STRUCTURE SIMULATION AND BLADE DESIGN OF AN AIRCRAFT ENGINE

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ABSTRACT

Structural analysis have progressed at a level such that they are now increasingly used all days in activities of mechanical engineering

In 25 years at SNECMA, analyses have for main objective to provide in both detail and overall a knowledge of the behaviour and damage of the part, they are an help with the decision in design conception via optimization.

We are currently in a period of utilization of more and more simulations , what allows to reduce significantly the number of tests. Researches allow to develop tools simulating the behavior increasingly precisely.

These simulations have become of necessary tools, to reduce costs , to reduce cycles, to design robust. Take into account very early manufacture constraints in simulations, improved the simultaneous engineering.

It is demonstrated here after that the large use of simulation during the period of life of the product, will allow to improve them, and to answer as quickly as possible to quality and reliability needs of the companies.

Finally, it is necessary to insist on the inter-operability of tools of simulation, centered on a numerical geometrical model. This inter - operability has to accompany the concept of extended enterprise and the world cooperation necessity. These are the keys of the success of industrial products design for the next century

INTRODUCTION

Structural analysis are progressing since several decades. They have progressively allowed to simulate various types of life situation, in the same time its utilization has become more user friendly. A great part of this progress is du to dramatic improvement of capacities of computing hardware performance. The time to perform analyses has decreased very strongly, in the same time size and the complexity of models have increased. Software have progressed to allow engineer to visualize problems very complex.

SNECMA uses since near 25 years, finite elements tools to design engine parts. However, these analyses were, in general employed to help to the comprehension of the behavior of the structure, and to provide elements participating to choice the optimum design. An important part of the design qualification was based on very numerous tests. These tests are used to validate decisions, and to demonstrate that design met the specifications. It has become rapidly evident that we could reduce very significantly the number of tests, therefore the costs associated, if it was possible to perform appropriate simulations. The level has to be such that the simulation brings a level of confidence equal to a test.

The competition on the civil aeronautic market, has obliged all actors to conduct actions to reduce by more than 2 the design cycle. The simulation is a fundamental tool that allows to reach this goal. Structural simulation is “virtual”, so all actors can see virtually all the designer and manufacturer views of the part, all the life situations without spending no more than “paper “ and computer time. Manufacturer can earlier decide to launch tools because they have a improved risks visibility.

Satisfaction of the client needs to increase more an more the quality of the engines. The simulation is an essential answer, because it allows, especially to guarantee the robustness. The competition is severe, markets will be won by offering clients, systems “on shelves”, therefore it will be necessary to be able flexibility in conception. The extended simulation, associated with technologies on “shelves” is the right answer. We show here after today simulations, and future developments. In this paper ,the simulations are illustrated on a part witch is in the heart of the engines : The BLADE [Fig.2].

Structural analysis today

The analysis by finite elements are largely used. The goal of these analyses is to determine, especially on blades, a distribution of constraints coming from aerodynamic pressure loads, centrifugal effects, and heterogeneous temperature fields that vary during the aircraft mission. They are also used to predict modes and frequencies of vibration [Fig 3]. These analysis are made to demonstrate the structural integrity of the blade. Mainly, for the dynamics calculations, results are compared to experience and provide an help to the decision [Fig 4].

Thus the design and analysis with theoretical tools are possible. However the confidence that we can have in a theoretical model to represent the real structure varies greatly, it depends on quality of tests available, and the level of novelty compare to the experience. An other view of the simulation is its utilization during early project stage, concept, detail, manufacture stages, and in use stage. Process has been formalized at SNECMA by the plan “AQCORD”, during each phases, different simulations are used:

- At the early project stage structural layout can be size by using spread sheets, know-how rules, with a minimum number but necessary and relevant of parameters coming from 3D studies on previous conception. At this stage the unique representation of the blade is analytical formulas and keys numbers on spread sheet.

- At project stage more sophisticated tools are used: 2D representations , simulation by sophisticated analytic formulas of main response. We uses simulations tools with representations coarse mesh, optimization tools in mass and constraint by positioning blades modes and frequencies conforms to design practice [Fig 5].

- At the concept stage we use intensively finite elements calculation. Distributions of constraints, modes and frequencies are quantified very precisely, error estimator technique, adaptive mesh refinement are used. Generally, the test evidence in this phase is required to assess new material properties and to investigate novel construction method).

- During validation phase, simulations are made with the exact test conditions (boundaries, dimensions), results are compared to tests and provide evidences of conformity to specifications, regulations .

- During the manufacture phase, the first simulations of die, castings are made. They allow to obtain significant information and to minimize the numbers of prototypes

- When the blade is use in service, the numerical simulations give us an very precious help to qualify the blade following a minor cost reduction modification or a new industrial strategy. The simulation allows also to fix very quickly all drift in the manufacture process or in service, after a detailed report, the analysis is a very useful help to take quick decision; so we can minimize the effect on an important engine flee

Future Developments

Theoretical Basis

The whole principle of using analysis to simulate the real structural behavior relies on theoretical methods being available of appropriated effects. Extensive research programs are pursued at SNECMA in association with engineer schools and universities. These programs move forward theory rapidly, they enable greater understanding of more detailed problems. This will become the underlying theory of to morrow's software. Some areas of particular interest concern dynamics simulations on structures, such as impact [Fig 6], blade fragmentation [Fig 7], retention, and vibrations. Not only are the effects of these phenomena difficult to model but in many case the applied loading environment is also difficult to establish. Others areas which may lead to improved analysis concern the effects of local features such as bolted flanges, contacts [Fig 8], the welded joint, small vent holes in the blade. The ability to introduce these local effects into a larger analysis would lead to improve the representation of the real structure. [Fig 9]

Material data

No important progress in structure analysis will be obtained without a appropriate accurate material data knowledge. The characteristics obtained with 1D specimens are generally well known. Important research programs are sustained by SNECMA to better represent the 3D viscoelastoplastic behavior of materials, especially on turbine blade. It is necessary to add in depth studies on damping of materials for dynamic problems, and on rupture criteria for fragmentation, perforation. Finally, we have to make major effort to improve material properties in the damage domain, it is necessary to calculate a reliable damage after a finite element analysis of a blade during each flight. All these data are coming from tests and it is very expensive to identify a very important number of laws parameters, this is a restrictive factor for the precision of the analyses. The decision to use a new material is critical and can drive to limit very strongly the confidence in the analysis.

