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The Helicostation – A necessary computing environment for CFD applications in industry

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ABSTRACT

This last decade has shown tremendous improvements in the development of Computational Fluid Dynamic (CFD) tools. Although CFD has already been applied in the fixed wing industry for years, it came up that what was a dream for the rotorcraft industry would soon become a reality : have an on-site wind tunnel to numerically blow full scale complete helicopters every day !

This paper addresses an industrial part of the CHANCE project, gathering the helicopter research teams of the ONERA and DLR and Eurocopter, now an EADS company : the build-up of an easy and friendly numerical environment – the so-called Helicostation- which houses all necessary software for an aerodynamic project beginning from shape design and ending to flight testing.

The need for a global aerodynamic computing structure in industry comes from the fact that around 80% of the workload lie in the first steps of a project : the CAD (Computer Aided Design) a smoothing and the mesh generation before the CFD calculation. 10% lie in the CFD calculation itself, provided that it be robust and time efficient, while the last 10% lie in the results analysis. In the CHANCE project, the second stage (CFD software) is managed by the research centres. The rest remains at industry's responsibility. The challenge is thus to ease the workload during these phases, distribute it efficiently among development teams on distant sites, to avoid duplication or lack of time when looking for or exchanging some information, keep a trace and secure the information to ensure transfer of knowledge and preserve the industry know-how. To reach this challenge, specifications for the Helicostation have been issued. They are discussed in the paper and have led to a prototype architecture of the Helicostation. The master idea of the Helicostation is : best circulation of information.

The architecture is fully described. The heart of the Helicostation lies in its data base and common format CGNS. It is the master piece to ensure an easy exchange of information between the different software and flexibility to accept new coming tools in the future. Two other blocks cover the software tools which have been integrated in the Helicostation. One block is dedicated to the technical tools (ranging from the shape modelling and mesh generators to the graphic postprocessors), among which the CFD software elsA® and FLOWer developed by the research centres within CHANCE. Another block is devoted to the management tools (user's access rights, saving and storing for tracking, project management). Each block functionality is discussed in the paper.

Finally, a prototype version of the Helicostation is presented. This model proves the ability of the concept to allow quick and easy exchanges inside and outside the Helicostation. A sequence covering CATIA® design step, then shape smoothing, mesh generation, CFD calculation and graphic analysis of the solution is illustrated on the NH90 helicopter fuselage, for which a full set of CAD data were already available. Time savings and gain of efficiency are assessed as well.

INTRODUCTION

This last decade has shown tremendous improvements in the development of Computational Fluid Dynamic tools. While private companies have put on the market more and more powerful computers, ranging from vectorized ones (Cray, NEC, Fujitsu, etc) to super scalar multiprocessor ones (DEC, SGI, etc) to cut down CPU time, possibility has thus been given to develop and run efficient mathematical algorithms to solve the 3D Euler then 3D Navier Stokes equations. At the same time, complex grid generators, which can handle multi-block structured as well as unstructured meshes, with a large choice of topologies and millions of nodes, have been provided on the market, to take advantage of the available huge memory space on new generation computers. Although already applied in the fixed wing industry, it came up that what was a dream for the rotorcraft industry would soon become a reality : have an on-site wind tunnel to numerically blow full scale complete helicopters every day !

This is the reason why the CHANCE common research program was launched in 1998 between France and Germany, gathering the helicopter research teams of the ONERA and DLR and the Eurocopter Company, now an EADS entity. The ultimate goal of CHANCE is to provide designers with an aerodynamic numerical environment able to simulate the flow around a complete helicopter in its flight domain. This paper addresses an industrial part of CHANCE project : the build-up of an easy and friendly numerical environment – the so-called Helicostation- which houses all necessary software for an aerodynamic project beginning from shape design and ending to flight testing.

