

ROTORCRAFT PRE-DESIGN ACTIVITIES AT DLR

– RESULTS, STATUS AND OUTLOOK –

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Abstract

The German Aerospace Center (DLR) is currently developing an integrated and automated tool for helicopter preliminary design and evaluation. To support the design process and the evaluation task, an integrated rotorcraft design and evaluation toolbox covering the conceptual and preliminary design stages was developed. Further work will extend this toolbox with special regard to novel rotorcraft configurations and includes the development of suitable models for the interaction of different components of the helicopter. The paper gives an overview of recent activities in rotorcraft design as well as detailed descriptions of the process chain and software modules for rotorcraft preliminary design developed at DLR. First results of the integrated toolbox are shown. Furthermore the current activities at DLR regarding the topic and an outlook on planned activities are presented.

1. INTRODUCTION

The design of rotorcraft is a highly complex process. Compared to fixed-wing aircraft the design space is wider and more heterogeneous. Pre-design tools are frequently used by the rotorcraft manufacturing companies. In general, they are based on detailed knowledge of existing helicopters and heavily use empirical methods. Despite this being an efficient means for the preliminary design of helicopters, the exploration of new unconventional designs is very limited. In recent years there has been a renewed interest especially in the design of unconventional concepts differing from the classical main and tail rotor configuration.

Hence, the subject of rotorcraft design has been addressed by a variety of aerospace research organisations in recent years, for example by NASA^[8], NLR^[4] or Georgia Tech^[9]. The French aerospace lab ONERA started a similar project in 2011^[1] in active collaboration with the German Aerospace Center (DLR).

DLR started to work on the development of an integrated design software toolbox in 2009. As a collaboration of the Institute of Flight Systems, the Institute of Aerodynamics and Flow Technology and the Institute of Structures and Design the DLR internal project RIDE (Rotorcraft Integrated Design and Evaluation) started in 2010 and has successfully been

completed in 2012. The objective of the project is to provide a basis for a multidisciplinary, integrated and automated tool for preliminary rotorcraft design with a strong focus on the analysis and assessment of selected configurations. The DLR project EDEN (Evaluation and Design of Novel Rotorcraft Configurations) started in 2014 and is based on the toolbox developed in the RIDE project. The main objectives of this project are the assessment of novel rotorcraft configurations and the assessment of the effect of new technologies with respect to the overall configuration. The development of suitable models for the interaction of different components of the rotorcraft is another main task of the project.

The developed design toolbox provides a basis for future activities, as the basic methodology can be adopted for any rotorcraft design as long as the underlying physical models are augmented to correctly represent such configurations. Starting from a blank sheet and only using a customer specification as a driver for the whole design process it covers a wide design space and can provide high flexibility for the design solutions.

The DLR activities in the area of helicopter design are not primarily focused on the ability to design new concepts, but rather on the application of the gathered knowledge to the assessment of existing configurations. Thus the evaluation of concepts is possible even if very few data are available (e.g. if only

a concept study should be assessed with respect to an intended operational use).

This paper describes the structure of the design process chain and the various tools. A first pre-design study carried out using the developed toolbox is presented. Finally the current status of the DLR activities on the subject of rotorcraft pre-design as well as an outlook of planned activities are given.

2. PRE-DESIGN SOFTWARE TOOLBOX

The DLR approach divides the design process into two stages (see figure 1). Firstly, the conceptual design tool generates a suitable configuration based on the requirements thus providing a starting point for the subsequent computations. In this stage a statistics-based approximation is combined with simple physics-based methods and a genetic algorithm to obtain a favourable solution.

In the following stage (preliminary design) the design is refined by bringing in the perspectives of different disciplines. The geometry module uses parametric representations of helicopter fuselage geometries in a modular assembly system to generate a three-dimensional Computer-Aided Design (CAD) model (CATIA)^[22]. The aerodynamic properties of the fuselage are calculated using a linearised potential code with coupled viscous boundary layer calculations (VSAERO)^[14]. Then a generic structure of the fuselage is determined on the basis of static analyses of suitable load cases (ANSYS)^[23] using an automatically generated finite element method (FEM) grid. The engine parameters are obtained by means of an exhaustive database of existing turbine engines. A statistical mass estimation completes the refined design. The resulting final configuration is at last evaluated using the flight mechanics code HOST (Helicopter Overall Simulation Tool)^[3]. The output data of the various modules can finally be compared to the customer requirements and thus the design can be evaluated. The evaluation is done manually at the moment, although it is planned to be integrated into the automated process chain. The range covered by the conceptual and preliminary design modules is geared towards performance-centric rotorcraft design, as factors including costs or noise are not considered in the tool chain yet.

The Common Parametric Aircraft Configuration Scheme (CPACS), a data exchange file format based on the Extensible Markup Language (XML), developed at DLR originally for the description of fixed-wing aircraft^[13], was augmented to incorporate rotorcraft-specific parameters and now serves as a common interface for all the software modules.

The various tools are described in detail in the following.

