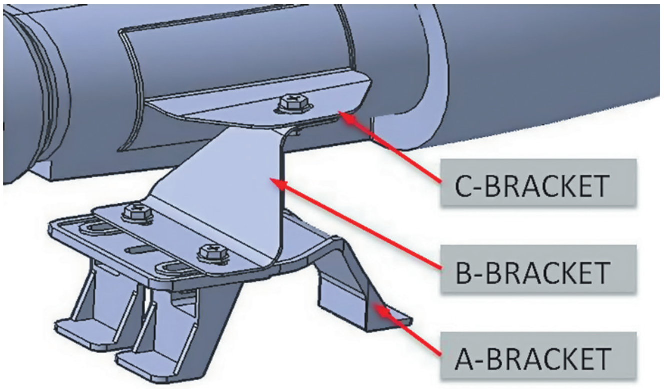


Figure 6. Types of brackets

BRACKET DESIGN REQUIREMENTS

Figure 7 shows the bracket installation environment. The design requirements are listed as having been received from the customer in the task execution.

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. It is an implied requirement that the sharp edges should be avoided in the design, which would otherwise cause injury to installation engineers.

The design shall be adapted to the structural elements shape such as frame section, among others, though minor modifications are allowed on the clip design. The bracket position shall be movable in X, Y, and Z directions. However, it will be locked in the final one. Holes in the structures are strictly avoided for installing the brackets, thus eliminating the use of fasteners for fixation. The indexation function, also called as repeatability or fool proofing, shall be provided in the design. This helps the bracket to be placed easily at its

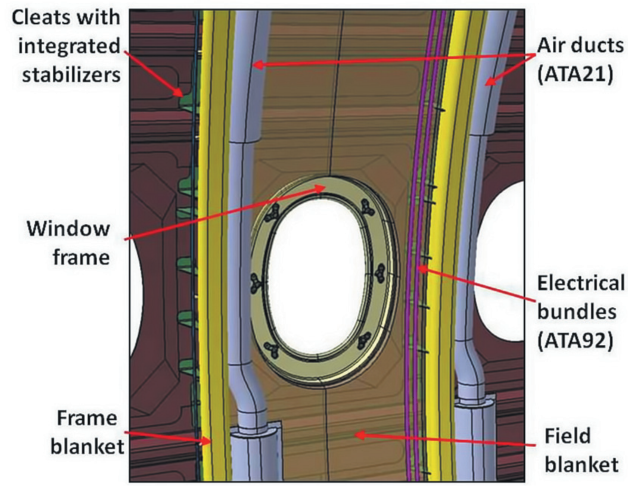


Figure 7. Installation design environment

dedicated position. The bracket assembly will not be possible in another location than in the intended position. The general guidelines considered while designing the brackets are further listed.

Plastic part design considerations

The basic wall thickness shall be kept uniform to facilitate the uniform flow of the material and cooling, which results in reduced defects (GE, 1997). The wall thickness transition, where unavoidable, shall be in the order of three to one (Fig. 8).

Basic draft angle is required for ease of ejection.

Draft angle is provided in the design so that parts can be easily ejected from the mold. Hence, the walls are designed with a slight draft angle as illustrated in Fig. 9. A draft angle of 1º per side is considered as the standard practice. The smaller draft angles cause problem in removing the completed parts from the mold. However, a little draft is better than no draft at all.

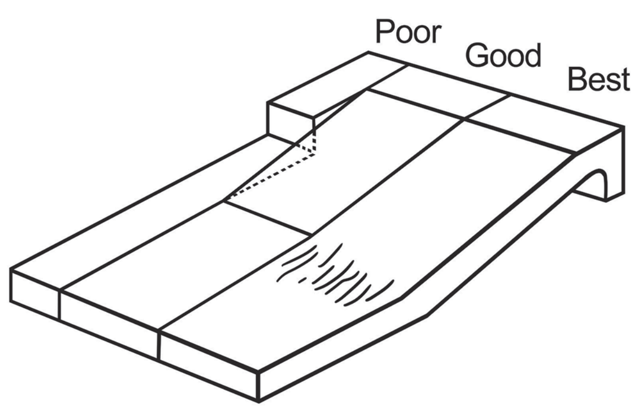


Figure 8. Wall thickness

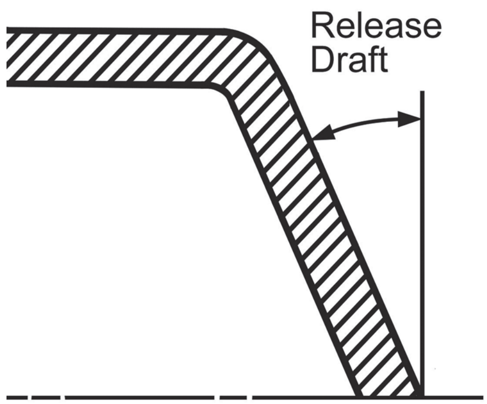


Figure 9. Draft angle

Corners shall be rounded to reduce stress concentrations and fracture. Inner radius should be of at least the thickness of the walls.