1 CHANCE PROGRAM

In 1997, a challenge was raised in the aeronautic french world to build up the numerical wind tunnel. To put the challenge as high as possible, it was decided to choose a full helicopter in flight as the targeted application for assessing the quality of the future electronic wind tunnel, since this application represents an envelope of difficulties, ranging from rotating/non rotating parts to large eddies and viscosity phenomenon including wakes, through very low to high transonic and locally supersonic Mach number areas. This challenge corresponded also to a need to modernise and rationalise the numerous Computational Fluid Dynamic tools, most of them largely distributed, leading to unavoidable multiple versions difficult to maintain and control, while each had its own specificity and domain of validation. The elsA© code (ensemble logiciel de simulation d'Aérodynamique, ref 1) was ready to grow up at ONERA, from the previous CANARI (ref 2), FLU3M (ref 3) and WAVES (ref 4) codes, to provide a multi purpose CFD platform in order to cover all aeronautical neeeds (fixed wings, engines, missiles, space launchers, etc).

The specific situation of the helicopter partners offered the possibility to build up a bi-national program for helicopter application : CHANCE (Complete Helicopter AdvaNced Computational Environment). Indeed, Eurocopter was already a merger of Aerospatiale helicopter branch in France and MBB helicopters in Germany, while the helicopter teams of the French research centre ONERA and the German research centre DLR (Deutsche Zentrum für Luft- und Raumfahrt) were just merging. The project CHANCE was born in 1998 with the ultimate goal to provide industry with an aerodynamic numerical environment able to simulate and analyse the flow around a complete helicopter in its flight domain. But, alike elsA©, CFD development was not the only topic to address. There was a need to develop a user-friendly environment which could house the different software usually run to perform an aerodynamic study, in a similar way as the existing « Aerostation » in Aerospatiale Toulouse Airbus branch (ref 5)

Thus, CHANCE program was split in different tasks, which can be grouped for simplification in two main activities :

- the CFD development includes on the French side reformulating CANARI and WAVES into a single code and improving it to allow the calculation of an isolated rotor in hover with Navier-Stokes, then the calculation of an isolated fuselage with N-S, then the calculation of a full helicopter with an actuator disk approach for rotors, and ultimately the calculation of the full N-S helicopter. On the German side, the same goals will be achieved on the basis of the CFD code FLOWer (ref 6). Aeroelastic couplings will be included.
- The user-friendly environment development includes the selection of a common preprocessor for CAD modelling and meshing, the selection of a common post-processor for

graphic analysis, the definition of general inputs/outputs for the software, the selection of a common data format for files, the development of a common architecture for data exchanges and storage.

While the first activity is mainly handled by ONERA, DLR and the University of Stuttgart, the second activity is under the responsibility of Eurocopter. This second activity and its advancement statement, are described in the following paragraphs.

2 SPECIFICATIONS FOR THE HELICOSTATION

A complete helicopter is a complex system enclosing different parts (fuselage, sponsons, air intake, exhaust system, fairing engine, main and tail rotors, stabilisers, weapon arms, rockets,...). The aerodynamic configurations of interest are numerous (pitch attitude, quartering flight, high speed and hover performance, stall onset when manoeuvering, acoustics in descent flight and in high speed, engine gas recirculation, infrared emission, rotor flow interaction with weapons at launch, air intake performance,...). The use of a general engineering tool for aerodynamic calculation like elsA®/Flower leads moreover to a large choice of numerical calculation options (transition and turbulence models, numerical scheme in space and time, acceleration techniques of convergence, aeroelasticity coupling,...).

This ambitious project requires a powerful management system for industrial partners in order to ensure quality and efficiency in the management of the calculation configurations. In addition, the data exchange problem needs careful investigation for such a multipurpose and multi-partners development program. The daily use in industrial context of an aerodynamic tool requires flexibility and friendly user's environment. All these requirements are relevant of a software tool called 'Helicostation', the specification of which are derived from the above statements and are described thereafter.

a) Nowadays, use of numerical tools is performed intensively in industry. The number of softwares used and data files created therefore strongly increases. To ensure quality and efficiency in the management of the CFD calculation process, an **easy to use** 'Helicostation' has to be built up. To fulfil this requirement, user's tasks should be separated from management tasks and the user should be provided help for the technical tools.