User environment

In order to effectively use the developing methods, the software and hardware environment needs to be able to cope with the demands place on it. Fortunately the performance of affordable computers is increasing rapidly, thus the potential to analyze structures of enormous complexity, considerably greater today, will be reality in a few years. Techniques of programming object bring also the possibility to have open platforms [Fig 10] [Fig 11]. Advanced functionality exist or will be available in a short time especially in PATRAN, to provide to engineer an information easily accessible, and easily comprehensible. Visualizations such that animations in real time are the key of the comprehension of the structure behavior. Automation of the process to built a finite element model, help to put the boundaries conditions, help to analyze results, use more and more of deposit process, and in a close future use of knowledge with inference engine will participate in the reduction of errors and time.

I t will be possible to simulate more and more in detail complex geometry and complex loads without strong hypothesis or approximations. This possibility generates models with numbers of degrees of freedom equal 10^4 to 10^5 and soon more than 10^6. Maintaining the calculation under control has to be a constant concern of the software vendors , concepts of adaptive meshing, control of the solutions with errors estimators have to constitute major evolution of PATRAN. Possibility to create complex models rapidly, to introduce non linear effects at the level of a small detail will provide a realistic alternative to commonly employed approximations today The future solutions will be developments of "zoom " or multi-scale techniques, several details and the global model are analyzed simultaneously, information are exchange in parallel to global and local model frontiers so as to guarantee equilibrium .

Integration of all the tools use in the process is also an essential factor to provide a direct access at all data in all systems [Fig 12]. It allows assure the optimum flow of information. It is necessary to notice that the geometric model is the heart of structural analysis activity.

Tools for stress analysis will have to be piloted directly by the system of CAO. In current environment of the SNECMA design office, PATRAN has to continue rapidly its effort to link CATIA. In addition the possibility to easily exchange with CAO systems, analysis system, pre and post processing is also a necessity to facilitate the work with different companies in cooperation. This flexibility is also interesting to incorporate new tools. In summary, keys elements of the future environment will be : automation, integration, visualization.

CONCLUSION

They are obvious weaknesses in the ability of analysis to accurately predict all structural behavior, It is demonstrated that tests also have deficiencies to represent real life. Thus the combination of tests and the simulation is the best means to provide a high confidence level in a quick design of complex system. With the likely improvements in calculations capacities, and theoretical methods, future tools will be increasingly efficient, and will allow to simulate situations of life in details. These simulations will have to be used intensively in demonstrators projects, so as to validate process, new technological systems, upstream of development projects The use of simulation during all along the life of the blade, will allow to improve them, and to reply as quickly as possible to requests of quality and reliability. Finally, it is necessary to insist on inter-operability of simulation tools, centered on a numerical geometrical model. This inter-operability has to accompany the concept of extended enterprise and the world cooperation necessity. The keys of the success of industrial products design of the next century.

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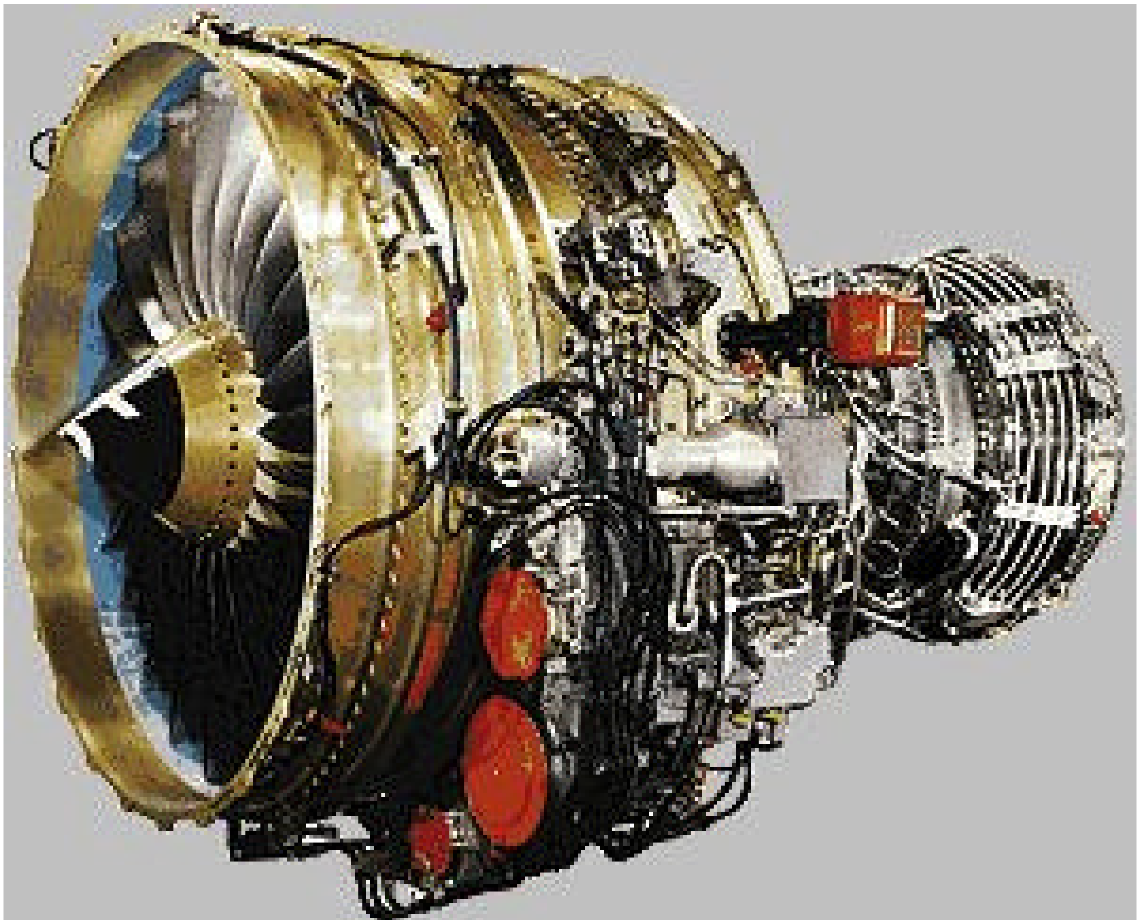


