DESIGN AND STRUCTURAL ANALYSIS OF A PYLON OF AN AIRCRAFT WITH ENGINES AT THE TAIL CONE

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Abstract. *A trade-off is very important in the current product development scenario. It is necessary for all the choices reasonably selected during the conceptualization phase, in order to ground the decisions and to make sure all the further activities of the project won't be affected by unilateral choices, or maybe forced to step backwards because of technical feasibility problems. As more complex the product becomes, more advanced analysis are required to support the decisions starting from conceptualization process. That happens in the airspace products, where tools generally used to detail the final project are introduced in the first decisions made in the preliminary design, by minor changes in the way these tool are used. In this context, this study brings a local view of the conceptualization of an aircraft, mainly describing the converging process for a region where two turboprop engines are mounted. In this aircraft configuration a small wing holds the propulsion system in the fuselage tail. The converging process based on stress distribution and buckling analysis starts from a preliminary structural layout and goes to a coherent one. A project cycle was presented using a simplified method to obtain the loads for the region. During the study the Finite Element Method was used in Catia V5™ and Nastran for Windows®. In the end, a variety of layouts proposed were analyzed and one feasible structure was disclosed.*

Keywords*: Pylon; Engines mounted at the tail cone; Conceptual project; Structural analysis; Structural design*

1. REAR ENGINE AIRCRAFTS

This article is aimed at the conceptual project of a pylon region for an aircraft with engines mounted at the tail cone, published in Verri (2008). More specifically, the aircraft consists of two turboprop engines, tractor, low wing and "T" empennage. The dimensions are for a fifty seat airplane.

The great concern was to provide a feasible structural layout for the region since there were some technical problems brought because of the use of propellers in this kind of configuration. The propeller requires a bigger clearance between the engine and the fuselage, so, the feasibility of the whole configuration depends on this.

For better understanding of the problem it is necessary to compile the current scenario of aircrafts developed. Not only by raising information from current production airplanes but by also checking what was built in the past. Also, there are two different groups of airplanes to be studied: the turbojets and the turboprops.

For turbojets the solution is simpler because the whole propulsion system is built-in under the nacelle, and, the span of the wing, pylon, that holds the engine at the rear region can be very small. For example, for the EMB 145 the pylon has approximately six hundred millimeters, the pylon is assembled almost normal to the center of the fuselage diameter and the spars of the pylon are attached to the frames of the fuselage.

On the other side, there are the turboprops. There is no commercial one currently flying with this kind of configuration. In Brazilian history we can see the remarkable CBA-123 for nineteen passengers in pusher configuration. In this case the pylon has a seven hundred millimeter span. Comparing the dimensions for EMB 145 and CBA-123 it is possible to foresee how big the pylon would be in a commercial turboprop airplane for fifty seats. Adding to this problem the CBA-123 was a pusher configuration where the datum of the propeller crosses a region of a smaller diameter of the fuselage, then, for a tractor configuration the clearance would be bigger.

Summarizing, the use of turboprop engines at the tail cone brings structural, aeroelasticity and aerodynamic complexity that should be evaluated, from the beginning of the project. The structural evaluation was made using an interactive process to converge to a coherent final layout of the pylon region. The approach for the structural evaluation was an adaptation of a common development process that would happen during the Detailed Project because, in this case, the evaluation occurred during the Conceptual Project phase. The anticipation of the structural evaluation using design tools is very important to foresee the technical problems and also to confirm the technical feasibility of the proposed configuration. The outputs of the structural evaluation described throughout this article will be the initial data for the aeroelasticity evaluation, aerodynamic refinement and other important steps of the development process of the aircraft.

2. CONVERGING PROCESS AND METHOD OF ANALYSIS

Because of the intrinsic nature of the conceptualization process, involving unknown technical solutions, having a short time period for checking technical feasibility and the lead time for mature information to come, this study logically followed an interactive process. The main idea was to analyze the structural model of the pylon region starting from the initial layout, conceived in the early studies of the airplane configuration that happened before the go ahead for the conceptual and preliminary design phases of the project, then, to increase the know-how about the configuration after every structural analysis. The process includes two interaction steps, one for the structural convergence (Interaction A) and another for the update of the input information of the project (Interaction B). The process is described in Figure 1.

Describing in more details the analysis done and the software used for each evaluation, Figure 2 shows the entire detailed path of converging analysis. The analysis, from Initial Layout to Layout D, was evaluated only using Catia V5™ considering stress results and for Layout E, after better results in terms of stress distribution, the model was tested in terms of buckling. Using Catia V5™, available in http://www.3ds.com (DS), for the initial analysis was the solution found to gain time because of the amount of necessary changes for the finite elements mesh from one model to the improved one. After the update of the inputted information Nastran® was introduced and every model was analyzed in both stress and buckling analysis.