Some tools have to be developed, including :

- a set of tools for task management (to be defined below);
- a predefined (batch) process with friendly-user interface for technical tools.

b) As numerical calculations require important CPU time even on a supercomputer (response time requirement for both elsA® and FLOWer is 1 week for a rotor polar curve with 3 points), calculations have to be **stored safely**, as an experimental result would be. A particular attention should be paid to the storage of meshes, because a grid construction represents several weeks of manpower. In addition to numerical data and meshes, all needed information in order to exactly identify data files, has to be provided. Once those files are stored and fully documented, anyone should be able to **easily find any desired information about any work already done**. Indeed, the feedback time for a calculation cycle remains important, thus inducing great human and computational cost, which we wish to decrease :

Documentation must provide the necessary information :

- to follow code evolutions (versions, functionalities), and thus be able to choose the most appropriate tool at each stage of a full process ;
- to check all the control parameters in the process ;
- to display the content of projects, in order to find information easily and to avoid repeating calculations or mesh generation, thus saving tremendous time;
- to manage safely the data files by ensuring the tracking;

To fulfil these requirements, all data files shall be accessed only through a single interface of the 'Helicostation'. All actions inside the database have to be recorded in order to identify the creator (destroyer) and the date of creation (destruction) with comments.

A specific process is being developed to sort out or search for some key words (design nomenclature, calculation parameters, etc) in order to analyse the request with any work already done.

c) In the frame of the CHANCE project, developers on distant sites are requested to exchange data (such as shapes, meshes, results). Therefore a **<u>common format for data files</u>** has to be defined. This format will be used at each step of the project (grid, calculation, analysis of results, etc.…).

This common format shall contain :

- all information needed to run a calculation (grids, numerical parameters, boundary conditions, etc…);
- all technical results (N-S calculation, grid quality information, etc…);
- all information to manage data files (tracking, project management, access property, etc…).

Furthermore, in order to comply with the users needs, which will probably evolve, it should be possible to upgrade this common format regardless of the technical tools (i.e. grid generator and solver).

d) The 'Helicostation' is an industrial tool and must then take into account the evolution of commercial software and of industrial needs. Therefore it must be **<u>easily 'upgradable'</u>**.

To fulfil this requirement, we need:

- to select a common format supported by a large industrial structure ;
- to personally develop interfaces between each technical tool and the common format with read/write procedures as part of the Helicostation, to be able to quickly modify them in case of upgrade or implementation of new commercial products;
- to have an 'Helicostation' frame based on object oriented techniques, in order to be able to modify or to add any functionality without changing the others;

e) The numerical calculation involves different people : it's a shared tool. One has then to **<u>pay attention to the safety and the sharing of the data</u>** (under access right restriction).

To reach those requirements, one has to develop tools in the 'Helicostation' kernel:

- to prevent direct access to data files;
- to limit and to control the user's rights;
- to restrict (or to propose) the number of parameters to be shared;

f) The Helicostation will be shared between different companies at distant sites. In order to optimise shared resources, one has then to **<u>pay attention to minimise the waiting time when accessing some resources on a partner's site</u>**. Indeed it must be possible to perform a study while using a mesh available at partner 1 site, using the CFD software available at home but run on partner's 2 platform, and then bring back home the solution to analyse it. The master word is fluidity of data exchanges.

To reach those requirements, one has to develop tools in the 'Helicostation' kernel:

- A fast system which regulates data exchanges between different computers environments ;
- A global system which ensures compatibility between platforms to prevent any time delay in data exchanges and tools access.

Thanks to these specifications, the workload during the CAD-modelling or meshing phase, as well as during any preparation phase before a software use (grid generator, CFD solver, graphic analyser), will be limited. It will also be distributed efficiently between development teams on distant sites. Duplication or lack of time when looking for or exchanging some information will be avoided. The work performed will be tracked, the information will be secured and the transfer of knowledge will be guaranteed to preserve the companies know-how.

3 HELICOSTATION ARCHITECTURE

To fulfil the above requirements, a specific Helicostation architecture has been set up. It can be described in two levels :

- The first level (the basic one) describes the links inside and outside 'Helicostation' between the technical tools (fig 1). All the technical tools are interfaced with a common format associated with read/write subroutines library. This represents the minimal configuration to allow data exchanges between partners. The data exchanges between partners are then done under the common format of the 'Helicostation'.