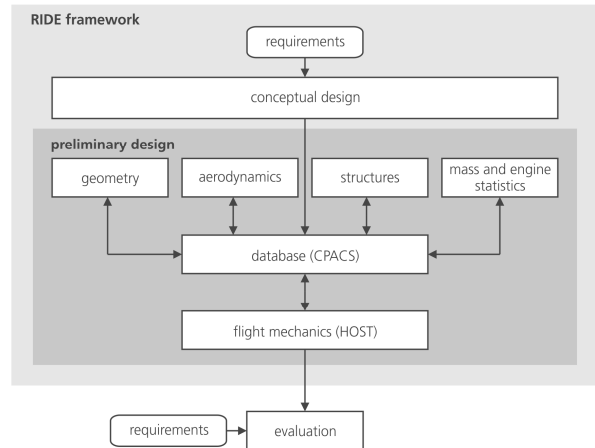


Figure 1: Process chain of the RIDE project and interactions between individual modules

2.1. Data Management

The CPACS data exchange format is the key component of the DLR design environment. It is used as a common interface for communication and data exchange between the user and between all integrated software modules. The development of CPACS started in 2005 within the context of the internal DLR project TIVA with the objective to create a common parametric description of the system "aircraft" suitable for all disciplines involved in the conceptual design and analysis process. XML technology has been selected for the implementation of the CPACS data exchange format. In March 2012 CPACS 2.0 has been released to the public under an open source license^[5].

Consequently CPACS has been selected as core technology for the rotorcraft design toolbox. In the early RIDE project phase several extensions have been defined in order to address rotorcraft-specific tasks. They were compiled into a RIDE-internal CPACS version (CPACS4RIDE).

2.2. Conceptual Design

The starting point of the design process chain is the COMRADE (COMputer-aided Rotorcraft Assessment and DEsign) module, which performs the basic sizing of the helicopter based on the customer specification. The basic structure of the module is shown in figure 2. The only mandatory user input is a specification or a typical mission of the helicopter to be designed. The underlying databases for the engine and mass statistics are set by default, although they can be altered by the user (e.g. to allow for restrictions of available engine types). Various calculation parameters, such as aerodynamic coefficients or parametric fuselage dimensions, are set by de-

fault. They can also be altered manually by the user in order to tailor the sizing process.

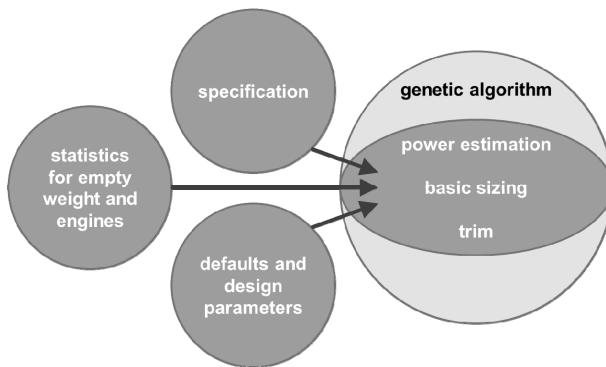


Figure 2: Basic inputs and structure of the COMRADE module

Among the parameters estimated by the module are the main dimensions of the helicopter fuselage, which are derived from the payload specification. The empty mass of the helicopter is estimated using a statistical approach based on a database of more than 140 existing helicopters. Details of the statistical method used here have been published previously^[12]. Furthermore the main and tail rotor parameters are estimated using momentum theory augmented with estimations of tip loss and global separation on the rotor blades. The fuselage drag is taken into account by applying a fixed drag coefficient to the calculated fuselage drag area. After calculating the power required for the given flight condition, the engine characteristics are estimated by regression using a database of existing engines. The performance estimations are completed by calculating the required fuel weight and trimming the helicopter.

The whole sizing and performance estimation code is embedded inside a genetic algorithm used to determine a near-optimal solution for the given design specifications. The algorithm performs a heuristic search for design variables specified by the user considering constraints (i.e. minimum and maximum values), which can also be set manually along with the desired resolution of the variable. Therefore all design variables to be determined by the algorithm are combined into a string variable (resembling a bit array) which forms the genetic representation of the design space. Afterwards a random initial population is generated. The subsequent reproduction facilitates random crossover and mutation operations and is evaluated by a fitness function which can comprise any output variables of the embedded calculation module described above.

2.3. Geometry Design

The implemented geometry generation module (GEOGEN)^[10] is based on automation of the commercial CAD/CAE system CATIA V5 via its VBA (Visual Basic for Applications) programming interface. It basically instantiates components from a catalog of predefined templates, adapts their parameter values, assembles them and finally exports the generated geometries to CPACS. Like all analysis modules of the RIDE design environment, it reads all input parameters from a CPACS dataset and writes the generated geometry back to this dataset. The component catalog is an XML database containing interface definitions and filenames of available geometry components. The generated assembly is also returned as a CATIA part document in native CATIA format (CATPart). The definition of component types and components in the component catalog resembles techniques known from object-oriented programming languages:

- Component type definitions.

Component types are used to define standardized interfaces for components and hence allow any component in an assembly to be exchanged by components of the same type. They correspond to abstract base classes in object-oriented programming.

- Parametric geometric components.

