A FEATURE-BASED APPROACH FOR AN AUTOMATED SIMPLIFICATION OF STRUCTURAL AERO ENGINE COMPONENTS

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The developed approach introduces logical and geometric reasoning based on CAD analysis as a starting point for the transfer of a geometry to a suitable and simplified analysis model. In the presented case, the approach is shaped towards aero engine casings but the fundamental idea can be transferred to other types of structures. The geometric reasoning is built upon information and data concerning substructures of the component which have been decomposed by using feature information from the CAD model and analyzed regarding certain criteria. Based on this evaluation, the process provides potential simplifications and modelling variants and selects a suitable one according to experience-based values. These representations are automatically created and assembled to the simplified model. All the collected information is stored in a database which serves as input for a well-funded set-up of the properties of the associated Finite-Element (FE) entities. Finally, a validation and performance evaluation of the presented process is done on an exemplary application model. Associating the geometric information with the FE entities, thus the simulation results, also provides opportunities for a more sophisticated geometry-based post-processing at the same time.

ABBREVIATIONS

API	*Application Programming Interface*
CAD	*Computer-Aided Design*
CAE	*Computer-Aided Engineering*
CoG	*Center Of Gravity*
DOF	*Degree(s) Of Freedom*
FE	*Finite-Element*
MAC	*Modal-Assurance-Criterion*
MAS	*Medial Axis Structure*
HPTC	*High-Pressure Turbine Casing*

1 INTRODUCTION

There is a high necessity for an effort reduction during the creation and simulation of models for structural analyses. Simplifications of various types are often introduced to decrease computational complexity, thus calculation times, in order to be able to respond quickly to design suggestions and iterations. Especially in early design phases, the design is likely to be changed more frequently, which in turn requires a frequent set-up of adequate simulation models. This involves often an undesired amount of manual effort, tedious parameter guessing and tuning as well as final validation steps. In the current state, most of these simplifications tasks are done manually by engineers making the selected design decisions based on experience and model understanding. Consequently, the objective to automate this procedure involves mimicking the engineer’s logic and reasoning and the implementation of the resulting manual steps in order to improve process efficiency. For this reason, the fundamental focus of the presented work is to establish and convert this kind of knowledge and reasoning in computer language for this process. Achieving a general approach, however, is not possible, not robust enough or does not lead to desired results. In this regard, this process benefits from results of a prior recogni-

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tion framework that identifies and categorizes structures and boundary conditions within an assembly. The presented process can focus on specific component categories, adapt and optimize its algorithms for these part types, hence increasing both abilities and robustness. In the presented case, the process for identified aero engine casings is presented with them inheriting an attractive simplification potential due to their commonly thin-walled structure.

2 STATE OF THE ART

The topics of Computation-Aided-Design (CAD) geometry simplification, complexity reduction and dimensional Finite-Element (FE) reduction for deriving a simulation model have been in the focus of multiple researches. One approach to reach this target has been to investigate the use of parametric CAD/CAE models for an overall model integration for simulation purposes. Gujarathi et al. describe a CAD-CAE integration method using a common data model (CDM) which contains all information for CAD modelling and CAE analysis in [1] and [2]. A parametric CAD mid-plane model is associated to the CDM data and thus integrated in the full-featured CAD model. Lee et al. present in [3] a similar approach which makes use of a master model which contains model information for both CAD and CAE environments. In case of design changes, the master model is modified which implies an adaption of the integrated submodels. Another work, [4], introduces an intermediate model concept which sets up a connection between modelling and analysis context to increase the efficiency of analysis model preparation. Later, Hamri et al. investigate methods, models and tools for a CAD-CAE integration [5]. In this work, the objective of a robust link between CAD and CAE environments is tackled by implementation of a higher-level topology descriptor and mixed shape representation methods. [6] further describes an approach to link FE meshes created on abstracted geometry to their original model. Creating integrated models however appears to be dependent on parameterization and its complexity is proportional to the CAD detail level, thus requiring a consistent and tedious set-up.

Other research works directly pursue the main target of simplifying CAD components regarding FE analyses. The most common technique in the following works is the reduction of thin-walled 3D structures to 2D FE-Shell elements. The work [7] investigates different methods for this model preparation and applies the medial axis transformation (MAT) [8] for the simplification of 2D and 3D aero engine casing structures and Wang et al. and Yong et al. [9] [10] [11] further showcase the approach for structural aero engine optimizations. Dey et al. present an approximation of the medial axis for CAD models while ensuring convergence to cope with the bottleneck of 3D medial axis calculation in [12] and [13]. Regarding this issue, also studies involving potential multi-CPU processing have been conducted by Zhu et al. [14].