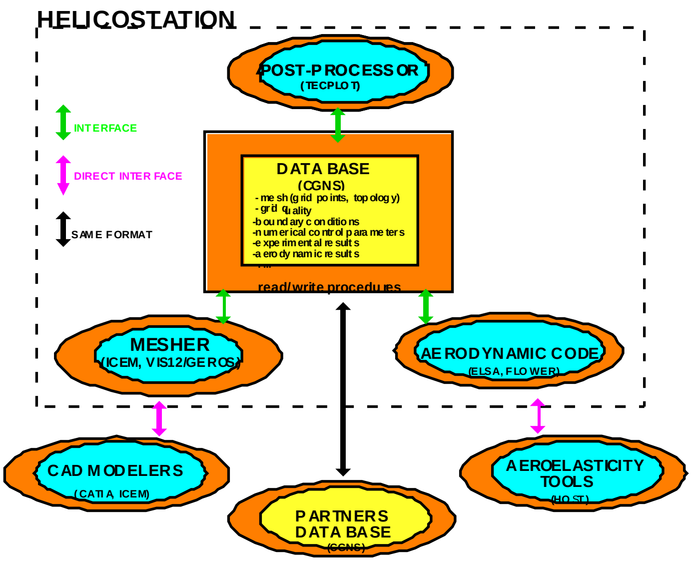

Figure 1: Example of integration of some technical tools around a common format for storage

The CAD tools appear outside the Helicostation because they are already available in each partner's company, being generally used by the mechanical design departments. Most of the mesh tools support SET or IGES format to import the CAD shapes.

Within the CHANCE project, the aeroelastic tools (HOST (ref 7), CAMRAD (ref 8), etc) will not be interfaced with the common format, but directly with the aerodynamic tools, whether weak or strong aeroelastic coupling. However, considering that data exchange between two codes is done via data files, the possibility to store these data under the common format is still open.

- The second level describes the links between the users, the technical tools and the database (fig 2).

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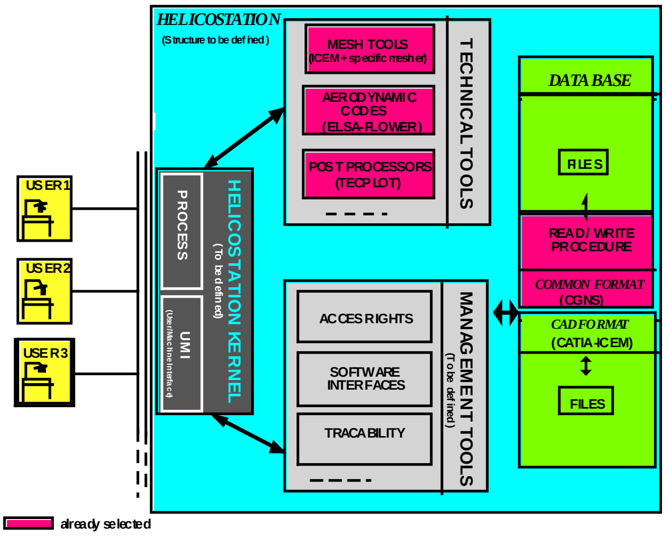

Figure 2: 'Helicostation' with kernel between user and database and technical tools

Two different parts containing tools can be distinguished:

- The technical tools including grid generators, flow solvers, post processors and others technical tools;

- The management tools containing the tools to manage the access rights and other management tool (data base read/write procedures, tracking, …).

A kernel manages all these tools : it is the only available interface with the users. It ensures safety of the data base: one basic idea for the quality control is to prevent any modification of a data file unless via the management tools of the 'Helicostation'. The necessary information for the management tools are stored in a common format, with their associated read/write procedures. The database is embedded in the Helicostation. kernel and management tools are necessary to achieve the objectives of safe storage, tracking, easy to use, easy to upgrade and safe management, including common format.