Components serve as a framework for the interface definition and the creation or instantiation of CAD geometries using the component templates or script components described in the previous section. Each component is assigned to a component type, thus inheriting all parameter and sub-component definitions from this component type, corresponding to classes derived from abstract base classes in object-oriented programming.

A component catalog containing component type definitions and a set of basic components intended for the creation of rotorcraft geometries suited for preliminary design analyses has been created in the project RIDE. The generated components focus on the generation of conventional and tandem helicopter fuselage geometries, but also contain simple templates suited for the creation of stabilizer surface, rotor blade and wing geometries. Figure 3 shows example geometries generated using components from the RIDE component catalog.

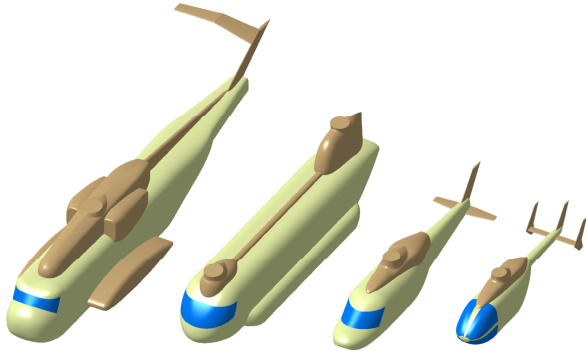


Figure 3: Example geometries generated using GEOGEN and the RIDE component catalog

The RIDE component catalog contains definitions for the following component types. The numbers indicate the number of currently available components:

- Fuselage (1)
 - FuselageFront (3)
 - FuselageMid (2)
 - FuselageRear (2)
 - Tail (2)
 - RearCap (3),
 - FuselageAttachment (3)
(e.g. engine cowlings, sponsons)
- RotorBlade (1)
- Wing (1)
- Profile2D (5)
- Point (6)

Figure 4 depicts an example fuselage assembly generated using components from the RIDE component catalog and its subcomponents.

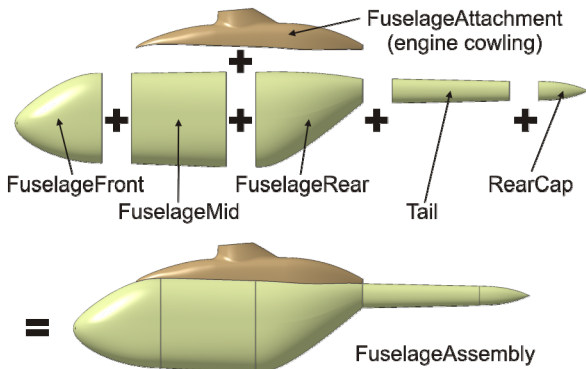


Figure 4: Example of a fuselage assembly using components from the RIDE component catalog

GEOGEN includes an option to check whether the generated assembly satisfies geometric boundary conditions usually coming from the requirements definition. The boundaries are specified by CPACS fuselage definitions in the input dataset. Two boundaries can currently be specified (Figure 5):

- An *inner volume* along with a minimum margin, used for specification of the required cabin volume.
- An *outer volume* along with a maximum margin, used for specification of the maximal outer dimensions.

If a boundary check fails, GEOGEN returns a predefined exit code without exporting the geometry to the CPACS dataset.

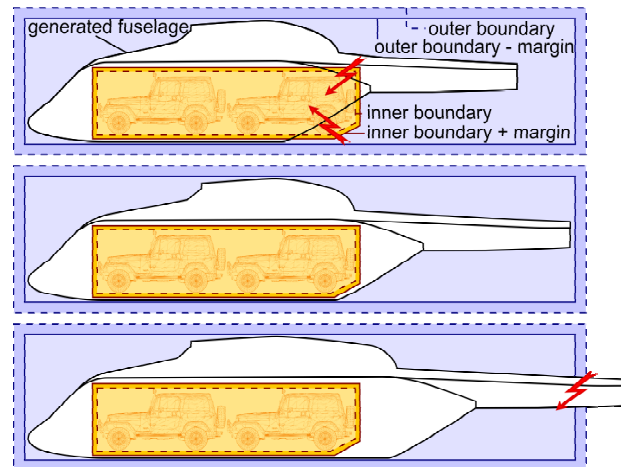


Figure 5: Boundary checks. Top: Inner boundary fails; Middle: OK; Bottom: Outer boundary check fails

2.4. Aerodynamics

The overall flight performance prediction of helicopters using the flight mechanics code HOST (section 2.7) relies on aerodynamic performance maps for isolated components (fuselages, tail surfaces, wings). In the RIDE toolbox several modules of multiple fidelity levels have been developed for the evaluation of the aerodynamic performance of isolated fuselages. This paper focuses on the module AEROFUSE, as it is the only module, which considers the effect of the local fuselage shape on the aerodynamic performance.