However, this approach appears to have drawbacks like computational costs for the 3D application. Especially in complex models, this approach can lead to coarse and comparably messy geometry, implying a negative impact on mesh quality and thus, simulation results.

Moreover, a complete geometry transfer to a 2D shell element is not leading to acceptable and physically reasonable results in some cases. For this reason, Robinson, Nolan and Armstrong et al. published researches on methods to identify thin regions which are suitable for 2D FE representations in [15], [16], [17]. In order to identify thin regions, a face-pairing approach is presented which yields the desired regions. Another approach is based on fitting ellipsoids to identifying thin and other types of areas [18]. Due to the segmenting, the mixed dimensional coupling is another topic being investigated in these papers. Nolan et al. [19] [20] introduce the simulation intent, a concept with the ability to define additional decisions to the progress from CAD to simulation model, e.g. boundary conditions. This approach targets a fit-for-purpose conversion of analysis models and a better connection between simulation studies and geometry.

The more complex a structure gets, the more complicated and extensive is the identification of thin-walled regions or other segments of interest and the subsequent transfer to an appropriate analysis representation. This step of decomposing a geometry model can entail benefits for various purposes, thus various approaches to achieve this have been investigated. Sun et al. and Chong et al., [21] [22] [23], describe methods to decompose geometry into smaller subparts and regions based on face pair information and manipulation. Boussuge and Tierney et al. [24] [25] put the focus on geometry symmetry for model segmentation. Another approach is presented in [18] which makes use of an ellipsoidal object to analyze the geometry. Topological analyses and approaches for a model segmentation are used in researches by Tierney, Lee and Wong et al. [26] [27] [28].

This decomposition can help segmenting a given CAD geometry into minor subparts and therewith introduce another possibility of model simplification: neglect minor structures. This decomposition and defeaturing step is addressed by researchers in [29], [30], [31], [32], [33] and [34]. The approaches described in these vary from topological aspects, mesh-based approaches to software related feature information exploitation.

Boussuge et al. are combining both aspects of geometry decomposition and thin-region analysis from prior researches in the works [35], [36] and [37]. In this approach, the CAD model is decomposed by exploiting topological information. Thereof, each substructure is analyzed afterwards using a medial axis approach. Using information from the derived extrusion body, the medial axis is applied to a two-dimensional section which is used for the three-dimensional shell structure by applying the extracted extrusion information afterwards.

Nevertheless, the decomposition effort and difficulty is directly dependent on the complexity of the structure. The fundamental condition of clear boundary contours as e.g. edges must not be given in these components which is necessary for topological approaches. Moreover, a decomposition of complex parts would lead to a larger number of small subparts in many cases which would imply a loss of feature associativity and thus context. Apart from that, not all substructures are suited to be represented as a 2D shell while maintaining a suitable detail level.

3 COMPONENT TRANSFER

3.1 Process overview

The described process benefits from a recognition framework developed in a prior research which recognizes and categorizes aero engine components. Based on the category information, the following process paths can be adapted and optimized specifically for each category. Casing structures come along with a significant potential for reducing computational complexity while maintaining a satisfactory result quality level. In the context of aero engines, a multitude of components has a thin-walled geometry in common and thus inherits an attractive simplification potential. For this reason, the developed approach is presented on identified aero engine casings.

Especially in preliminary design phases, parametric models provide advantages for design studies and optimizations [38]. These are often feature-based CAD parts where geometric modifications can be introduced via accessible model parameter.

Another aspect of feature-based models is that the construction history is accessible and in this regard provides additional data which would be lost otherwise. The approach of this research makes use of all available data and knowledge, as for example the relations of geometric entities such as feature-related faces, edges, the topology of sub-volumes and the relations between those, in order to reconstruct engineering logic and way of thoughts and to exploit that information. Evaluating this information builds the basis for decomposing the present model into meaningful subparts and thereof, build a substructure network, see section 3.2.