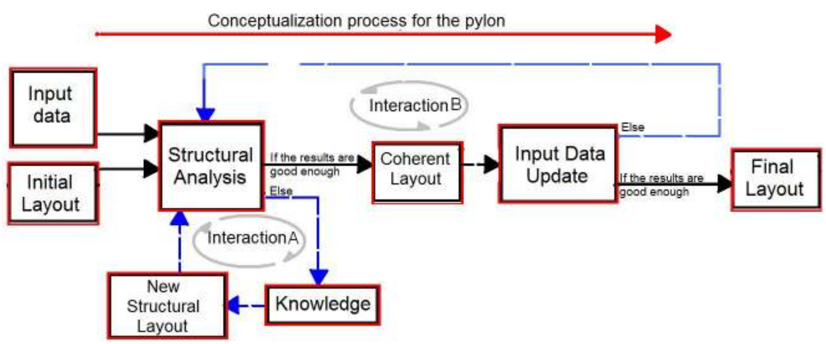


Figure 1. Block diagram for the conceptualization process of the pylon region

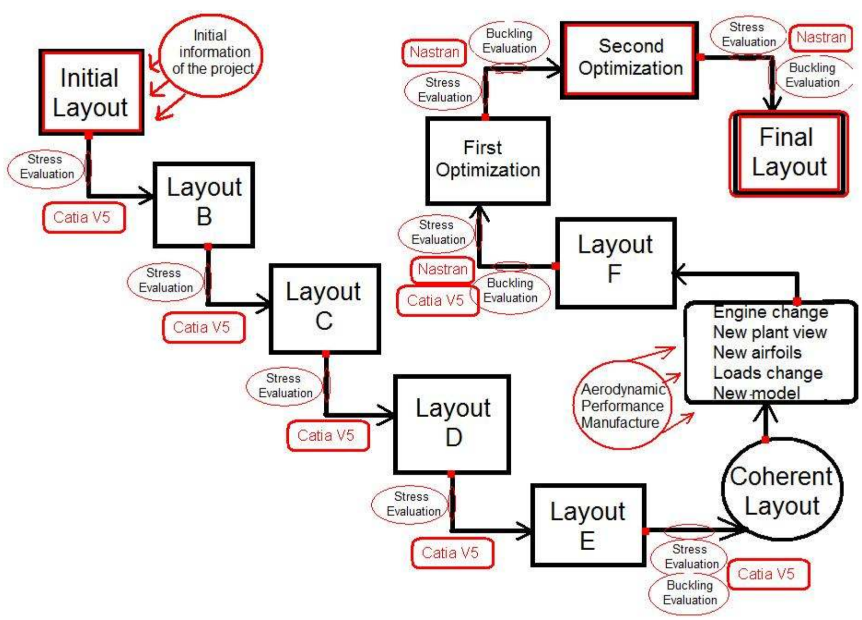


Figure 2. Detailed block diagram describing each step of the structural layout converging process

3. RAISING THE LOADS BY A SIMPLIFIED METHOD

The Federal Aviation Regulations, FAR - Part 25, was used as a reference for the dimensioning of the pylon region considering it as the minimum conditions for the airworthiness of transport aircrafts. More specifically about structure, FAR – Part 25 - Subpart C (CFR, 2008) describes the requirements for the aircraft structure and is divided into five items: General, Flight Maneuver and Gust Conditions, Supplementary Conditions, Ground Loads and finally Emergency Landing Conditions.

Every single condition of flight and ground must be analyzed to guarantee a safe structure according to all the FAR requirements. The loads must be raised for every condition foreseen during the airplane's life. Usually, all the information about mass distribution and aerodynamic coefficients are available in the Detailed Project phase. With the mass and stability coefficients it would be possible to raise the linear accelerations (NX, NY and NZ) and angular accelerations (QP, RP and PP) at the geometrical center of the airplane, then, to translate the accelerations to the pylon (Nxp, Nyp, Nzp). Using pressure distribution software it would be possible to raise the aerodynamic forces acting on the pylon. Combining the thrust and moments from the engine with inertial and aerodynamic forces would be possible to have a complete model – The indexes "X", "Y" and "Z" refer to the coordination system directions described in Figure 3 and "p" is the abbreviation for the reference system at the propulsion system geometrical center.

Although, the data for detailed calculations of loads are not available yet in this phase of the project, not for the Preliminary Project neither for the Conceptual one. The aerodynamic forces are not available because it depends on the airfoil which was not selected yet and the maximum thickness of the airfoils is also a result of the structural design. And also, the flight conditions that would bring results of aerodynamic forces at the pylon are still not available or under simulation. The stability derivates and the control surface deflections are also unavailable and without them there is no way to refine the calculations for the airplane accelerations.

Even without the detailed information to raise the loads for the pylon, there must be an appropriate study done during the Conceptual and Preliminary design to avoid technical feasibility problems in the future and to foresee technical problems that must be overcome during the product development. This is why all the necessary inputs for the structural analysis of the pylon region were obtained; even by simplified methods it provided satisfactory information in this phase of the project. The simplifications for the loads are presented below.

The available data at this phase are: linear accelerations thrust and mass of the propulsion system. The linear accelerations come from the requirement and the maximum conditions are obtained from the velocity - load factor diagram. Then, for the missing information, the following simplifications were considered:

A) The dimensioning load conditions are composed of maximums as a simplified translation of the variety of conditions that should be analyzed.

B) The aerodynamic forces are not relevant compared to the inertial forces, therefore, it will not be considered.

C) The airplane responses to the imposed conditions can be imported from an existing airplane since all the proportions are respected.

D) The requirements from FAR – Part 25 can be resumed and divided in limit and final conditions.

E) For the initial analysis the engine geometrical center can be considered at the forward engine support due to its propeller and power-train that translates the geometrical center to the front. For further analysis, after the update of the income information, the geometrical center was considered at 20% of the support's distance according to the existing propulsion system selected.

Then, the requirements from FAR can be simplified in dimensioning conditions for the airplane and they were divided in limit and final conditions with severe combination of the main factors, described on Table 1.