Add ribs for structural support, instead of increasing the wall thickness. Thickness of ribs should be from 50 to 60% of the walls to which they are attached. Their height should be less than three times the wall thickness.

Wall thickness of bosses should be no more than 60% of the main one. Radius at the base should be at least 25% of the main wall thickness. Bosses should be supported by ribs that connect to adjacent walls or by gussets on the base (Fig. 10).

External undercuts require side cores that are added to the tooling cost, some simple can be molded by relocating the parting line.

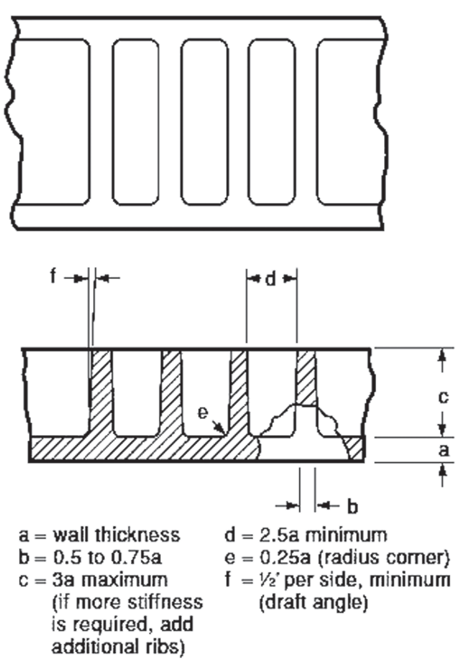


Figure 10. Boss design

Threading features in the brackets were not allowed (specific to this project).

INSULATION BLANKET REQUIREMENTS

The bracket should never disturb the frame blanket position (Fig. 7) and orientation while installation. The blanket compression zones are minimized in the design not exceeding 15 mm thickness. Frame and field blankets should overlap. The continuity of insulation between frame and field blankets must be respected. However, holes and cutouts in the blanket are accepted if they are completely sealed.

CLAMP INTERFACE REQUIREMENTS

The interfaces of the clamps or C-brackets shall allow holding one ATA 21 (Fig. 11) duct on one side and two ATA 92 (Fig. 11) cables on another one. This provides the flexibility to hold three interfacing points simultaneously. The system interfaces shall be interchangeable, and they should allow different configurations of systems, either for ATA 21 or for ATA 92.

The holding systems of C-brackets or clamps shall be flexible for easy removal. Systems are fixed without the help of any tools on the bracket, though sliding mechanism due to the ease of its installation.

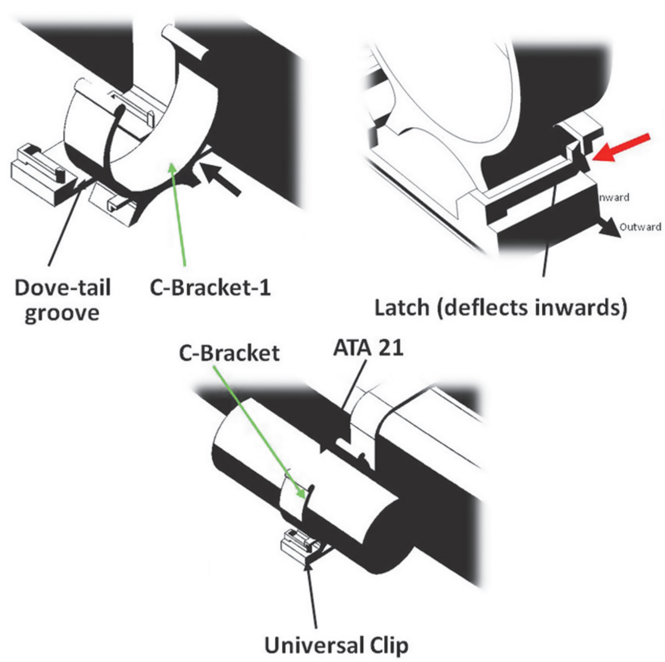


Figure 11. ATA-21 system installation process

The bracket should not exert excessive pressure on the ECS* ducts. These are nonstructural, pre-peg, carbon fiber composite ducts used for air circulation in the flight deck. ECS ducts help in maintaining the cabin air quality in commercial aircrafts, enabling survival, safety, and comfort of passengers. The ECS ducts are installed within pressurized and unpressurized sections of fuselage and wing. The required clearances with the adjacent structures must be maintained for proper installation and removal for maintainability.

MATERIAL SELECTION FOR BRACKETS

Brackets are produced by the injection molding process. Hence, ABS or polyamides are the preferred materials. Injection molding is the most commonly used manufacturing process for the fabrication of thermoplastic parts (Pye, 2000). A wide variety of brackets is manufactured, which varies greatly in their size, complexity, and application.