By means of several evaluation metrics these substructures are analyzed and categorized afterwards, see section 3.3. The identified category defines and guides the further process and thus the representation in the simulation model, section 3.4. This FE model is set-up on basis of the geometric information extracted in the previous steps which supports the generation of geometrically funded FE properties, section 3.5. In the last section, the approach is applied on exemplary application cases and the simulation results are put into comparison with fully-featured 3D representations.

3.2 Model decomposition

Feature-based models inherit construction history within the feature tree associated with the present part. Model decomposition is a difficult task and retrieving meaningful substructures is required to understand and transfer a component. The features in the model can substantially promote the understanding of the model, thus support a suitable geometry segmentation. This advantage depicts, however, also a potential bottleneck due to the dependency on a given construction history. Other approaches as described in the state-of-the-art chapter are not leading to desired results in many cases either. Since this work is targeting preliminary design phases involving parametric models, the existence of structured features can be taken for granted.

This feature tree is accessed using the Application Programming Interface (API) of the commercial software Siemens NX. The retrieved feature information is used to rebuild a data base similar to a constructive solid geometry (CSG) tree.

In order to convert the given feature information to a basis for substructure segmentation, an algorithm has been developed. This algorithm takes each component modification as a state and compares it to the next step in the history tree. Each modification is associated with the features, the related entities and the effect on its volume. Multiple branches of the feature tree are connected via boolean operations, thus depict a branching point in the descriptive tree. An exemplary and schematic feature tree including representative feature volume (as size) is shown in Figure 1.

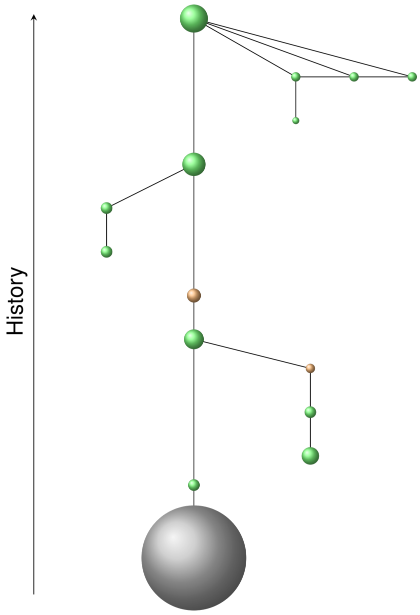


Figure 1 *Schematic feature tree*

The collected modifications are intersected with the final state afterwards in order to derive the exact boundaries and bodies. This results in an ordered data base of feature information associated with changes in volume and topology. Using this knowledge, the present CAD model is decomposed to substructures which serve as starting point for the identification and categorization in the next section.

3.3 Substructure categorization

After the geometry has been decomposed into subparts, the next step is to identify patterns and similar structures. On the one hand, this can improve the performance since only one representative of each group has to be evaluated. On the other hand, this serves the purpose of extracting additional model information and understanding.

One tool for embedding logics from the manual process and human cognition is the mathematical construct of a bounding box. For the application case of this research, casing structures, a cylindrical bounding box implementation has been developed to adapt to their quasi-axisymmetric nature. The engine center axis, volume information, bounding box orientation and dimensions as well as interface information build the basis for clustering and grouping the decomposed substructures. This process is shown on the exemplary application case of a high-pressure turbine casing (HPTC) depicted in Figure 2. Figure 3 shows the result of the model decomposition where the resulting substructures are displayed in colors.

Figure 2 *HPTC model*

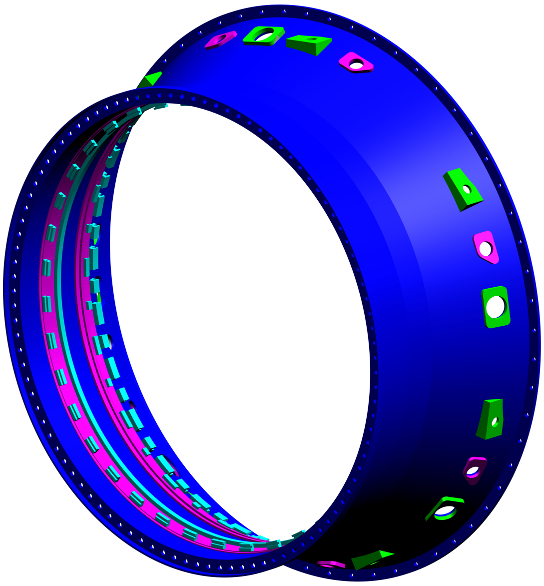


Figure 3 *Decomposed HPTC model*

After grouping the substructures, a network construct is set-up using the substructure groups and their interface information. The network extracted from the HPTC segmentation is shown in Figure 4. This already contains information regarding potential categories what will be described in the next sections.