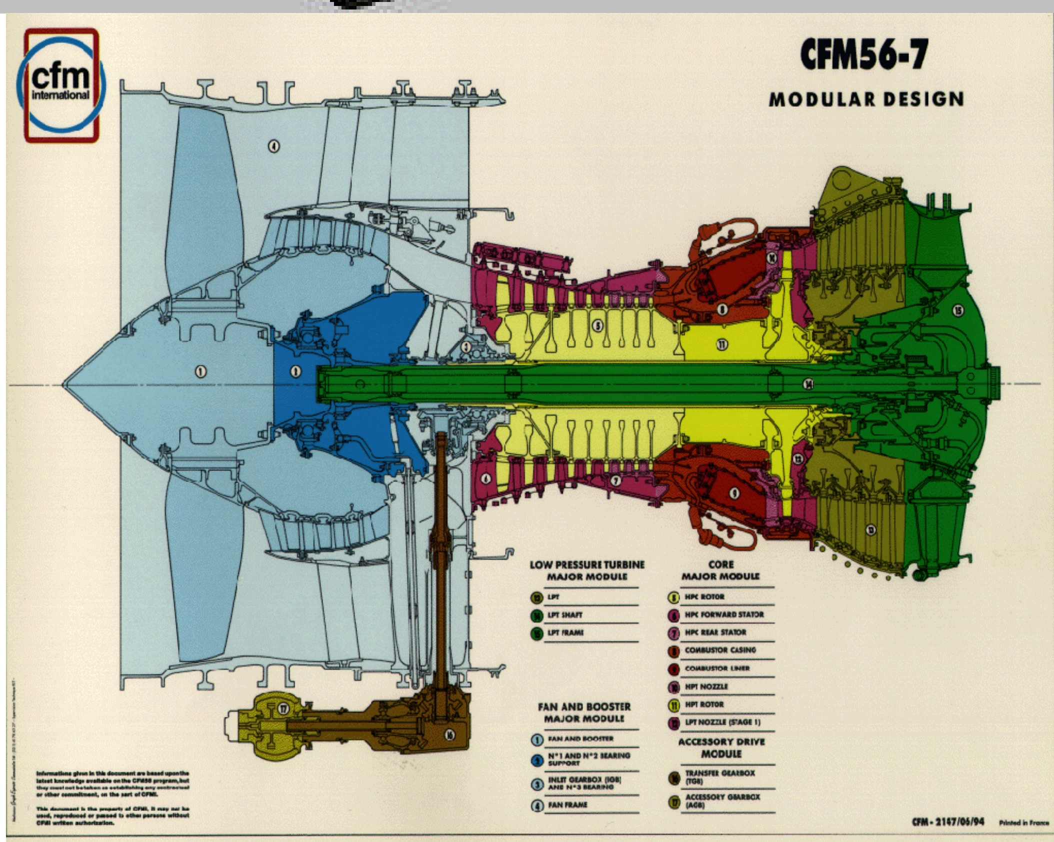


FIG 1-2: MOTEUR CFM56-7

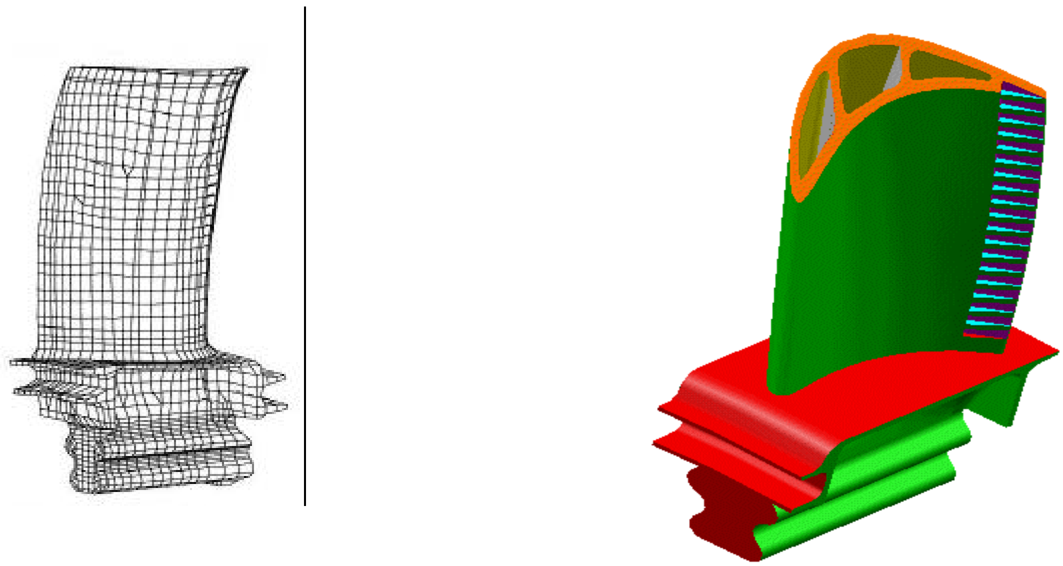


FIG 3 : CATIA and PATRAN MODEL

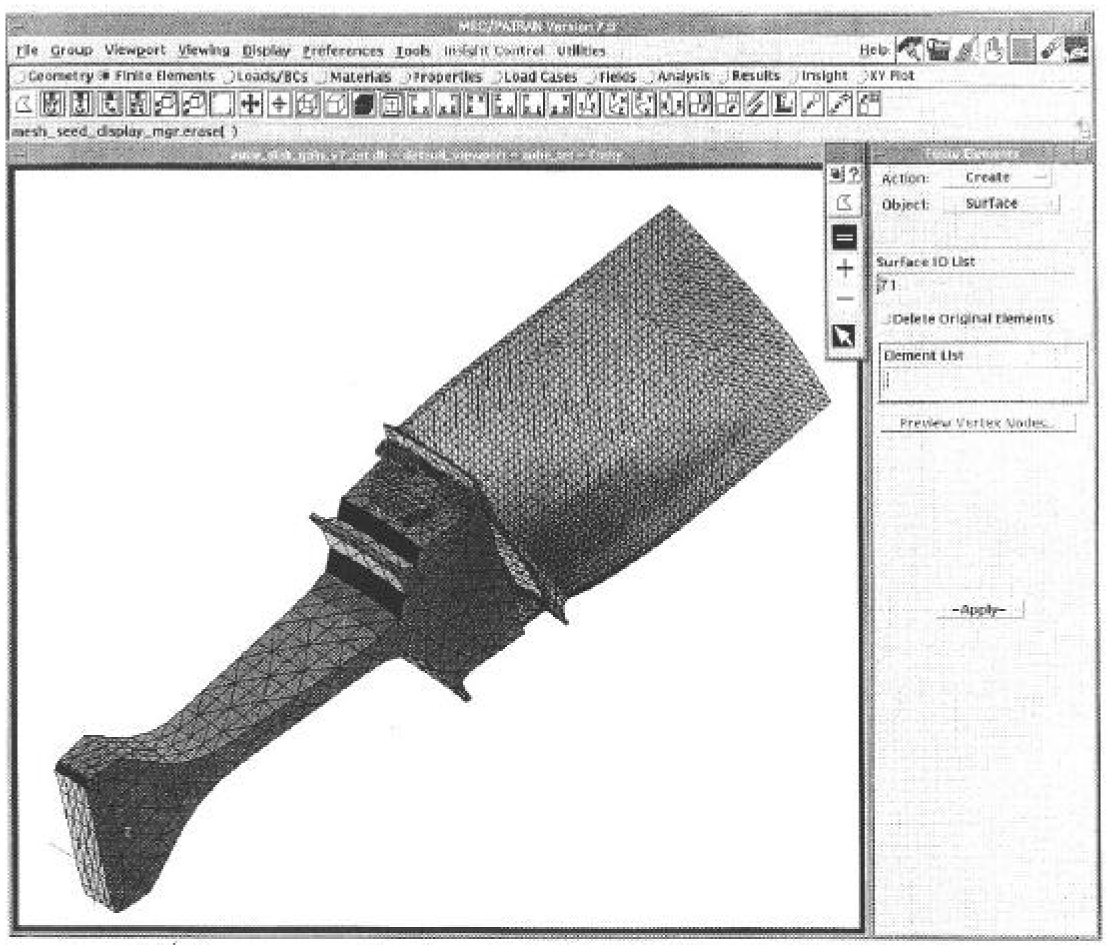