Table 1. Load conditions used to evaluate the pylon

Limit Conditions:	Final Conditions:
C.1.1) Maneuver + : thrust + maximum vertical load factor of maneuver	C.2.1) Requirement 9g forward
C.1.2) Maneuver - : thrust + minimum vertical load factor of maneuver	C.2.2) Requirement 3g upward
C.1.3) Ground + : vertical load factor (-) and longitudinal (+)	C.2.3) Requirement 3g sideward
C.1.4) Ground - : vertical load factor (-) and longitudinal (-)	C.2.4) Requirement 6g downward
C.1.5) Side Load + : maximum lateral load factor (+)	C.2.5) Requirement 1.5g rearward
C.1.6) Side Load - : minimum lateral load factor (-)	C.2.6) Sudden stoppage (in 3s)
C.1.7) Gust + : thrust + maximum gust load factor (+)	
C.1.8) Gust - : thrust + minimum gust load factor (-)	

Limit conditions are related to a safety factor of 1.5 because it represents the conditions that are going to happen during the airplane's life and no permanent deformation should occur in the structure. Though, the final conditions are related to a safety factor of 1.0 because these are emergency conditions.

The missing information for the airplane under development was replaced by those from a similar one with similar dimensions, weight, configuration, and also both for commercial flights. The EMB 145 was taken as a reference using correction factors for all data. This assumption regards that every commercial airplane needs to be within the same quality of flight, so, they will have similar maximum accelerations. Both configurations have rear engines, low wing and "T" empennage therefore its response will be similar too.

The reference system of coordinates for the loads is represented in Figure 3, the top view and side view show also the airplane's entire configurations. The raised information composing the load conditions is partially depicted in Table 2 and Table 3. Table 2 includes only conditions C.1.1 and C.1.2 for the First Phase of Layout Evaluation with Model A and Engine A (Engine A is related to PW127M from Pratt & Whitney). Table 3 contains the conditions c.1.7 and c.1.8 for the analysis after the update of information, Second Phase of Layout Evaluation, with Model B and Engine B (related to an engine intermediate between PW127M and PW150M). Note that for the first phase the moments were not implemented because of unavailable information for the engine. Units are in Newton (N) and Newton multiplied by Meter (N.m).

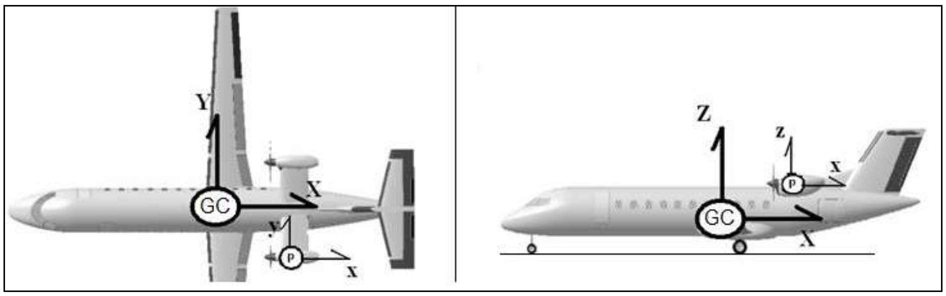


Figure 3. Reference system of loads. Top View of the airplane in study on the left side and Side View on the right

Table 2. Loads for condition C.1.1 and C.1.2 using Engine A with 640Kg (Aviation Week & Space Technology, 2008) including propeller.

Load set	Fxp (N)	Fyp (N)	Fzp (N)
C.1.1) Maneuver + : thrust + maximum vertical load factor of maneuver	-37030	0	-62405
C.1.2) Maneuver - : thrust + minimum vertical load factor of maneuver	-37030	0	48113

Table 3. Loads for condition C.1.7 and C.1.8 using Engine B with 730Kg including propeller.

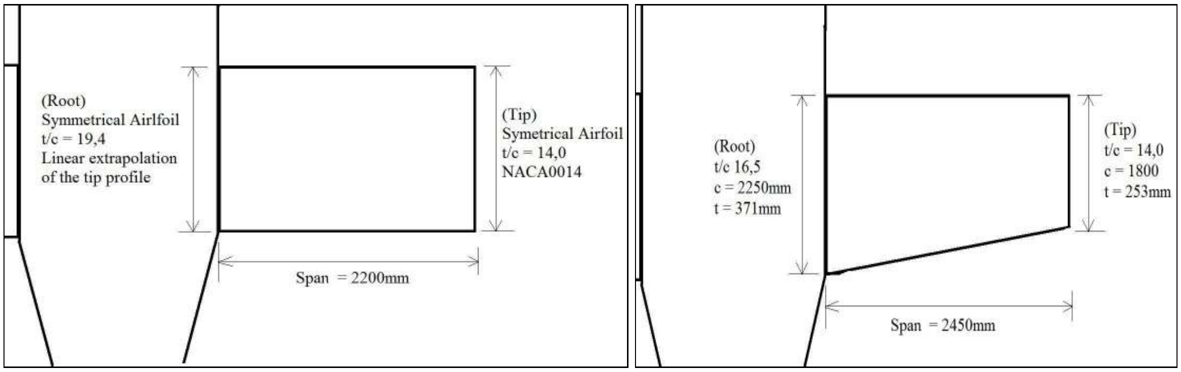
Load set	Fxp (N)	Fyp (N)	Fzp (N)	Mxt (N.m)	Mzt (N.m)
c.1.7) Gust + : thrust + maximum gust load factor (+)	-40327	0	-93256	26917	187
c.1.8) Gust - : thrust + minimum gust load factor (-)	-40327	0	72872	0	-5187

4. MODELING THE REGION

Initially the best approach for a feasible wing to work as a pylon was the one in Figure 4 (a), considering traditional airfoils with an uncertain maximum thickness coming from general aerodynamic practical rules, no sweep angle and a span for a propeller with 2.6 meters of diameter.