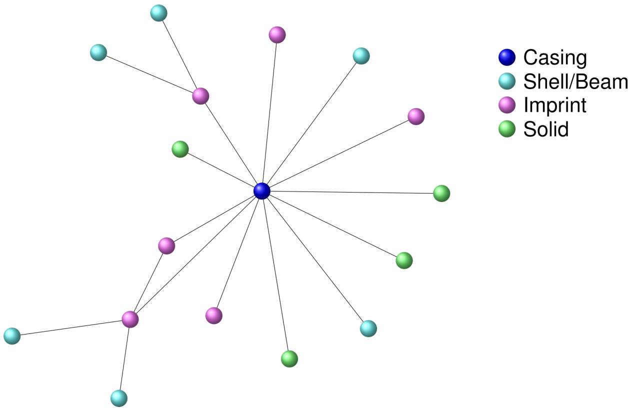


Figure 4 *Substructure network of the HPTC*

These interfaces between substructures derived from the network provide information about their effect on major load paths, thus structural influence. Apart from the interface information, several metrics are introduced to gather the required knowledge about the structure. These metrics are stored in a feature vector which is used for the analysis, see Table 1.

Table 1 *Structure feature vector*

Feature vector
Volume
Volume share
Neighbors
Casing neighbors
Hierarchical position
Number of bodies
Approximated height
CoG distance
Bounding box ratios
Midsurface-structure
Wall-thickness
Shell volume deviation
Beam-structure
Beam volume deviation

The volume and its share on the overall volume and the number of substructures in the associated substructure group depict the most fundamental parameter. The number and type of interfaces and their related dimensions as well as the number of neighboring structures form the assembly and load-path related part in the vector. The last parameter go into detail concerning body representations. The first aspect guiding substructure categorization are the dimensions and ratios which are derived from a best-fitting bounding box. Based on the volume and interface area, an approximated structure height can be calculated. This is put into contrast to the average distance of the center of gravity (CoG) of the structure to the interfaces.

The face-pair approach to derive component midsurfaces is not sufficiently robust nor does it provide feedback to its suitability especially in complex structures. A benefit of the presented approach is that the component is decomposed to smaller parts which are easier to analyze, thus a better target for the face-pair algorithm. Seen from another perspective, not every subpart allows a reasonable conversion to a shell representation. In this regard, the face-pairing result is investigated to distinguish if the resulting structure is appropriate or too complex for a simple shell representation. In case of a positive feedback, the maximum thickness of the face pairs is extracted and stored in the feature vector. The last shell related entry is the relative volume difference between the shell and the 3D structure.

The next entries are related to beam-defining properties. Structural characteristics of minor structures which share a beam-like topology can be surrogated by FE beam elements which reconstruct the stiffness and mass properties in these areas. For this reason, the bounding box properties are used for their identification and to find a proper cross-section. The resulting beam volume deviation from the original volume is the last parameter in the vector.

The aim of this approach is to embed engineering knowledge with the aim to mimic the engineers' way of thinking. Consequently, two different types of identification can be derived: the identification of reasonable modelling techniques for the present substructure and aero-engine related information concerning the substructure type. For example major casing structures are extracted using volume and bounding box information along with their quasi-axisymmetric nature. Combining the present information reveals structural vanes and struts connecting casings from outer and inner gas path sides if present. All this information can be fed to the network and update it with the information of major casing entities to extend the data base and model knowledge.

In the scope of this work, the focus is set on identifying appropriate model representations for each substructure.

3.4 Substructure representation

For each of the described categories, multiple level of detail representations can be chosen. The feature vector and the substructure evaluation in the previous steps predefine a set of possible modelling techniques. At the current state, experience values guide this selection of appropriate modelling techniques.

3.4.1 Medial Axis

One of the major intents of this approach is to transfer suitable structures to 2D shell representations. Especially larger substructures require a sophisticated approach to derive an appropriate and reasonable midsurface.