The module AEROFUSE generates aerodynamic performance maps of isolated fuselages. AEROFUSE is based on VSAERO^[14], a commercial linearized 3D panel code with coupled viscous boundary layer calculations, and a subsequent simple procedure for estimation of the pressure drag caused by separated flow. This additional procedure plays a

significant role in the aerodynamic design of the helicopter. Helicopter fuselage design is often driven by operational and functional considerations, while the aerodynamic efficiency only plays a secondary role. This leads to bluff fuselage shapes, whose flowfield is typically dominated by a region with separated flow at the aft of the fuselage, even in the cruise design point. Hence the drag component caused by separated flow cannot be neglected when considering helicopter fuselage drag. Potential codes do not account for the viscous pressure drag caused by separation when only using body surface panels. Using VSAERO, the effects of flow separation are usually modeled by manual definition of wake panels shedding at the separation line. But tests showed that this procedure cannot be easily automated and lacks robustness. Thus a simpler, more robust method for the estimation of viscous drag has been implemented in the postprocessing tool PLTCONVERT using the surface pressure and boundary layer data output by VSAERO. This method is based on the assumption of constant pressure in areas of separated flow. The assumed value for the pressure coefficient in these areas can either be set by the user or determined automatically. In the latter case it is derived by calculating the mean pressure coefficient on the separation line predicted by VSAERO's boundary layer code. The effect of the viscous pressure drag on the global force coefficients is then calculated by summing the pressure force differences due to the corrected pressure coefficient on all panels where separated flow is predicted by VSAERO.

Additional drag components, e.g. parasite drag due to attachments (such as antennas, landing gears or skids), surface imperfections or gaps can be evaluated using the existing fixed-wing analysis module HandbookAero. It enables the user to easily select predefined methods for the estimation of additional drag components (parasite, interference) using approaches found in well-known aircraft and rotorcraft design literature or based on experimental results for basic shapes, e.g.^[7].

A database containing geometry and aerodynamic characteristics of common rotor blade airfoils has been set up. The database can be accessed in the process chain using the analysis module AEROPOLE. It simply copies the data for selected airfoils from the database to the CPACS dataset. The functionality has been encapsulated into one tool to ensure consistency of the data in the CPACS dataset. Furthermore it prepares the process chain for the projected automatic evaluation of airfoil aerodynamic characteristics.

2.5. Improved Mass Statistics

The RIDE module MASERATI (Mass Estimation of Rotorcraft based on Statistics) calculates the rotorcraft masses based on equations which were developed by the evaluation of existing aircraft. Here the level of detail is low and currently limited to the weight of the complete respective group (e.g. body group, landing gear group or drive system).

Presently, four different methods for the calculation of the weights are implemented in MASERATI: Prouty^[17], Layton^[11], Beltramo^[2] and Palasis^[16]. The respective statistical equations were taken from the literature mentioned and are based on historical trends.

2.6. Structural Design

The structural analysis consists of two modules – Fdesign_rc (Fuselage Design RotorCraft) and ROFUMA (ROtorcraft FUselage Mass Assessment) – that are coupled and subsequently executed. Fdesign_rc distributes the frames and the longitudinal skin reinforcements (stringers) according to requested geometrical boundary conditions. It finishes with the generation of an updated CPACS file where the newly distributed frames and stringers are stored. This updated file is used by ROFUMA in a consecutive step to generate the geometry respectively the mesh and to conduct – according to the requested analysis type – either a static analysis or structural sizing against strength and stability.

Fdesign_rc and ROFUMA are written in the Python programming language. They can be run automatically without any user interaction. Thus, these tools can easily be integrated in the overall process chain. Recent work focused mainly on the development of Fdesign_rc.

These two structural modules will be explained in detail below.

2.6.1. Generation of Fuselage Structural Elements (Fdesign_rc)

Fdesign_rc reads the outer fuselage geometry from the CPACS file created by other tools preceding the structural modules. According to the definitions in the chosen design set it generates the frames and stringers as well as skin panel distribution (work on this sector is going on) and writes a new updated CPACS file for subsequent use.

In former versions of Fdesign_rc the frames were equally distributed along the fuselage length while the stringers were equally distributed along the circumference.

A new approach allows a much more detailed distribution of the frames and stringers. Therefore, it was necessary to modify the tool-specific node in the CPACS scheme.

Fdesign_rc uses so-called design sets. Several different design sets can be defined in CPACS while only one set at a time can be used to generate the airframe structure. Design sets can be defined (inside the XML interface) using the elements described below:

Master frames: In this XML-node frames are defined that have to be located at certain x-positions of the fuselage.

Master stringers: Master stringers are - analogue to the master frames – longitudinal reinforcements that have to be placed exactly according to their definition in this node. A master stringer is defined by regions between master frames and a corresponding z-position. This node is also used for the definition of the cabin floor.

Additional frame regions: A frame region is embedded by two master frames (which are defined in the master frame node). For each additional frame region a maximum frame pitch is defined. Fdesign_rc distributes the frames equally in the corresponding zone making sure that the maximum pitch is not exceeded.

Additional stringer regions: Between two master stringers a unique stringer distribution can be defined by entering a maximum stringer pitch.

Additional stringers: This node is used to place stringers that do not start at the first frame and end at the last one. It is possible to define a stringer in this node that runs – in contrast to the surrounding stringer pattern – between two frames. This node is particularly important for the definition of cut-outs.

Default frames: All regions of the fuselage that are not located inside an additional frame region are provided with frames according to this default frame definition. A maximum pitch for the frames is defined in this node.