FIG 2: AUBE DE TURBINE MODELE GEOMETRIQUE ET ELEMENTS FINIS

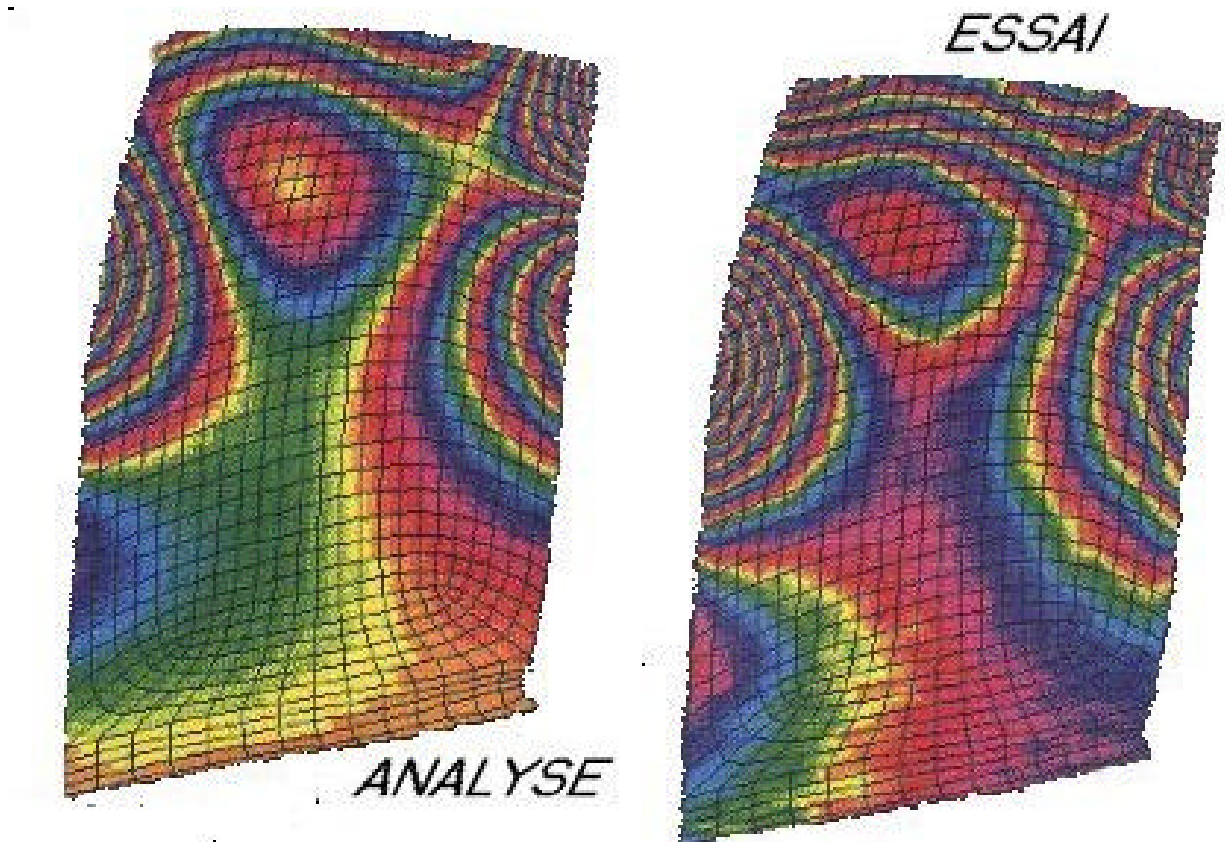


FIG 4 : ISO DISPLACEMENT ON HIGH MODE
COMPARISON ANALYSE/ESSAI (HOLOGRAPHIE)