As already mentioned in previous sections, the face-pair approach is not guaranteed to lead to desired results in many of these cases. Moreover, one critical aspect is that a complex and messy midsurface has a negative impact on computational complexity which is not desired while aiming for a reduction. For this reason, a medial axis approach combined with additional logics has been developed in the scope of this work.

First, a proper section of the target substructure is extracted which serves as 2D input for the process. Another information which is derived from the component is about assembly and substructure interfaces. One of the critical aspects is that boundary conditions and the major load paths are represented in a proper way in the reduced model. Furthermore, the information about the interfaces has to be maintained even in the reduced model, so the final interfaces have to be mapped to the original ones.

From this starting point, a Delaunay triangulation is executed on the 2D polygon section. The Voronoi diagram can be derived from the Delaunay data including inscribed circle information which in this context describes the wall-thickness. Using a depth-first-search algorithm [39], the Voronoi edges can be combined to a preliminary medial axis structure (MAS) involving branches and branching points. The next step is to filter minor branches by analyzing length and thickness trend in order to remove neglectable complexity. To reduce the number of points and smoothen the branches, the Ramer-Douglas-Peucker (RDP) algorithm [40] is applied to the remaining segments.

Afterwards, the interface information is put into focus by matching and pairing interfaces with branch segments from the MAS. The pairing involves that these segments are of major importance for the load transfer. Due to this they are then adapted to the original interfaces to maintain boundary condition consistency. The process allows different types of adaptions depending on the interface type and settings, as for example ensuring parallelism, coincidence or further process-specific modifications.

This information is added to the MAS. On basis of branch interface information and branch properties, the main branches are separated from minor ones. This step is implemented to avoid minor geometric structures distorting the main path, thus increasing undesired complexity. Consequently, an iterative smoothening algorithm has been developed based on the fundamental RDP logic, see Algorithm 1. This method takes the locally present wall-thickness into account for the simplification.

Algorithm 1 *IterativeSmoothening*

```
$P \leftarrow \{ Points \in Branch \}$
$finalSegments \leftarrow \{\}$
while $P \neq \emptyset$ do
    $p_1 \in P$
    $P \leftarrow P \setminus \{p_1\}$
    $segmentPoints \leftarrow \{p_1\}$
    for $p_2 \in P$ do
        $segment \leftarrow \overleftrightarrow{p_1 p_2}$
        $d \leftarrow \{ (distance(x, segment), thickness(x)) \forall x \in segmentPoints \}$
        if $(\nexists (d, t) \in distances \mid |d - t| > \varepsilon)$
            $segmentPoints \cup \{p_2\}$
        else
            $segment \leftarrow \overleftrightarrow{p_1 segmentPoints.Last}$
            $finalSegments \cup segment$
            $P \cap segmentPoints$
return $finalSegments$
```

Finally, the minor branches are connected to the main paths while ensuring consistency with the branch points to avoid small and sliver faces later in the 3D representation. Another possibility is to neglect specified minor branches and represent them as 1D FE beams using the branch buffered with its thickness to create a section for setting up beam properties.

The associated shell thicknesses for each branch segment are calculated by an implementation of an adaptive piecewise-constant approximation (APCA) [41] with defined tolerances for thickness detail level.

Finally, the generated data including the interface pair information is stored in a database for the access from Siemens NX. There, the branches are created as parametric lines within a sketch and subsequently revolved. To transfer holes from the original component to the new midsurface representation, a boolean intersection is temporarily used. This reveals potential holes which can be projected to the new shell model and if desired transferred. A tolerance parameter can be specified to neglect minor holes what is often the case in simplified structures. The original interfaces are then mapped to the new interfaces of the midsurface bodies using the MAS database. A summary of the medial axis process is given in Algorithm 2.

Algorithm 2 *MedialAxis*

```
Section creation from Siemens NX
Interface transfer to section
Delaunay triangulation → Voronoi diagram
Voronoi vertices → Thickness
DFS → Branches → Medial Axis Structure
Filter branches length and thickness trend
Branches → RDP
Match branch segments with interfaces
Adapt to interfaces
Combine main branches → minor branches
Connect minors to main
Extend branches to polygon boundary
APCA → Thickness interpolation
Export MA information with interface data
```

3.4.2 Shell

The next category for transfer is the shell category. This applies to substructures which have been identified as potential shell parts and less complex or substantial than these from the previous section.