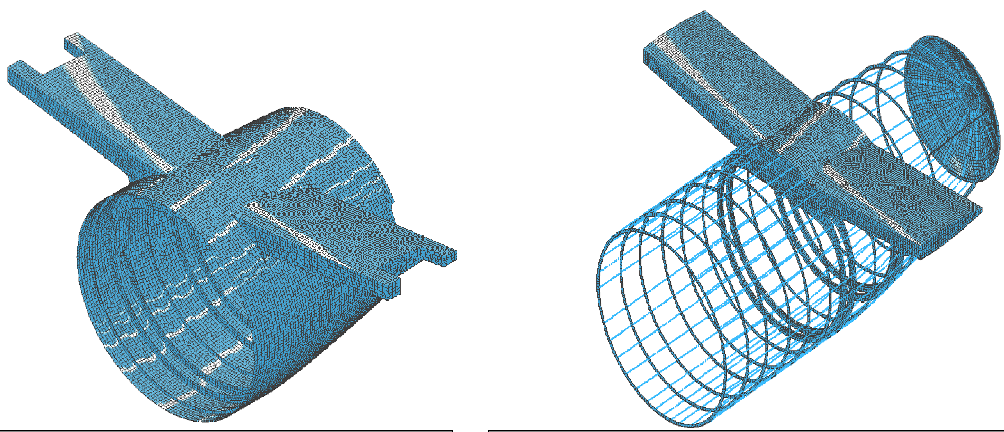
As more information came, the plant view became the one in Figure 4 (b) showing more details in terms of what the region really needed. The profiles were already a result of aerodynamic evaluations and the airfoil maximum thickness was a result of the structural evaluations obtained until the Interaction B. The span was for a bigger propeller of 3.0 meters and the sweep angle at the trailing edge was introduced due to the need of a bigger chord at the root to reduce the relative thickness (t/c).

The finite elements mesh used differs along the convergence process. For the initial analysis the model was simpler using CQUAD4 and CTRIA3 elements not considering the stringers for the fuselage and the region analyzed was smaller. For the evaluations, after the inputted update, the model was improved in terms of detail, the stringers were added to the fuselage with PBAR elements passing through the frames, the extension of the region analyzed was increased and the material properties also were refined. Both models are presented in Figure 5. The constraint for the models is a restriction in the translations and rotation for all the directions on the elements that matches the forward regions of the fuselage that were not modeled, simulating a rigid fuselage.



(a) Before the Interaction B (b) After the Interaction B

Figure 4. Plant view for the pylon wing – (a) Plant view for Initial Layout to Layout E. (b) Plant view for Layout F to Final Layout. "c": chord. "t": thickness.



Model A – From Initial Layout to Layout E
Poisson Ratio: 0.35 Elastic Modules: 70GPa
Material: Catia V5™ Aluminum
Stress Target: 280MPa Target Eigenvalue: 1.00

Model B – Starting with Layout F
Poisson Ratio: 0.33 Elastic Modules: 71.7 GPa
Material: Al 7475-T7351
Stress Target: 280MPa Target Eigenvalue: 1.00

Figure 5. Structural mesh for the pylon region. Material properties available in http://www.matweb.com (MATWEB)

The material used was only aluminum with different properties on each model. For the simpler one, Model A, the material available in Catia V5™ was used. The material was considered only as a source of Poisson Ratio and Elastic Modules for a qualitative visualization of results. Then, for Model B the selection was more complex so that the material selected was representative of the alloys used in the pylon region.

The stress target of 280MPa refers to the safety factor of one and a half imposed from the requirements to the maximum property of the material. The target of one for the eigenvalue refers to no buckling on the model, this being conservative in a linear buckling analysis. The evaluations considered constant thickness for each internal part.

5. FIRST PHASE OF LAYOUT EVALUATION

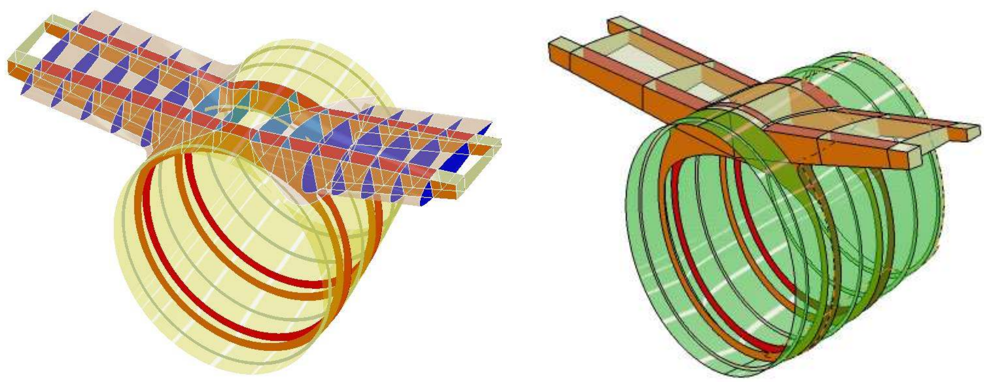
The whole process to obtain an adequate structural layout is shown in this first phase. The intention was to provide a feasible structure and to avoid design problems starting in the conceptualization and much is shown in terms of avoiding design errors, finding out best practices and foreseeing technical problems.