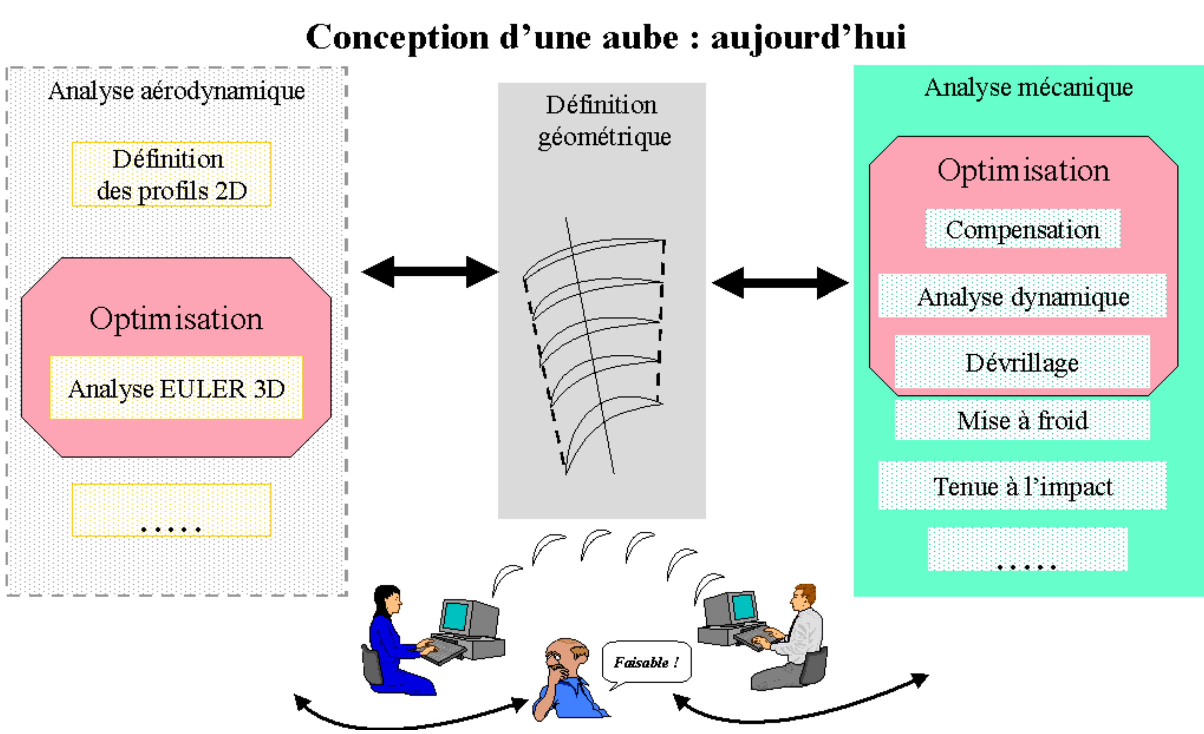


FIG 5: optimization process today

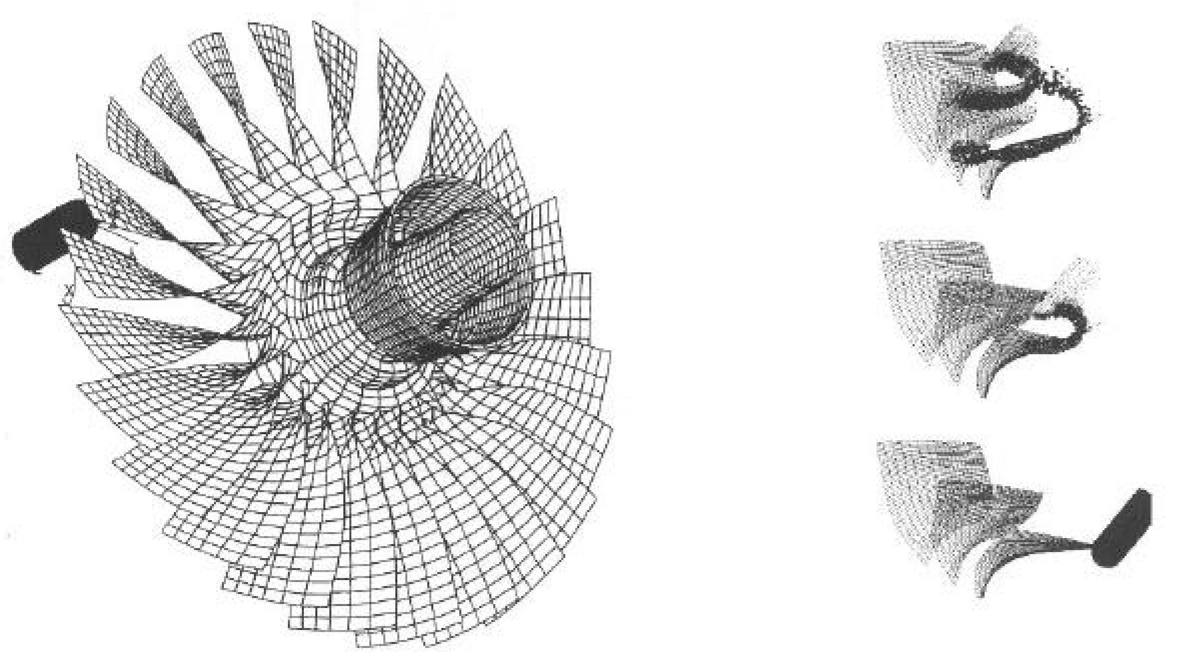
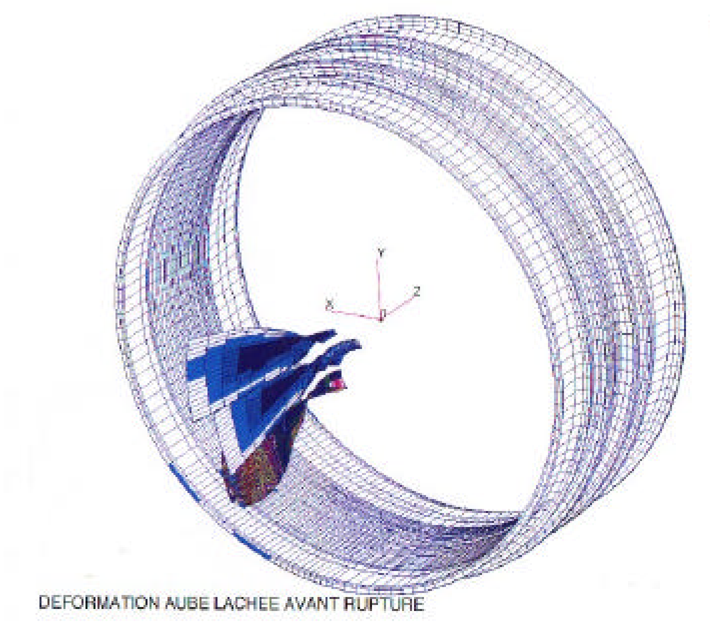