Default stringers: Analogue to the default frame definition, all regions of the fuselage where no stringers are placed due to the definitions given above, are filled by stringers which are given a maximum pitch in this node.

Using this approach it is now possible to define a more detailed airframe. This in turn provides the ability to model details like cabin floor (and therefore adaptation of frame and stringer heights in the sub-floor area) and cut-outs like doors or windows.

A generic frame distribution is shown in Figure 6. Two additional frame regions are shown. The first region is located between master frame 1 (at

$x = 2.2$ m) and master frame 2 (at $x = 3.0$ m). The maximum frame pitch for this region was set to $\Delta x_{\max} = 0.4$ m. The second additional frame region is located between master frame 3 (at $x = 5.5$ m) and master frame 4 (at $x = 8.5$ m) with a maximum frame pitch of $\Delta x_{\max} = 1.0$ m. Outside of these two regions the frames are distributed according to the default frame definition with a maximum frame pitch of $\Delta x_{\max} = 0.2$ m.

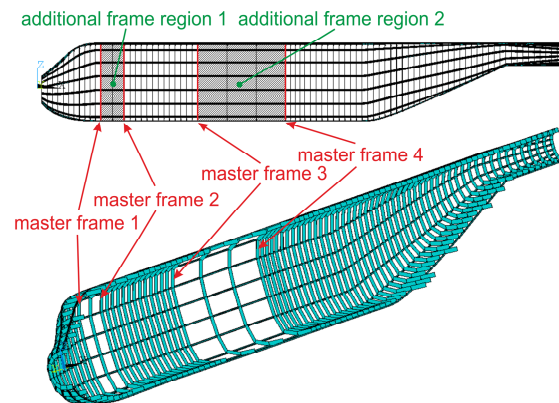


Figure 6: Generic frame distribution with new design set definition

2.6.2. ROFUMA (ROtorcraft FUselage Mass Assessment):

ROFUMA itself consists of three different parts. In the first stage a Finite Element (FE) model is generated by the use of ANSYS Parametric Design Language (APDL) and the preprocessor /prep7 according to the structural definition in the CPACS file. Additionally, non-structural masses (systems, payload, seats, passengers etc.) and external loads (main rotor load, tail rotor load) are applied to the model. These loads are applied on single nodes and distributed to a rigid region (defined in the CPACS file) by the use of rigid body elements (RBE3). Gravity can be taken into account.

In a second step static analyses are conducted to evaluate the structural response due to the selected load cases.

The third step, which is currently being integrated, comprises structural sizing. For this step the module S-BOT+ (Sizing roBOT+)^[18] has been chosen to be extended for rotorcraft applications.

A generic FE model in which additional masses like undercarriage, rotors and payload are constrained to the fuselage is shown in figure 7 (note that for visibility reasons the fuselage skin has been removed).

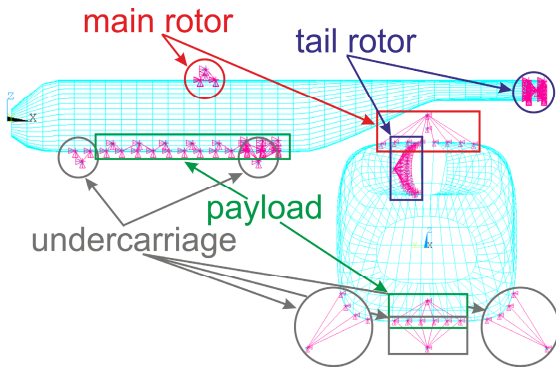


Figure 7: Generic FE model with constraints (additional masses) in front- and sideview

Recently composite materials have been added to the ROFUMA module to allow for structural analysis of composite materials.

ROFUMA uses ANSYS version 14.5 which resulted in a significant reduction of the time spent on model generation compared to former ANSYS versions.

2.7. Flight Mechanics Evaluation

The flight-dynamic modelling and simulation forms the core of the preliminary design process as all data generated by the preceding tools are eventually processed into the simulation of the rotorcraft. The simulation therefore serves as the central analysis tool for the design process. HOST (Helicopter Overall Simulation Tool) is a FORTRAN-77-based software developed in 1994 by the aerodynamic department of Eurocopter France. HOST is an integration structure for all the existing and future helicopter simulation tools modelling the mechanics of the flight of the helicopter and its dynamic behaviour in flight or on the ground^[3]. Since its introduction HOST was continuously extended with new models and new functionalities (flight control systems, dynamic engine models, additional rotor-induced velocity models, etc.).

The dataset structure of HOST is modular with the main configuration file to link all the functionalities and dependencies among the mostly physics-based helicopter modules (figure 8).