The midsurface itself has already been created for the analysis and can be reused. The average thickness of the face-pairs is applied as property to the individual faces. The next step is to identify the interface edges because these have to be connected to the new midsurface body from section 3.4.1. Also in this context, the objective of a clean model is given. Consequently, an algorithm is searching for similar edges within a small proximity to create edge coincidence to avoid areas where meshing will fail or lead to increased element number or distorted elements. The offset that is created therewith can be of importance for the simulation, hence is extracted and stored in the associated shell face properties.

3.4.3 Beams

Some cases also allow a reasonable beam representation. This implies a dimensional reduction from 3D to 1D, thus even decreasing the computational complexity more. In this case, the required properties are the section as well as the curve for the beam element application in the FE environment. One approach to retrieve the curve is to project the cylindrical bounding box centerline onto the associated midsurface casing. However, in order to ensure boundary condition consistency, the interface edge derived from midsurfacing (section 3.4.2) is used if available. The section properties, principal axes and the beam offset related to the projected edge or curve are stored in the representation database for the use in FE model setup.

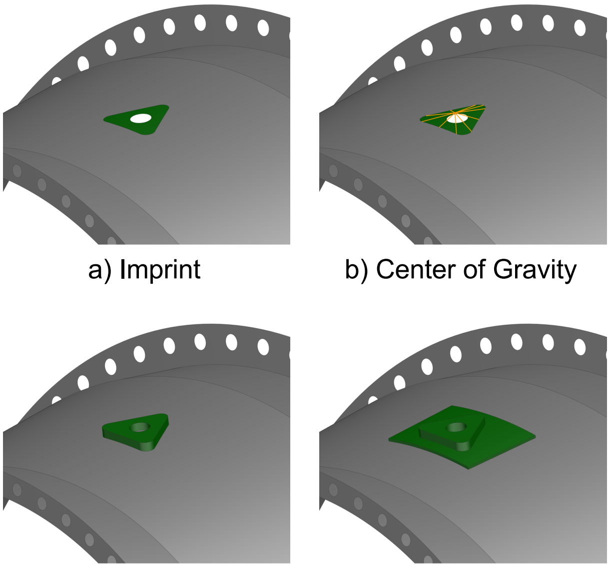
3.4.4 Solids

The last category is dedicated to the remaining substructures not suitable for 1D or 2D representations. The process allows several paths for the FE transfer of these structures depending on their properties. Thin and flat subparts have a comparably small additional effect on stiffness and mass properties in the related areas. A common approach to consider these structures is to project the substructure onto the casing midsurface and increase the thickness of the projected area by a certain value, see Figure 5a). To avoid undesired complexity, this process provides the possibility to project a bounding rectangle instead of a complex interface.

Another method is to reduce mass and inertia properties of the structure to a single point packed with this mass information. Afterwards, this point is connected to the casing surface via interpolating FE elements (e.g. RBE2/RBE3 in NX/MSC Nastran), see Figure 5b).

However, these types of representations are not able to reproduce the structural influence of more complex parts. For this purpose two additional modelling techniques have been introduced. In these methods, the structure is maintained as 3D volume. The “glueing” approach, Figure 5c), uses FE glueing methods to connect the subpart to the casing. The hybrid approach, Figure 5d), aims for considering also the structure base as 3D part and creates interface edges to the surrounding shell. The shell interface edges are designed perpendicular to the hybrid interface faces. In both cases, the database has to be extended by this interface information, either face-face or face-edge connection, in order to direct this knowledge to the FE environment for the application.

However, this automated cutting, splitting and preparation is not guaranteed to be applicable in every scenario. Another undesired result would be many hybrids close to each other and thus, leading to small instances which increase complexity. For this reason, a proximity algorithm based on bounding boxes is implemented that checks distances to other substructures or critical areas and decides if a hybridization is reasonable, similar to the human perception. Furthermore, it identifies close potential hybridization structures and combines them to a single solid to reduce complexity. An example is shown in the application later in section 3.6.


a) Imprint b) Center of Gravity

c) Glue d) Hybrid

Figure 5 *Solid representations*

3.5 FE model creation

As already mentioned in the previous chapter, much information about the model has to be directed to the FE environment. For this reason, a database is automatically set-up which containing every possible information concerning the FE representation, meshes and boundary conditions. This database is accessed by a subsequent separated process module which is responsible for the automated FE model generation, model preparation steps, meshing steps and simulation steps including boundary condition application. After the FE model has been set-up, the process outputs another database file containing the associations between the substructures, their feature vectors and the final FE element, node and property ranges. This fulfills the purpose to allow and motivate a more sophisticated post-processing of the simulation results with combining and associating geometric CAD information and simulation results.