FIG 6 : BIRD IMPACT ON FAN BLADE



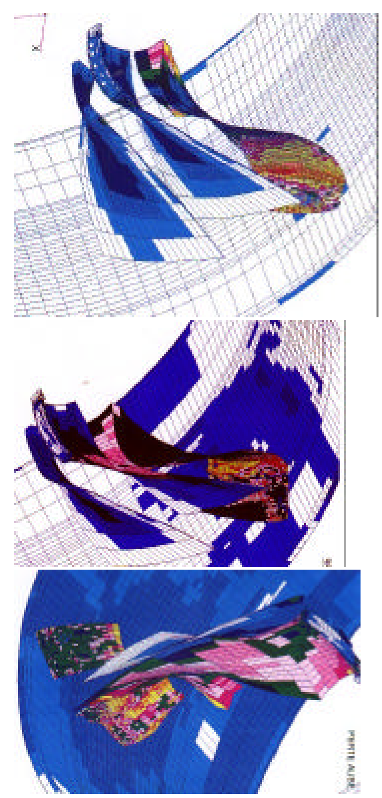


FIG 7 : FAN BLADE OUT

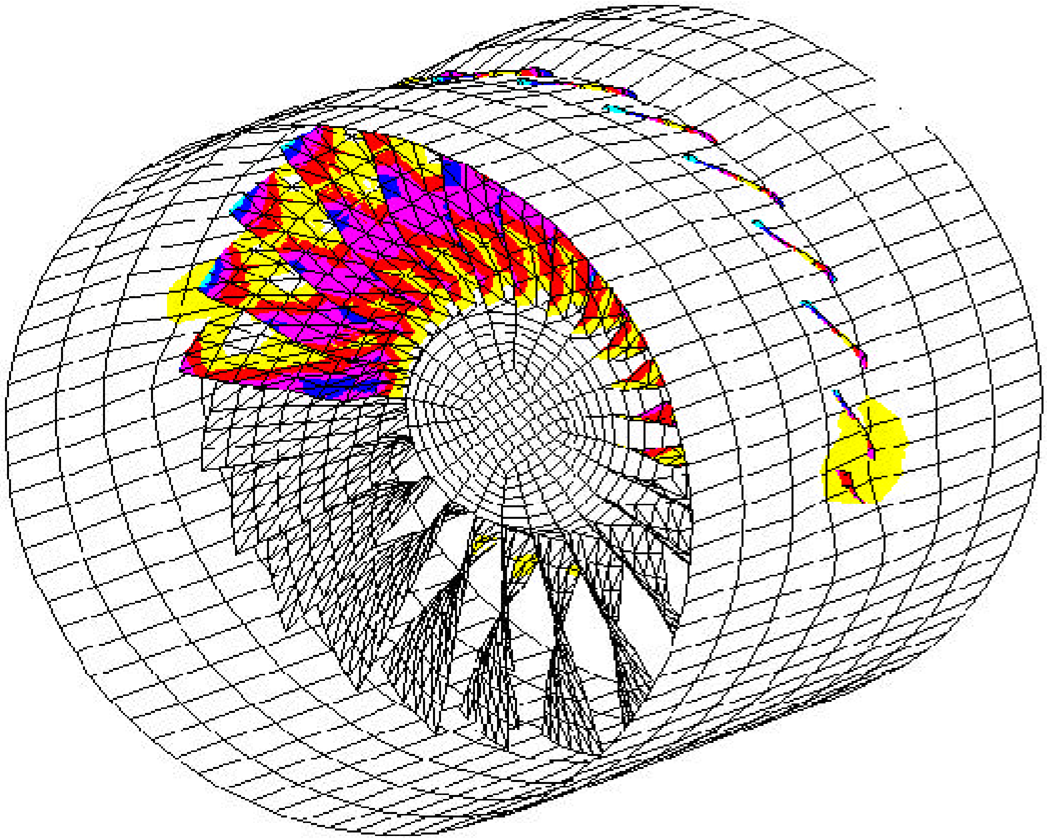
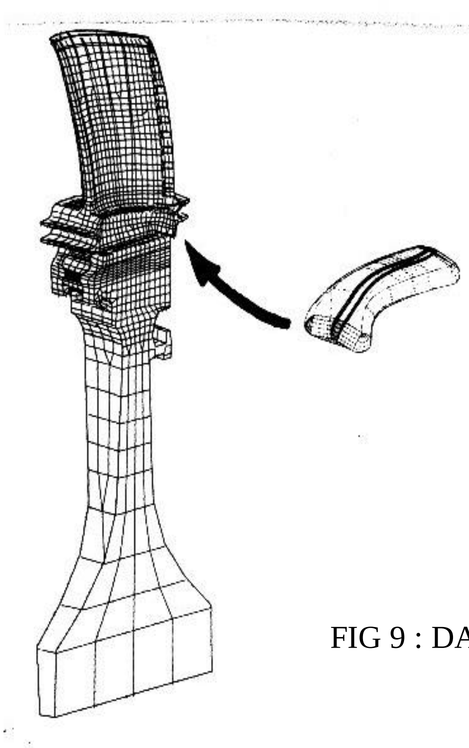