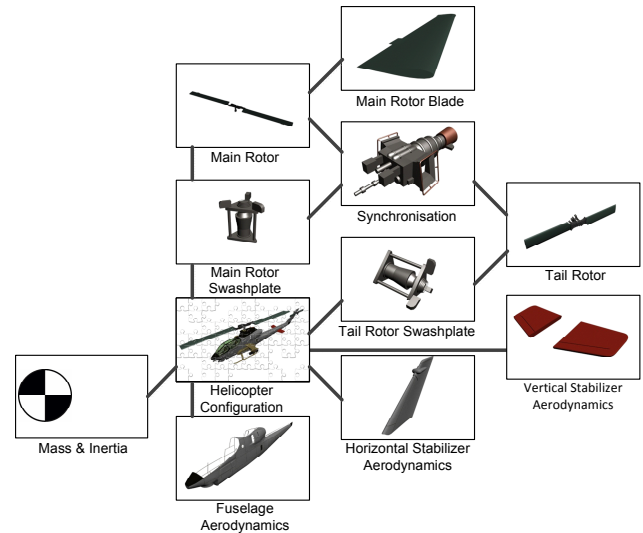


Figure 8: Setup of HOST input files for a dataset representing a conventional helicopter configuration

The depth of the modelling of the rotor system is variable (actuator disc, blade element method, rigid or soft blades). It is necessary for the complete integration to transfer the data from CPACS into HOST input files, to enable an automated HOST execution and to process the obtained data inside the design framework. The automated generation of a complete HOST input dataset based on the CPACS input is performed by supplementary routines written in the Python programming language.

In order to be able to design tandem rotor configurations, an estimation of the rotor-rotor-interaction based on the approximation given by Harris^[6] was included into the HOST simulations. Figure 9 shows that the approximation gives satisfactory results in comparison with CH-47 flight manual data.

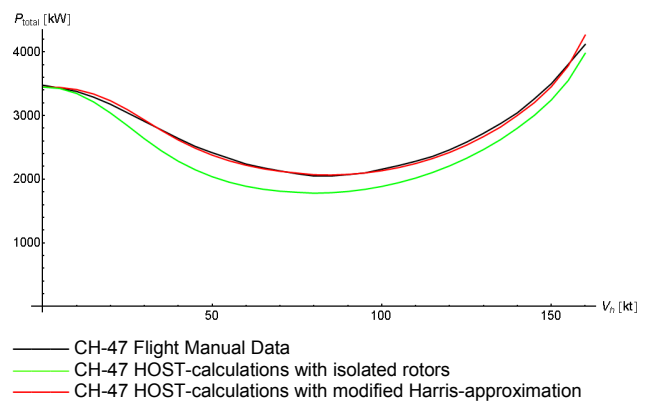


Figure 9: Total power dependent on forward speed for HOST-calculations with and without rotor-rotor-interaction compared to flight manual data

For any helicopter with two main rotors the rotor controls have to be reduced to four or five pilot inputs in order to model them in HOST and apply the same equilibrium law as in the conventional case. Therefore the rotor controls are determined from the pilot inputs using a mixing unit inside the HOST simulation.

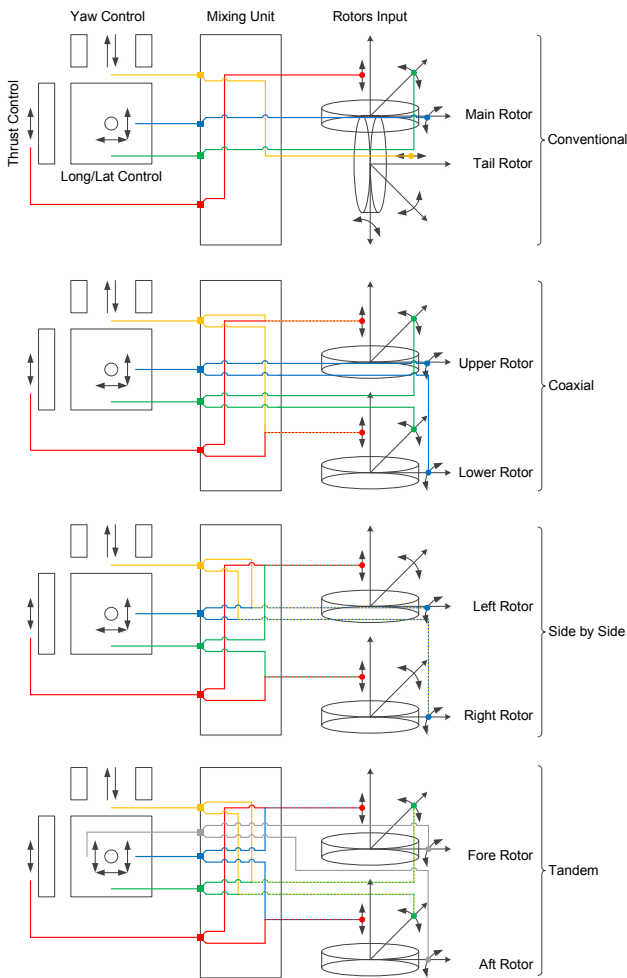


Figure 10: Transformation of the rotor controls to pilot inputs for different configurations

3. RESULTS OF A FIRST PRE-DESIGN STUDY

To ensure the plausibility of the results the toolchain has been tested with a configuration very similar to the well-known MBB Bo-105 helicopter. Figure 11 shows the fuselage geometry components of the configuration.