BEST PRACTICES

Clamps must be of a size that will grip the bundle firmly without crushing the wires and yet tight enough to prevent movement within the clamp. Wires and wire bundles are supported by clamps, which are snug fitted on wire bundles avoiding the wire pinching.

Clamps on wire bundles should not allow the bundle to move through the clamp against the pulling force when applied. Clamps must be installed with their attachment hardware positioned above them, wherever is practicable so that they are unlikely to rotate as a result of wire bundle weight or chafing.

Clamps must be installed in such a manner that the electrical wires do not come in contact with other parts of the aircraft when subjected to vibration.

DESIGN SOLUTION PROCESS

Having in mind all of the design requirements and recommendations, the following design charter is framed in the development of innovative brackets design.

Several concepts were developed with a criteria list consisting of design key drivers, i.e., systems integration, structure impact, assembly, maintenance, and manufacturability. The various concepts developed were evaluated against the advantages, disadvantages and risks associated with each concept, thus evolving the best concepts scoring high on all the driving factors.

Table 1. Concept design driving factors.

Core areas	Merits	Demerits	Challenges involved
Systems	Interchangeability No holes in blanket, hence no customization Blankets are fixed by the clips	Nil	Adjustment to be made to respect tolerance between frames
Structure impact	No holes, therefore less stress concentration on the structure	Require gluing	L-plate not glued at right angle position
Maintenance	Easy removal and replacement		Removing the clips carefully
Assembly	Ease of assembly No special tools required Reduced assembly time		Attachment between L-plate and stabilizer can be done carefully.

Table 1 illustrates the key driving factors adopted for design validation to one of the design concepts.

Task specific checklists were developed. Each delivery was checked against the minimum requirements listed in it. This ensures that the design criteria have been followed all through the design cycle and there are no deviations from the scope of the project. Some of the key checkpoints are the following ones:

- to respect the concept description and design specification;
- to interface with structure on degrees of freedom, indexation and avoid use of special tools;
- to interface with ATA 21 and 92 systems for proper integration;
- to industrialize, including defining the material, ease of manufacturing, and so on.

OBSERVATIONS, ADVANTAGES, AND VALUE ADDITION

The proposed design concepts provide the features of an ease assembly and interchangeability. The designs ensure that no holes are provided in neither of the brackets, thus avoiding the weak sections or stress concentration on the blankets and frames. The designs also ensure that no standard or special assembly tools are required for the bracket installation, which save a lot of assembly time. It is easy to replace the spares by the maintenance staff during the periodic maintenance. It is also very moderate on manufacturing aspects of the new concepts. The weight to cost ratio, which is an implied design criterion, was also taken care in the basic design.

CONCLUSIONS

The concepts are simple in design and have less number of parts, keeping the manufacturing cost minimum. The manufacturing cost depends on geometrical simplicity without undercuts as much as possible that eliminate the incorporation of special mould inserts into the tool, in addition to machining time and cost.

The design concepts offered single solution for all installations that included frame, field blanket, ATA 21 and 92. The conventional design methods adopt independent clamps for the installation of each system that require more effort and time by three times.

The innovative solutions offered have an advantage on assembly time, they saved 30% of original time with minimum number of standard tools used for assembly or dismantle (Fig. 12). The 30% time savings was calculated based on time consumed for the assembly and disassembly sequence process.

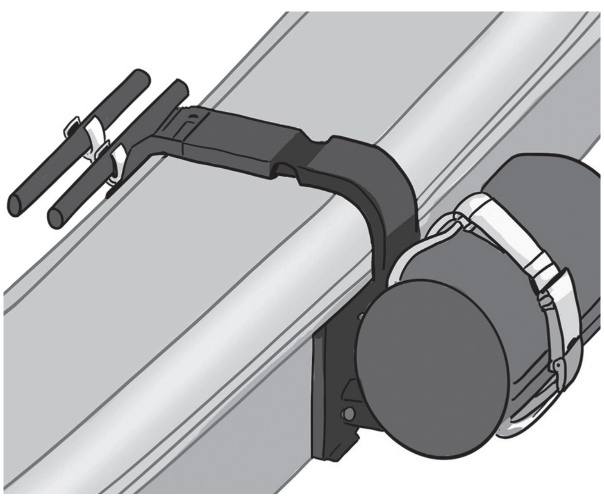


Figure 12. Single solution design

It is very easy to replace the brackets during the periodic maintenance due to its simple design in nature like use of sliding fits, snap fits, and so on.

The concepts were assessed between the list of merits and demerits against each function drivers, such as systems design, structure design, manufacturing, assembly, DT keys drivers, and other main drivers. This evaluation quantified the parameters in the selection of the most appropriate concept, which had a high score on average parameters.

Among the varied design solutions offered to the customer, six brackets have been patent-registered subsequently they found a place in customer's library of standard brackets.

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