This phase was composed of the evaluations of the Initial Layout to Layout E, where along every three dimensions design and its structural analysis, the acquired knowledge was used to build the next model, so that, in the end, a coherent structure was presented to the next phase.

During the brainstorm process to build the idea of a new airplane, several combinations of different existing technical solutions or new ones are evaluated superficially by multidisciplinary people doing a trade off to reach the best configuration to give the market what they want. More specifically about the pylon region, the idea is the same, although, when the initially conceived design is checked by structural analysts there are some important changes that should be taken in consideration.

The Initial Layout is the one in Figure 6 (a). It describes very well the structural needs for the region. The use of double reinforced frames is already used in current airplanes being a failsafe design. Also, the location of the pylon in the height tangent of the fuselage in a continued way, not ending at the frames, is more efficient during symmetry maneuvers and more indicated in terms of aeroelasticity.

Although, some considerations must be made. There are many more ribs than the model needs, because the main source of loads is the mass of the propulsion system that has its geometrical center located slightly behind the first spar, therefore, not generating excessive torsion to justify those ribs. The center part of the torsion box is discontinued, the lower skin of the pylon does not cross the fuselage, and then, the model will have a stress concentration in the intersection of the pylon to the fuselage. Another important aspect of the design is the height of the spars that is lower in the center piece, the height should increase to the root of the pylon wing where the moments are bigger. Concerning the wing fairing in the attachment of the pylon to the fuselage, this skin cannot be considered as a structural part because it concentrates the incoming stress.



(a) Initial Layout (b) Layout B

Figure 6. Three dimensions model for the pylon region – (a) Initial Layout used as an input from the market and airplane configuration study. (b) Layout B including the indentified need from the initial design.

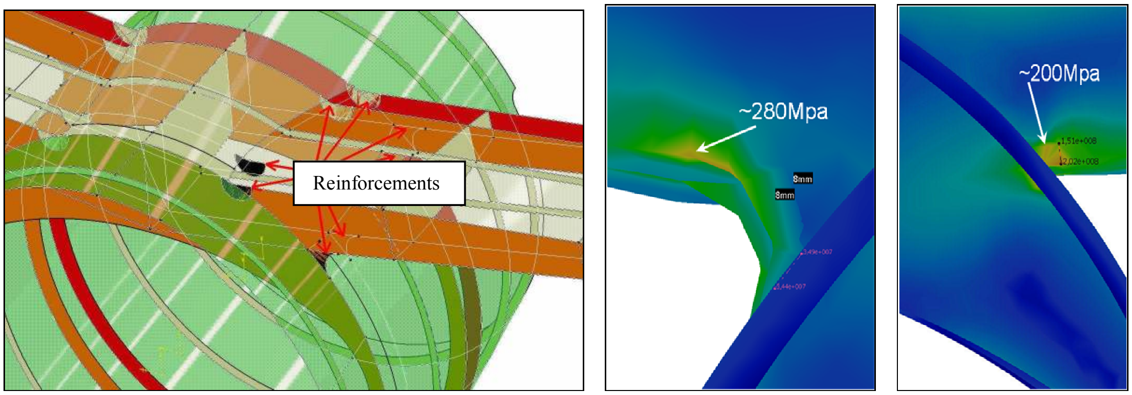
Having the evaluation of the Initial Layout it was possible to build another model having the necessary design details firstly identified. The second model evaluated is the Layout B of Figure 6 (b). Now, the lower skin of the pylon crosses the whole span and the number of ribs is reduced to five. This second layout was more coherent in terms of structural resistance but it still included the use of the wing fairing region with small radius in the attachment of the main spars to the main frames. The advantage of this would be great because the interior of the wing fairing is not really used at all. The problem of this design radius in the joint is that it still concentrates the stress because these little radii are outside the main box.

So, the next model has reinforcements on that radius to reduce the stress and therefore solving the problem. This Layout C is presented in Figure 7 (a), showing all the added reinforcements on the lower radius and also in the top joint region because it also showed big stress concentrations. The analysis result for Layout C was that even by greatly increasing the thickness of the reinforcements it was not enough to reduce the stress. Figure 7 (b) shows the stress analysis in CATIA V5™ where 8mm of reinforcement reduced the stress to 280MPa for the conditions C1.1.

The next step was to check if these radii were needed, because even by reinforcing them the problem was not solved. Layout D has no radius in the lower joint region and the results are much better in terms of stress. The maximum stress is 200MPa for C.1.1 shown in Figure 7 (c). The interpretation of the comparison between Layout C and D is that the radii are undesired details for the design in this case for this joint region.