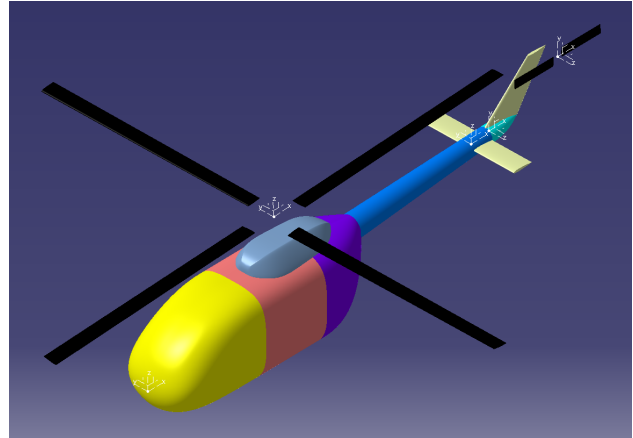


Figure 11: Bo-105-like configuration used as a test case

The results obtained by using the toolbox compare well to the real-world Bo-105 equivalents^[15]. The mass estimation algorithm calculates an empty weight of 1475 kg, which is slightly overestimated compared to the actual empty weight of the Bo-105 ranging from 1277 kg to 1374 kg depending on the version. The fuselage aerodynamics including transition and separation are estimated satisfactorily. Figure 12 shows a typical pressure distribution for the chosen fuselage geometry. The HOST simulation code, incorporating the results of all tools, gives an overall power requirement of 636 kW for the forward flight at maximum cruising speed (130 kts), which compares well with the engine rating of the Bo-105 (2x298 kW maximum continuous power), especially considering the overestimated mass properties.

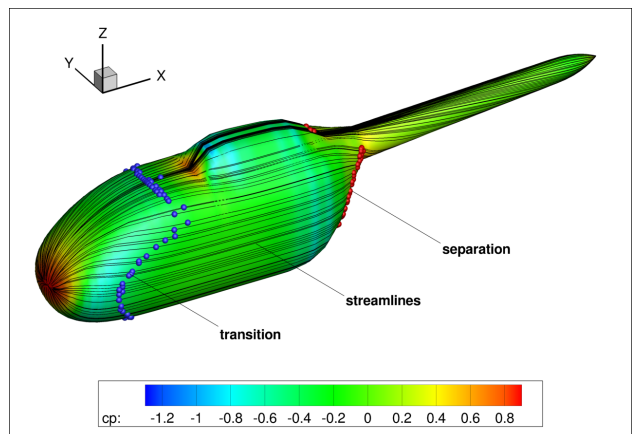


Figure 12: Estimation of fuselage aerodynamics for the Bo-105-like configuration

The described toolbox can be used to evaluate the effects of certain design decisions on the performance of the helicopter. Thus, starting from the Bo-105-like configuration described above the effects of

a fuselage enlargement have been studied. The easiest way from a design perspective to enlarge the fuselage volume is to extend the fuselage rear end towards the tail rotor and to shorten the tail boom simultaneously. For demonstration purposes the helicopter rotor dimensions and positions as well as height and width have been chosen constant within the design study. Figure 13 shows the geometries used in this study resulting from the variation of the length of the rear fuselage segment from 1300 mm to 3800 mm in steps of 500 mm.

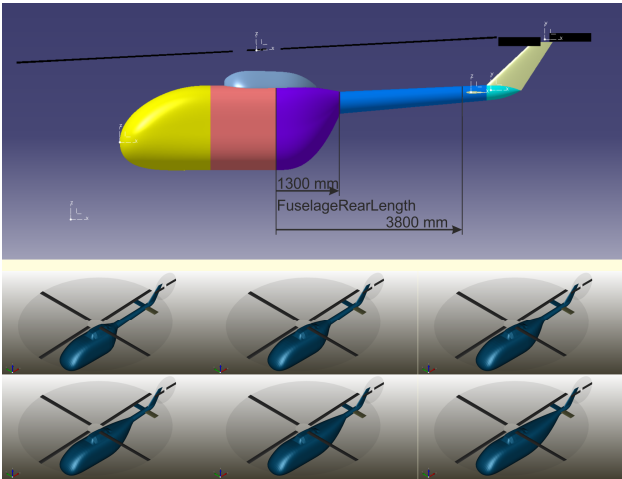


Figure 13: Resulting geometries of a pre-design study with respect to fuselage enlargement

The mass estimation algorithm gives a constantly increasing empty weight ranging from 1475 kg to 1572 kg with increasing fuselage volume (see figure 14). The results of the fuselage drag estimation (figure 15) show a rapidly decreasing pressure drag with increasing length as the form of the fuselage becomes more streamlined. The trend of the predicted viscous drag component also seems plausible. Its constant increase corresponds to the increase of the ratio of the wetted surface to the frontal area. Finally, the power estimation of the HOST simulation tool (calculated for a maximum cruise speed of 130 kts) shows reasonable trends (figure 16). The parasite drag power corresponds well to the predicted total fuselage drag. The induced power is nearly constant with only a slight increase due to the relatively small increase in empty weight. The shape of the profile power curve can be explained with varying momentum coefficients and pitch angles.