FIG : 8 BLADE/CASING CONTACT SIMULATION



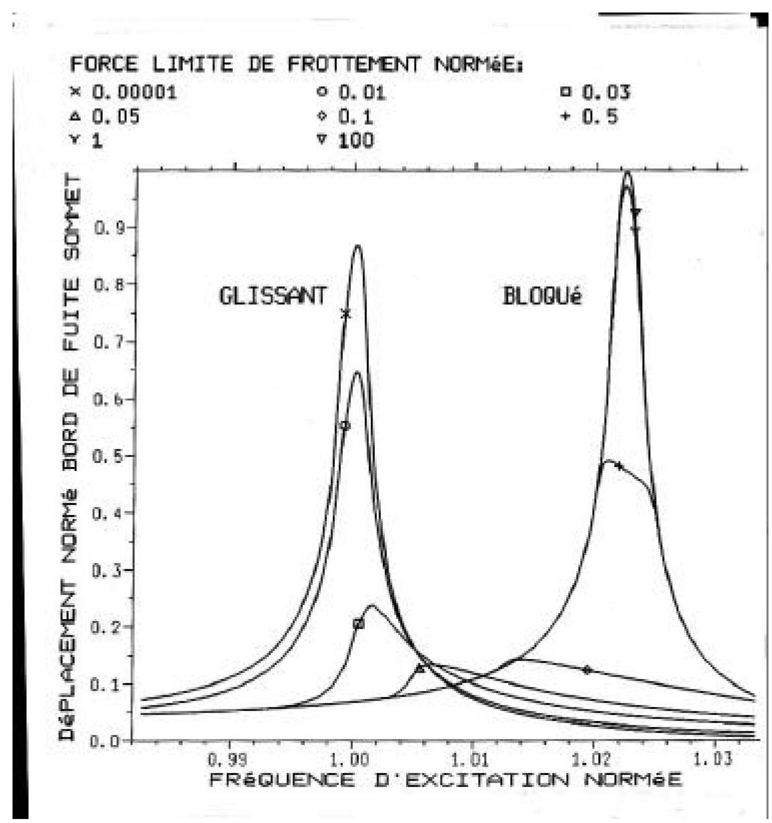


FIG 9 : DAMPING SIMULATION ON BLADE /DISK SYSTEM

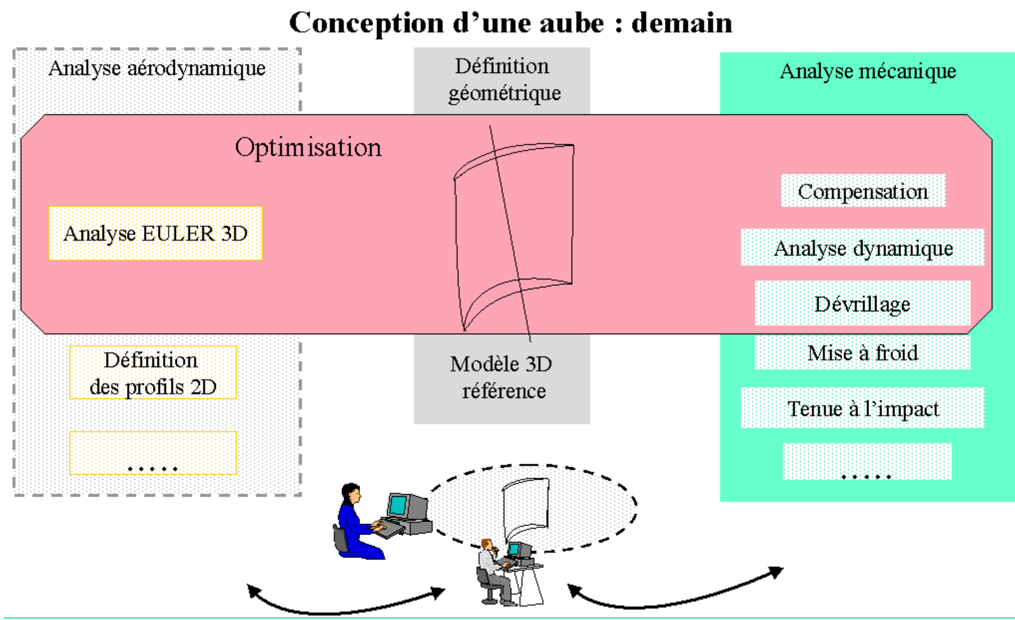