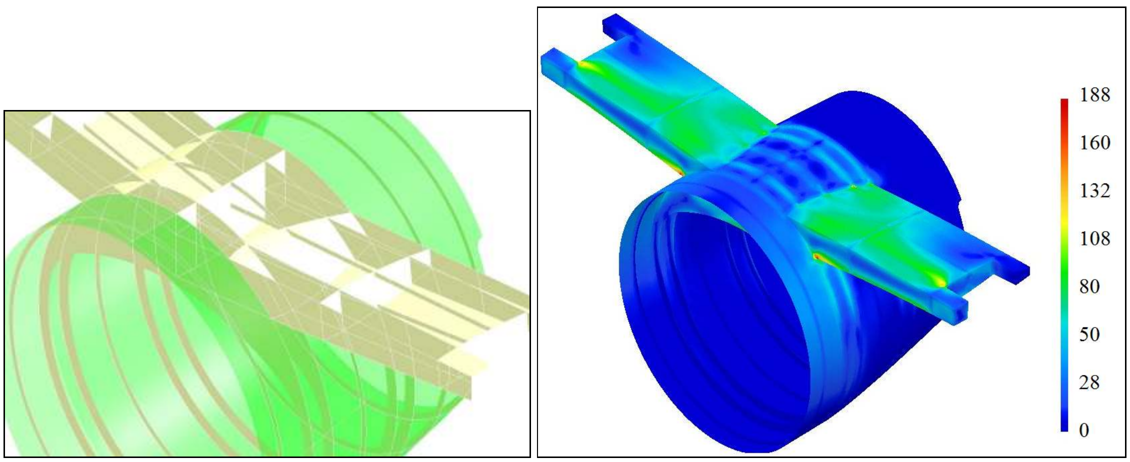
Removing the radii for the lower joint region was enough to reduce the stress concentration in more than twenty eight per cent, although, the superior region also needed an improvement. Removing the top radii was not enough to guarantee a continued stress distribution because the structure itself does not present continuity along the superior skin and superior stringers. The solution for a new design was to prolong the upper skin throughout the fuselage as well as for the stringer that changed the main direction at the joint. Another important missing item was the tangent rib right at the joint of the pylon to the fuselage, extremely important to transmit the income loads to the frames of the fuselage.

Then, Layout E was designed after four interactions removing every detail checked as undesired and including those that bring structural efficiency. Figure 8 (a) shows the design for the new layout with a zoom detailing the internal region of the joint. Figure 8 (b) depicts a colored Von Mises stress distribution for load C.1.1 with a very smooth distribution. Even when applied top direction (z direction) loads like load C.1.2 and C.1.4 the stress concentration was acceptable.



(a) Layout C (b) Stress for Layout C (c) Stress for Layout D

Figure 7. Comparison for Layout C and Layout D – (a) Layout C with reinforcements located at the stress concentration radii. (b) Von Misses stress distribution for Layout C showing a maximum of 280MPa. (c) Von Misses stress distribution for Layout D showing a maximum of 200MPa having no radii for the joint.



(a) Layout E design (b) Stress for Layout E

Figure 8. Layout E designed for reduced stress concentration – (a) Layout E design using a concept of continuity along the structure (b) Von Mises stress distribution for Layout E showing a maximum of 188MPa.

Since the model was already with acceptable values of stress, the buckling modes could be evaluated as an additional structural restriction. The results for the buckling simulations for two of the main loads used during the phase one is presented in Table 4. The results are below the minimum of one representing a premature instability of the structure, therefore, requiring an increase in the local rigidity of some parts of the structure.

Layout E was an improved version of the pylon region already showing the possibility of convergence in the results even if it still had local buckling. If more time was spent in this proposal the structure probably would be within the target values of stress and buckling. This is why Layout E was considered a coherent one since the income information for the pylon region was going to be updated and no optimization was needed at that time.

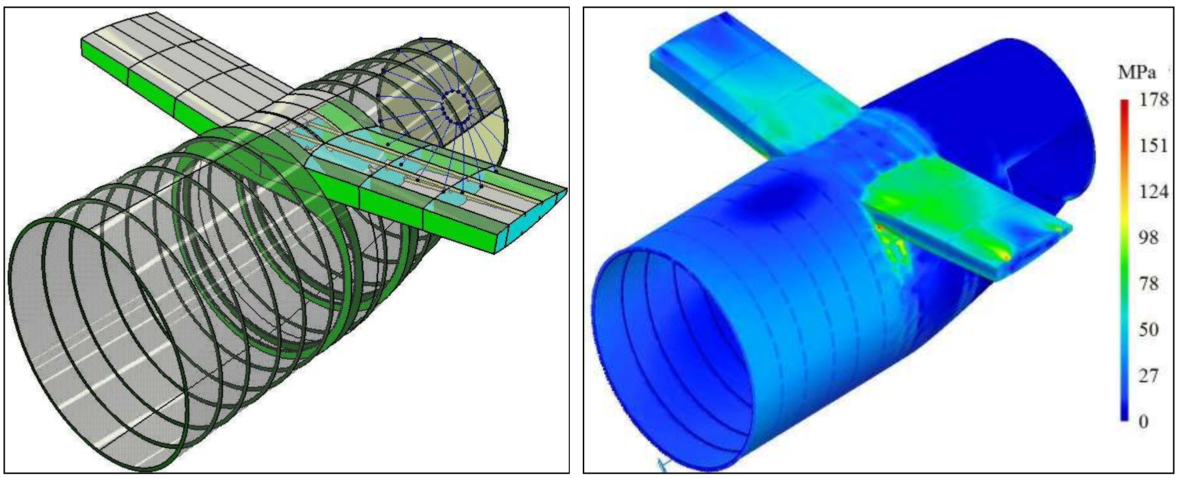
Table 4. Eigenvalues for C.1.1 and C.1.2 for Layout E using Catia V5™.

Mode Number	Eigenvalue	Load set	Buckling region
MODO 1	0,90	C.1.1	Skin
MODO 2	0,91	C.1.1	Skin
MODO 3	1,00	C.1.1	Skin
MODO 4	1,04	C.1.1	Skin
MODO 1	0,71	C.1.2	Frame
MODO 2	0,75	C.1.2	Frame
MODO 3	1,12	C.1.2	Skin
MODO 4	1,14	C.1.2	Skin

6. SECOND PHASE OF LAYOUT EVALUATION

This phase consisted of evaluations for the coherent layout found during the first phase with adaptations for the updated information coming from the different areas involved in this project. The income information was a result of the studies of the market, aerodynamic, manufacture and propulsion teams that were working in parallel to the structural development. The main changes were for the propulsion system to achieve the thrust required by the market, then, modifications for the propeller, plant view, model and loads were required, but the structural knowledge from the first phase was still used.