3.6 Benchmark

At the end, this work presents exemplary results of the automated aero engine casing transfer process. The high-pressure turbine casing (HPTC) already discussed in section 3.2 is used as application case.

First, this component is meshed with 3D quadratic tetrahedral elements (CTETRA10) while ensuring at least two elements over thickness. The resulting FE model serves as reference for the study.

The next step involves the automated transfer of this structure to a suitable FE component by the described methods which is depicted in Figure 6. In this image, the physical properties serve as basis for a colorized visualization.

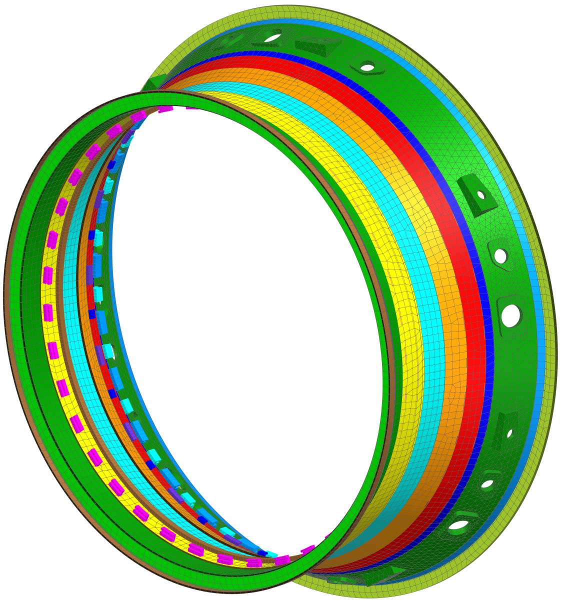


Figure 6 *Converted FE Model*

As already indicated in section 3.4.4, the process decides to build a complete 3D ring in this case including all bosses as solid subparts in order to avoid minor and small instances. The vane fixings are modelled as beams while casing thickenings are represented as an imprint. For the visualization, beams are displayed using the related section and the shell elements are visualized with their thickness and offset.

For validation reasons, a modal analysis is conducted to evaluate and compare the basic structural characteristics as for example eigenmodes and eigenfrequencies. The MAC criterion [42] is a popular method to put eigenmodes of two similar components into comparison. The MAC for the present case is shown in Figure 7. The major conclusion that can be drawn thereof is that the eigenmodes of both components are matching, hence are comparable. From this point, the eigenfrequencies are investigated next. Figure 8 depicts the associated relative eigenfrequency deviations compared to the reference.

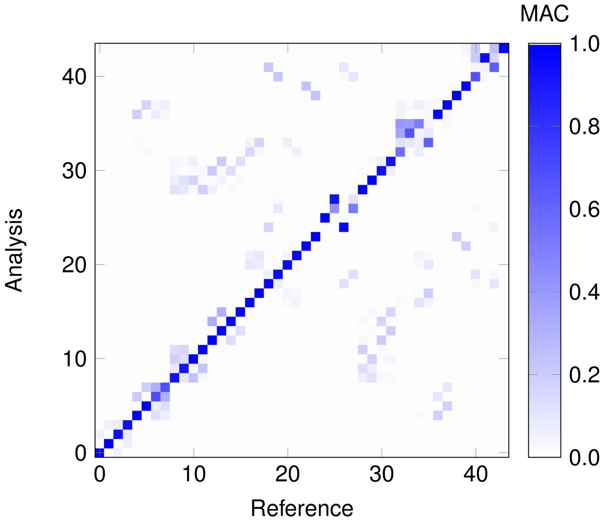


Figure 7 *MAC matrix*

Regarding these deviations relatively small differences can be observed. The absolute maximum deviation remains below 3% while the average deviation is -1.12%. This slightly more flexible behavior could be related to a different stiffness at shell connections due to the 2D element nature. However, it has to be kept in mind that simplifications generally are not expected to completely match the reference but rather pursue the target of simplifying while maintaining a satisfactory quality. In this regard, the result seems promising especially when the computational complexity is considered and is an important aspect.