Management of information exchanges between distant sites on multiple platforms is described thereafter :

- Helicostation computer development is based on JAVA language for Man Machine Interface and C ANSI for other functionalities.
- Data for management and tracking are stored in a relational data base. Such choice guarantees a multi-platform efficient use of the Helicostation.
- To ensure use at distant sites, two solutions are under way : a network distribution with a unique access rights management, or a duplication of a common synchronized data base, at regular intervals. This latter choice is justified by response time constraints as well as networks congestion avoidance.

4 THE TECHNICAL TOOLS OF THE HELICOSTATION

Although the Helicostation is built up in such a way that it can handle any technical tool, providing that an interface be created between the input/output format and the common Helicostation format, default tools have been selected and provisioned inside the Helicostation to become the reference technical tools (mesh generator, CFD solver, graphic post-processor)

4.1 CAD tool : CATIA®

In the research centres no specific CAD tool is used. The common CAD tool selected at Eurocopter is CATIA®. This tool has been used and mastered for several years. It is widespread in the aeronautical industry. The only requirement is to be able to interface the in-house grid generators with the existing CAD tool (see below).

4.2 Mesh generator : ICEM®

Several mesh tools, ranging from commercial to specific research grid generators, have been evaluated at Eurocopter. These tests have pointed out some difficulties : the CAD / mesh generator interface, the flexibility and versatility of these tools, the feedback time for industrial use, and the necessary training and customer support.

- The CAD / mesh generator interface revealed some difficulties to transfer shape from CATIA®. Although they have been partially solved, some particular treatments are still required leading to considerable extra time. This is due to the universal IGES format used to transfer the surface definitions, which still has to be improved. One solution to overcome such problems is to transfer geometry directly through native formats.

- It is almost impossible to find a grid generator which would be flexible and versatile enough to generate any kind of grid. Different algorithms are needed for complex grids (i.e. multiblock around a helicopter fuselage), and for very simple grids (i.e. single-block blade fitted C-H, O-H, C-C or O-C about one rotor blade in hover). For example, although very advanced, both ICEM® and Megacads, specifically tailored for multiblock grids, are not adapted to generate a simple single-block grid for rotors of acceptable quality within a short time of work (1 day).

- Structured meshes do require spending a lot of time and skills (compared to unstructured meshes) due to the definition of the mesh topology, the control of the grid spacing and the smoothing of the block junctions. Helicopter meshes are often characterised by complex shapes, whose modelling require a considerable amount of man-power. The feedback time for a mesh generation is then very important for industrial purposes. Therefore software incorporating methods aiming at reducing this feedback time are highly desired.

- Each grid generator besides its positive features presents some weak points, which are usually overcome by experience (know-how). The number of skilled users and their training is therefore of great importance. However, due to the rate of turnover, it is difficult within industry to develop and maintain an efficient policy of internal skilled and secure know-how in mesh generation.

According to the difficulties encountered during the mesh tools evaluations, it appeared that the ICEM® CFD mesh was fitted for our industrial use of the elsA® / FLOWER codes. Assuming that, in order to generate multiblock grids about a complex helicopter fuselage, a specifically tailored tool like ICEM® is necessary, simpler grid generators for isolated rotor blade problems have been maintained in addition to ICEM®.

GEROS (ref 9) and VIS12 grid generators, specifically coded for generating Euler algebraic single-block blade fitted grids, are already in use within the partnership and create smooth grids in very short time.

Other tools are already available in the Helicostation. Starting from an Euler grid, they refine the mesh in the boundary layer region according to the Reynolds number of the calculation. These tools, together, can be used to convert easily and quickly an Euler grid into a Navier-Stokes one. This is already done by EADS

Toulouse with the MIRABELLE tool (ref 5). GEROS and VIS12 have such capability.

4.3 Graphic post-processor : TECPLOT®

All partners use TECPLOT® software which is well suited for aerodynamic visualisation (vector, streamline, contour plot) on structured grids.