The model for this phase was the one from Figure 9 (a) and the evaluations transited from Catia™ to Nastran® showing also a comparison between these software. The tested layouts were from Layout F to the Final Layout where two of the three models analyzed during this phase are for thickness optimization showing better convergence of the whole layout after the evaluations of the first phase. Some changes were required to Layout E to be transformed into Layout F: one additional stringer was added to the center of the upper and lower skin to reduce buckling, one additional rib was implemented because of the bigger span and the thicknesses were adjusted to a probable enough value.



(a) Design for the second phase (b) Stress for Layout F

Figure 9. Pylon region after the update of the income information. (a) Three Dimensions model showing the internal disposition of structures (b) Von Mises stress distribution for Layout F loaded with c.1.7.

Comparing stress distribution for Layout F in Catia™ and Nastran® is possible to see how close the results were. The maximum Von Mises stress for Catia™ was 178MPa, Figure 9 (b), and for Nastran® 181MPa depicted in Figure 10 (a). This was another reason why the income information from the first phase was used for Layout F and the model showed a very acceptable distribution of stress without the concentrations first removed.

Layout F analyzed shows the buckling results in Table 5 where the minimum safety margin was forty nine percent showing the need of an optimization. The comparison between software for the buckling results showed a considerable difference, Catia™ captured eigenvalues lower than the minimum for Nastran® and those are very small local buckling results, even if the main eigenvalue were also found in Catia™. The buckling comparison led to the use of Nastran® as the reference since it is well known in the aeronautic sector and easily used to certify the airplane. The minimum eigenvalue for Nastran® was 1.76 for c.1.7. Software Nastran® information is available in http://www.mscsoftware.com (MSC).

After two interactions, modifying the thickness of the model, the results for the buckling and stress are those in Figure 11. The buckling mode for the worse condition is depicted on the left side that shows the instability of the upper skin of the pylon. The minimum safety margin was nine percent. The maximum Von Mises Stress was 225MPa with a safety margin of 20%, the Von Mises stress distribution is presented in Figure 10 (b).

At this stage of the process it is possible to confirm the convergence of the results and the history is well demonstrated by Figure 12 (b) where the weight of the pylon structure was measured for every layout analyzed. It includes both optimizations (named as “Optim. 1” and “Optim. 2”). The second optimization had to step backwards in terms of thickness because the model for Optimization 1 had eigenvalues lower than one, therefore, the weight was pulled from 408Kg to 437Kg.

The results for Optimization 2 were considered enough and it was named as the Final Layout. The resultant geometry with the main dimension for the three dimensions model is presented in Figure 12(a). There is also the thickness for the internal structures of the pylon.

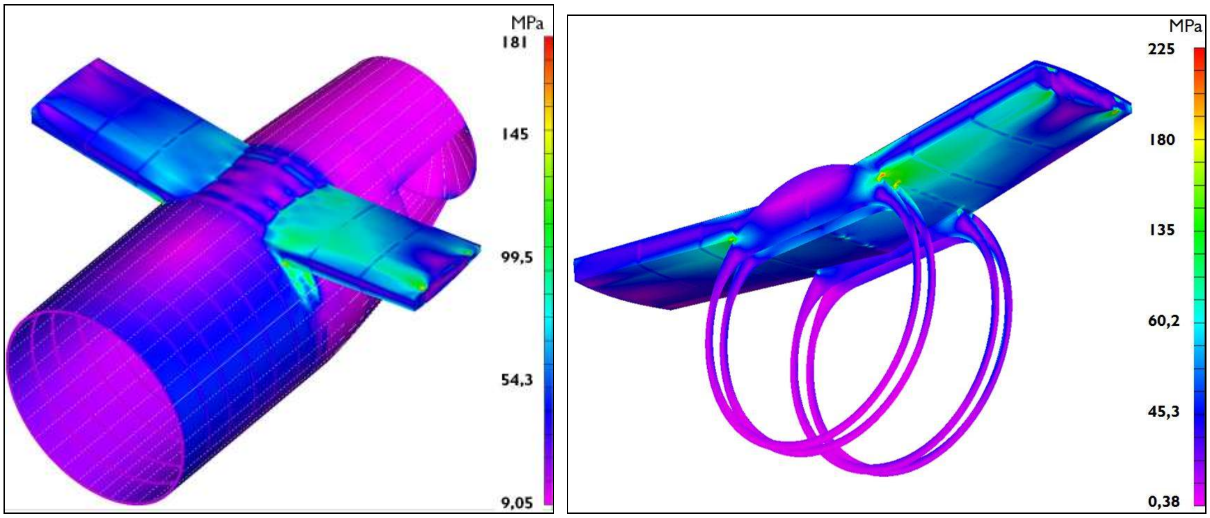
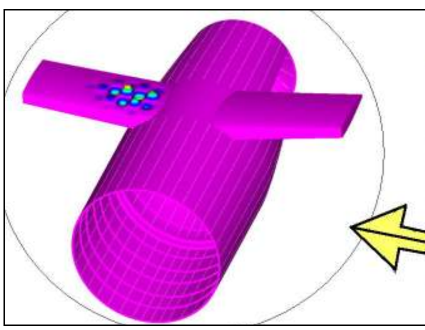


Figure 10. Von Mises stress distribution using Nastran®. (a) Results for Load set c.1.7 applied on Layout F. (b) Results after two optimizations of thickness with hidden fuselage.