FIG : 10 OPTIMIZATION FUTURE PLAFORM

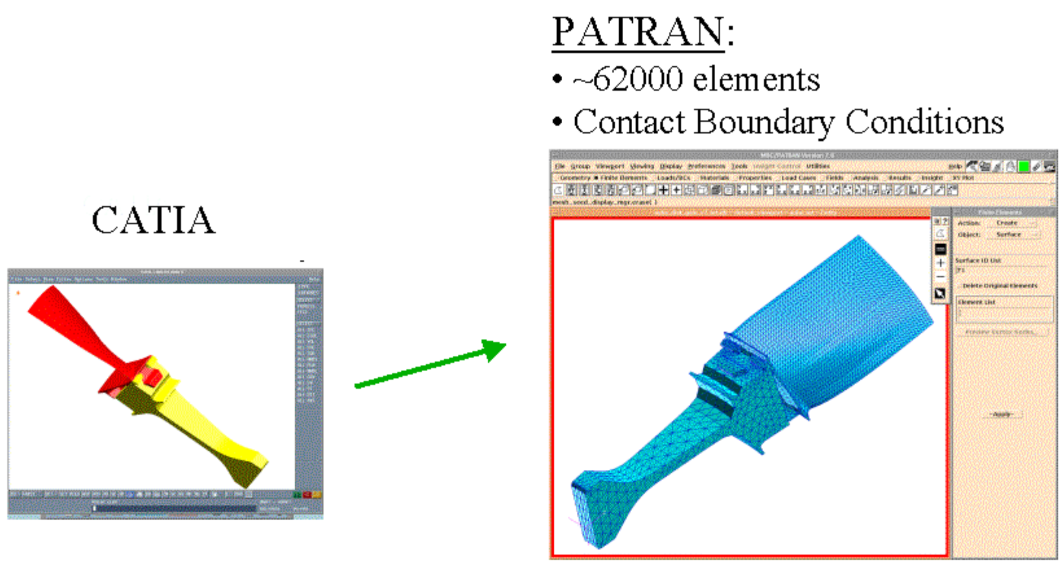


FIG : 11 INTER-OPERABILITY CATIA/ PATRAN

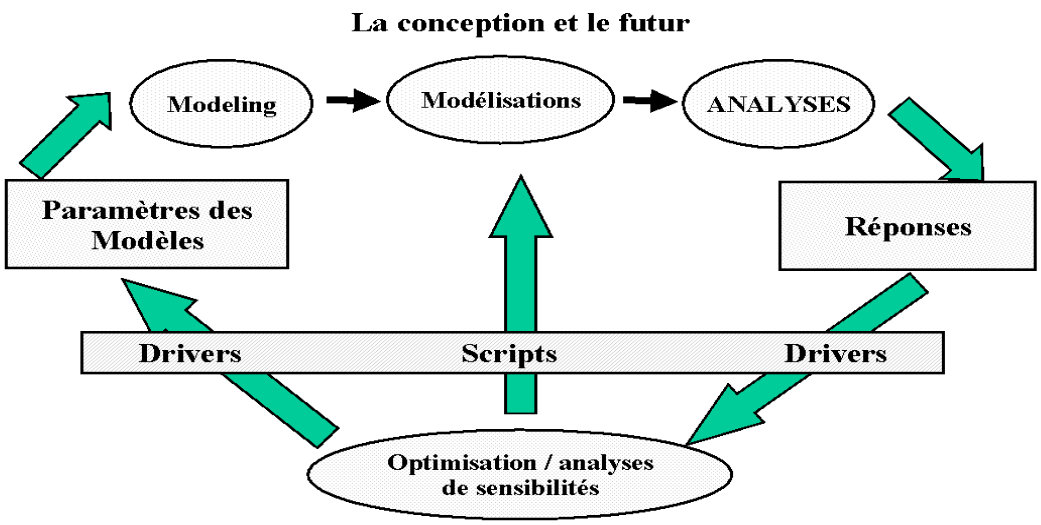


FIG : 12 INTER-OPERABILITY MODELING/SIMULATION