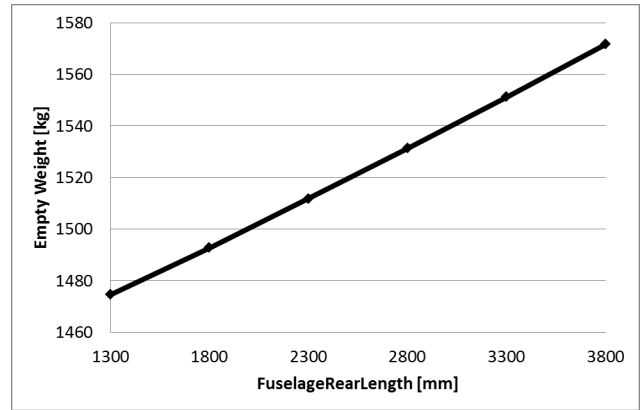


Figure 14: Pre-design study: weight estimation

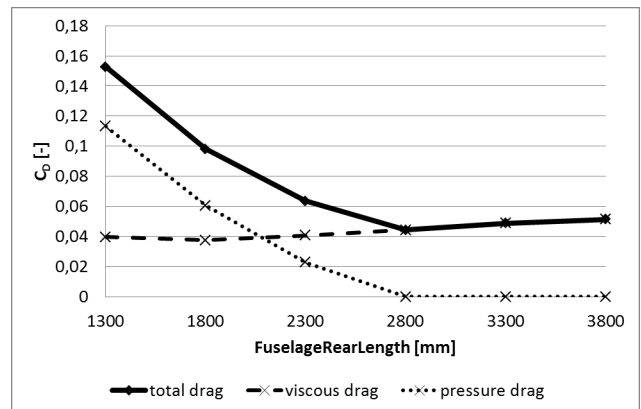


Figure 15: Pre-design study: fuselage drag estimation

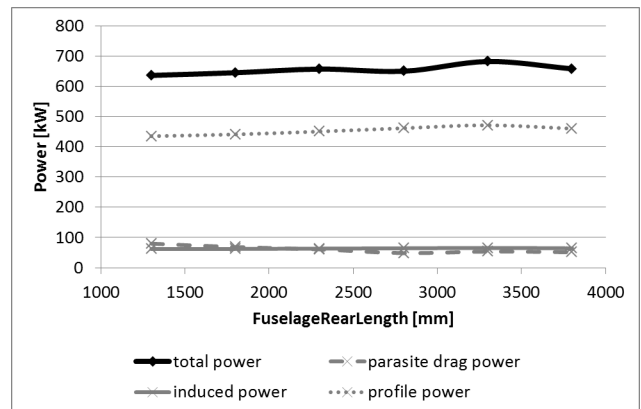


Figure 16: Pre-design study: power estimation

4. STATUS AND OUTLOOK

In the course of the DLR project RIDE a truly integrated design environment for transport helicopters has been developed. A three-dimensional geometry and detailed structural design solution accompanied by profound data on flight performance calculated by HOST are determined starting from very few customer specifications. The RIDE toolbox allows the analysis of conventional configurations as well as a simplified modelling of tandem rotor arrangements. The use of CPACS as a common interface for all modules has proven to be successful. Thus, the definition of individual interfaces between interacting modules is not necessary, ensuring maximum flexibility regarding the process chain. Additionally, intermediate results are easily accessible and can be examined as all data generated by any module at a certain stage of the process are present in the CPACS data set exchanged between the tools. The process chain has been implemented in ModelCenter and is fully functional. One single calculation of the whole chain is executed in well under five minutes on a standard PC, which should be sufficient for a preliminary design study.

The current DLR project EDEN will further improve the toolbox with a strong focus on the modelling and design of novel rotorcraft configurations. This includes the extension of the geometry generation module to be able to automatically generate additional components like pylons, wings, etc. The generation of different fuselages for multi-rotor configurations is another work package. Regarding the structure generation future work will be spent on the generation of further geometries like cabin floor, cut-outs and variable profile geometries for the frames and stringers. Another focus lies on the generation of external geometries like additional lift generating devices (wings) to account for unconventional helicopter designs. Therefore, much work will be spent on different model ranges where the stringer distribution will differ significantly between different regions (e.g., the tail rotor segment that features less stringers than the cabin segment). As crashworthiness aspects are of particular interest in helicopter design, the CPACS-based tool AC-CRASH (AirCraft Crash)^[19],^[20] will be extended by integrating rotorcraft structures. This step will enable automated crash analyses by the use of the explicit FE solver PAM-CRASH^[24]. Finally the various configurations have to be converted into a HOST dataset.

Concerning the whole process chain an iterative optimisation procedure has to be introduced as currently the only sizing task is done using the relatively simple model in the conceptual design phase. However, in order to further improve the design result all modules have to be integrated in a global sizing loop.

Another main task of the EDEN project is the development of simple models for the interaction of different components of the rotorcraft (e.g. between rotors, between rotor and wings, between rotor and propellers, etc.). This is a crucial part of rotorcraft performance estimation, especially with respect to novel configurations. The aim is to develop models that are suitable for the use in a pre-design environment in terms of accuracy as well as complexity and calculation time, respectively.

5. REFERENCES

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