(+) Multiple windows to display the results

(+) Easy data alteration

(+) Macro command to load the data treatments and graphic display and to be able to run them in batch mode: macro and layout

(+) Easy management of zone

(+) Structured and unstructured mesh

(+) Windows metafile format for graphics and AVI format for video

(+) compatibility with CGNS format

(-) No dynamic display for 3D visualisation (during rotation or translation)

(-) No dynamical extraction along curve, but the result is saved in a file

Two other tools are available in house : QUICKVIEW developed by EADS Toulouse and VISUAL3D developed by ICEM® CFD.

Thus CATIA® (CAD), ICEM® HEXA (mesh generator), elsA®/FLOWer (CFD solver), and TECPLOT® (graphic post processor) are the basic tools already embedded in the Helicostation. But the Helicostation has been designed to welcome any kind of tool, providing that the interface between its input/output files format and the common data format be developed.

5 THE DATA FILE COMMON STORAGE FORMAT : CGNS

In the Helicostation, a number of data will have to be stored and accessed for exchange during the whole process, to cover the following purposes :

- running software
- providing information on previous projects
- managing project process
- managing access rights
- replaying calculation
- storing grid geometry and topology
- storing CFD solution

To store these data a common storage format has to be defined. The major constraint for this one is to be easily upgradable.

- all data in the data file must be self-identified.
- The content of such a storage format must be described precisely according to data required for Helicostation (for management and technical purpose)
- All data related to post treatment, requiring specific file, like macros for TECPLOT® (which cannot be used by another software) are not stored in the common format. These information are stored in native format. Nevertheless, these files must be associated to the project files. A standard graphic format (.wmf, .ps or .avi) could be chosen to keep major results (figures and video) in the project datasheets or to indicate the macro filenames to be used by TECPLOT®. A synthesis report could also be joined to the project data files.

Several storage format exist for numerical aerodynamic data. EADS Toulouse has developped the DAMAS-SDA storage procedure (ref 5) to store their data inside the 'Aerostation' (ref 5). Another format, CGNS (ref 10), developed by BOEING and ICEM® under NASA leadership, is now spread on numerous users, including EADS Toulouse and could become an ISO norm for aerodynamic data storage. The advantages of this format are :

- ICEM® CFD has developped a CGNS output.
- TECPLOT® is able to read and write in CGNS format.
- CGNS allows storing structured and unstructured formats.
- CGNS format includes a lot of partners all over the world, and has a clear and voluntary policy of development and support in the coming years.

These are the reasons why this format has been selected for the Helicostation to be the common data format. The different read/write procedures for interfacing with the existing software in the Helicostation (CFD solvers, specific grid generators, etc) have been developed and are now available to perform a whole project process inside the Helicostation, as is illustrated in the following paragraph.

6 A TEST EXAMPLE OF STUDY IN THE HELICOSTATION : THE CALCULATION OF THE AERODYNAMICS AROUND THE NH90 FUSELAGE

6.1 description of a process

A process is a succession of elementary tasks which are always required to execute a whole study.

As an example, the aerodynamic field around the NH90 fuselage is calculated since besides a full set of CAD data is available. The results are fully described in an other presentation in this forum session (ref 11). To perform it we have to define :

- The CAD geometry to select (to be chosen in the already available CATIA® data base)
- The grid file to use (to be chosen in the CGNS data base)
- The initial solution for restart (to be chosen in the CGNS data base)
- The pitch attitude range and the Mach number range
- The parameters of the calculation : the numerical and the physical model
- The name and the version of the code (parallel or not, number of processors., version, …)

and we want :

- To execute successively all calculation automatically in batch mode
- To generate a data file containing the pressure distribution, and another file containing the velocity field
- To extract the convergence history of each component of the drag coefficient
- To store the results in the data base
- To create an history file for tracking purpose

To calculate the aerodynamic field (velocity, pressure contours, lift, pitching moment and drag), the number of elementary actions are numerous if executed manually by the user. With the Helicostation, they can be described in a 'process' file in order to propose to the user the actions to do and the possible answers, depending on the data base content, and using graphical UMI. The actions which can be done automatically are directly executed by the 'process' (tracking files, displaying of existing grid or solution, creation of data file for calculation for each pitch attitude and Mach number, format conversion, data base storage, ….).