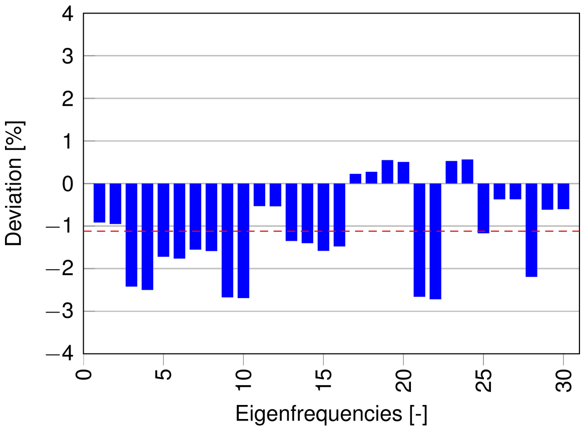


Figure 8 *Eigenfrequency deviations*

Figure 9 shows a comparison of the calculation time, the number of degrees of freedom (DOF), the result file size and the final volume of both models. The transfer and the simulation has been executed on an i5-6600K CPU with 16 GB Ram. As it can be derived from the chart, the computational complexity, the number of DOF as well as the result file size are significantly reduced by the presented approach. The simplified model shows a slightly higher volume what could be attributed to shell thickness overlapping effects and missing flange holes.

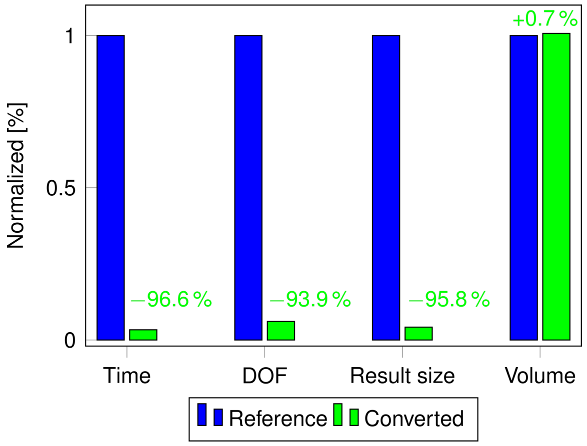


Figure 9 *Model comparison*

Finally, a performance evaluation of the automated transfer process is shown in Table 2.

Table 2 *Process performance*

Step	**Time [m:s]**
Feature tree	02:43
Substructure analysis	00:39
Medial axis	<00:01
Representations	00:43
Complete	04:05

Since most of the procedures take place in Siemens NX, a significant drawback is the limitation of the software to a single CPU core. Consequently, a multi-core implementation would imply a performance improvement opportunity. In the current process, this drawback has been mitigated and taken advantage of by developing a process structure which allows a parallel conversion of multiple components. For example on a 4-Core processor, the CAE transfer of four components will take as long as the conversion of the most complex component takes.

According to this performance evaluation, the feature tree set-up is taking the majority the time. However, the required duration is proportional to the amount of features used in the model, thus to model complexity. This time span is noticeably lower for simpler components what in turn matches the expectations.

4 CONCLUSION

In conclusion, the present work describes an approach that automates model simplification and CAE transfer by gathering as much geometric information as possible, mimicking engineering logics and directly accessing the information for FE model setup. In this approach, geometric reasoning combined with engineering experience guides the conversion of identified and categorized substructures to suitable FE representations. Moreover, logical reasoning is embed for example in case when complicated substructures hold a large share of the component. The process decides itself that a simplification will most likely not lead to suitable results and chooses the transfer to a 3D volume FE model instead. Otherwise, the process allows multiple possible modelling techniques in order to enable a variable level of detail in the CAE part. The results have shown that this approach is producing satisfactory results while significantly reducing the computational complexity. An important additional output is a database containing the link from FE entities to the original CAD substructures, thus allowing a better funded, geometry based and sophisticated post-processing. In summary, this paper presents an approach for a smart, reasoning and geometry based method for model understanding and suitable conversion to an analysis models based thereon.

The major potential for further research can be identified in the CAD decomposition method. The field of computer science and especially computer vision provide attractive approaches which are referred to as shape segmentation. First experiments in the scope of this work with available methods from this area have shown that the structures required for CAD/CAE modelling can be too small compared and complex to common shape segmentation application models for an adequate geometry decomposition. In this regard, additional research in this topic with regard to engineering problems could attract great attention.

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