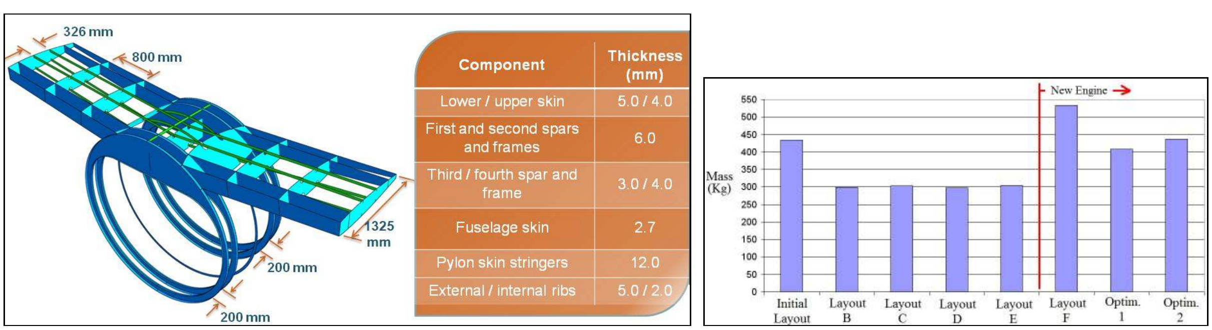
Table 5. Buckling results for Layout F using Catia™.

Load set	Eigenvalue	Location of buckling	Maximum Stress	Location of maximum stress
c.1.1	1.53	Rib tangent to the fuselage	170 MPa	Pylon root
c.1.2	1.75	Central lower skin	100 MPa	Pylon root
c.1.7	1.49	Rib tangent to the fuselage	178 MPa	Pylon root
c.1.8	1.71	Central lower skin	103 MPa	Pylon root
c.2.4	2.05	Central lower skin	89 MPa	Pylon root
c.2.6	4.30	Skin of the fuselage	109 MPa	Rear support of the engine



Load set	Eigenvalue	Safety margin for buckling (%)	Maximum Von Mises stress(MPa)	Safety margin for stress (%)
c.1.1	1.20	20	217	23
c.1.2	1.12	12	136	51
c.1.7	1.13	13	225	20
c.1.8	1.09	9	138	51
c.2.1	1.95	95	76	73

Figure 11. Results for the Final Layout. Detailed image for the buckling result of the load set c.1.8.



Component	Thickness (mm)
Lower / upper skin	5.0 / 4.0
First and second spars and frames	6.0
Third / fourth spar and frame	3.0 / 4.0
Fuselage skin	2.7
Pylon skin stringers	12.0
External / internal ribs	5.0 / 2.0

(a) Resultant geometry (b) Pylon mass evolution

Figure 12. Resultant and evolution. (a) Main dimensions for the Final Layout disclosure. (b) Mass of the pylon along the development process.

7. CONCLUSIONS

This article described a simplified process to obtain the loads and to evaluate the structure of a pylon region, for a configuration with engines at the tail cone of a fifty seat aircraft during the Conceptual Project phase. The used interactive process converged to a feasible layout in terms of buckling and stress. During the converging process the interfaces with other areas were well illustrated so that the design was a result of inputs and updates from market, aerodynamic, manufacture and propulsion teams.

An interpretation of the requirements from FAR was made for the pylon region and applied with reasonable considerations, according to the phase where this study occurred, using the existing information and adapted ones to compose the set of dimensioning loads acting on the pylon. The use of a simplified manner to compose the set of loads permitted an anticipation of the studies that would occur only in the Detailed Project.

The first phase of evaluations presented five layouts. Every structure evaluation brought best practices to be implemented on the model to avoid stress concentration resulting in a coherent layout. Some important details found were the better results of a continuous passing pylon, the undesired use of the wing fairing at the joint of the pylon to the fuselage as a structural region and the need of a rib tangent to the fuselage to reduce stress concentration. This phase had a reduced evaluation time by the use of Catia V5™, being faster to modify the mesh in the Analysis and Simulation module when the geometry was already designed in the Generative Shape module.

For the second phase the model was improved in terms of mesh, income information and the use of a bigger region. The main evaluations were for buckling, and the combination of ribs and stringers resulted in nine percent safety margin. This phase had only three evaluations and two for thickness optimization, concluding that the first phase, even with more simplifications and a small engine, was extremely important to gain time. At the end of the second presented phase, one three dimensions design was disclosed with thicknesses for the internal structures, mains distances, weight and rigidity.

The outputs of this study are extremely important as a first reference to the design of the internal structures as volumetric parts. The rigidity distribution is one of the inputs for an aeroelasticity evaluation that must be made. The weight is necessary for the weight breakdown to build the geometrical center envelope of the aircraft, the weight is also an input to foresee the costs of maintenance and fuel consumption. The whole layout is very important to start more detailed evaluations of the assembly and manufacturing process of the region. The results of the pylon configuration can be compared to other proposals.

Summarizing, the described study is a necessary step of the entire aircraft development process and its outputs are required for different areas involved in the project. The procedure to raise the loads and to converge to feasible structural layout can be used as a reference for future projects. Best practices were documented on how to avoid stress concentration and buckling instability for a pylon.

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10. RESPONSIBILITY NOTICE

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