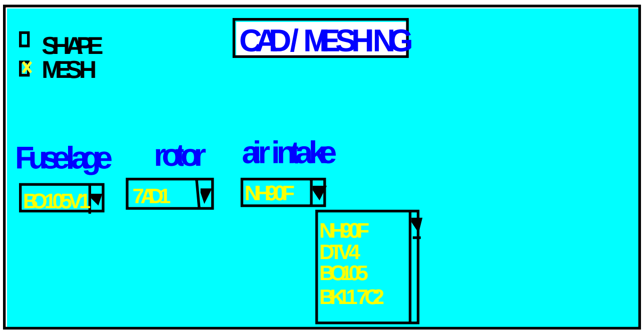

Fig 3 : UMI example : Selection of a data file (CAD or mesh)

Figure 3 illustrates the selection of a mesh file for mesh treatment, as seen on a PC screen. Here, the management tools for sorting the data file are used to help the user select the right data filename.

The user wants to do some mesh treatments : he can use an elementary 'process' which can help him search for the data file he needs.

6.2 architecture used

For the validation test of the calculation of the aerodynamics around the NH90 fuselage, the following architecture of the Helicostation was used. It corresponds to the actual status of development of the Helicostation.

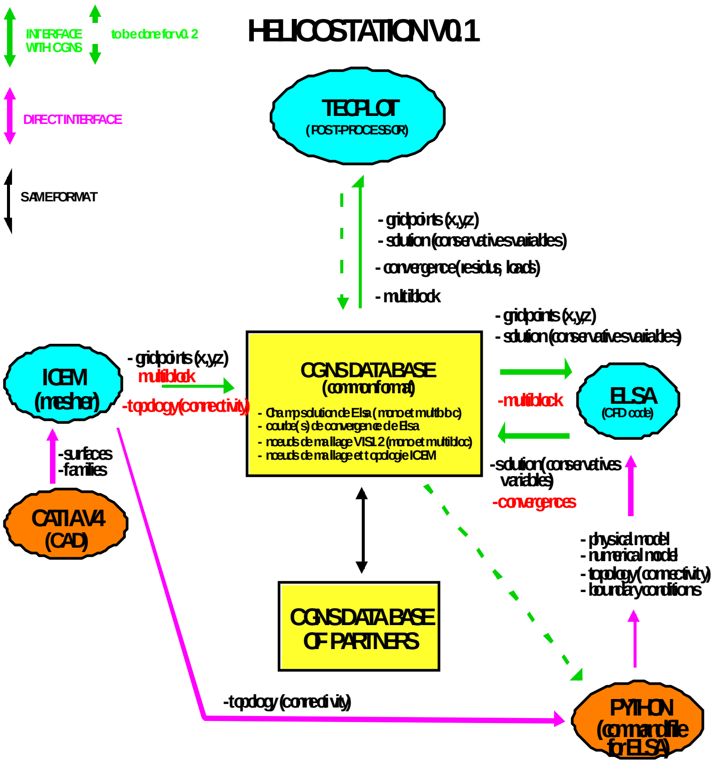

Fig 4 : helicostation links between software used for validation case

From CATIA® V4, the NH90 fuselage geometry is imported into ICEM® after simplifications (elimination of unimportant details for aerodynamics) and modifications (closure of holes, etc). Blocks are first defined (95 blocks here, for parallel mode computation).

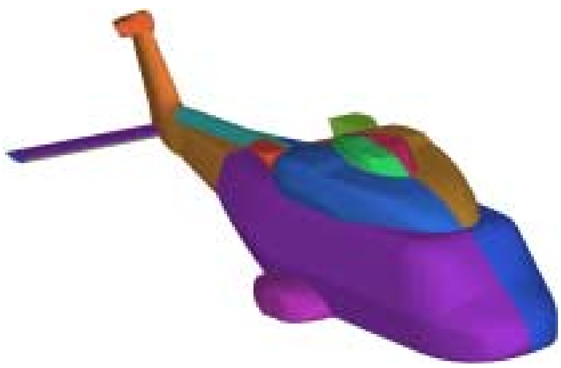

Fig 5 : NH90 aerodynamic blocks definition

It is then meshed, and the grid is stored in CGNS data base, while the topology is sent to the PYTHON user interface of elsA®. This latter phase is about to be substituted by a direct storage of the topology in CGNS and an interface between the PYTHON file job and CGNS.

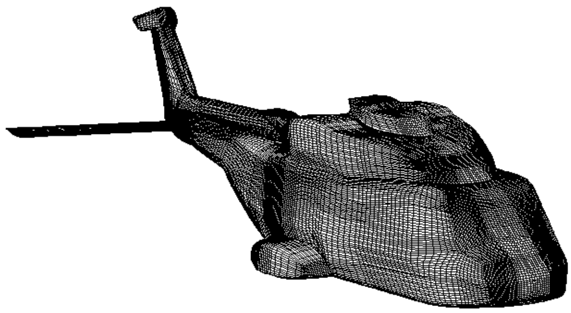

Fig 6 : view of the mesh around the NH90 fuselage

This meshing corresponds to 4.6M nodes, in structured grid for a Navier Stokes calculation. It guarantees Y^+ always below 1, except at the horizontal tail (needs further refinement). At each stage of the process, the Helicostation proposes the user to check, validate/modify mesh, or automatically pursue for the next stage as illustrated before.

Then the elsA® solver is launched by the Helicostation process and, at repetitive intervals the basic variables for convergence control are extracted through TECPLOT® while elsA® keeps on running. The user can hand back any time once elsA® has finished running. The solution is stored in CGNS format, to be analysed through TECPLOT®. The figure below presents a part of the solution : the Cp distribution along the bottom centre line of the fuselage (red square : measurements, green line : calculation)

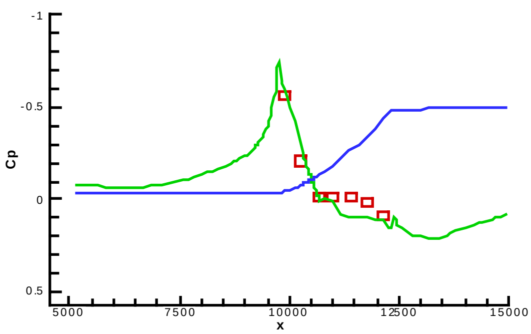

Fig 7 : NH90 Cp distribution centre bottom line

In this whole process, the CATIA® and ICEM® work (modifications, grid topology and meshing) represents today at Eurocopter about 20 days of work for an average skilled engineer, while the

CFD calculation time took 80 hours on a 6 processor SGI 3400. Thanks to the Helicostation, for a future study on the NH90 fuselage (including modifications or simply other calculations) most of this time will be spared and any mistake in gridding will be avoided. Indeed, we performed such trials and we spent only 5 days (including geometry modification and the necessary CFD calculation time). Outside the Helicostation, such a study would have taken 10 days (including data transfers in different formats and unassisted preparation of jobs), with a risk of mistake at each stage and thus an unknown risk of additional days of study.

CONCLUSION

A user friendly computing environment, called Helicostation, is under development at Eurocopter in the framework of the German/French helicopter CFD CHANCE project.

The goals of the Helicostation are multiple : provide an easy-to-use tool to run a whole helicopter CFD study from the CAD modelling to the aerodynamics solution analysis in a shortest time ; guarantee quality of the study by avoiding data handling transfer mistakes ; keep in-house know-how ; ease and optimize integrated distant teams work, data base and software sharing ; provide an evolutive and flexible environment to quickly welcome new software.

The former available functionalities of the Helicostation, structured around the common CGNS data base format and embedded inside a JAVA developed Man Machine Interface, have proven the ability of the Helicostation to divide by a factor of at least two the workload during a study and to avoid repetitive manual tasks, usually responsible for human mistakes.

Next work will now consist in developing the management tools to secure the system, the synchronized buffer exchange system to speed up data base access during distant work studies, and in completing the detailed Man Machine Interface.

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