

A Study on the Effect of Simplification Techniques of CAD Models used for Finite Element Simulations

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ABSTRACT

Now days, simulation plays a major role on product development section in industries. In recent the simulation is currently used in design, dimensioning and analysing of the mechanical parts. We focusing on the dynamics of the microscopic world and on realizing simulations that capture maximum complicity using minimum computation time and cost. FEM becomes the most useful approach in simulation of mechanical behaviour. For that it requires initial CAD model. It is not easy to analyse complex models. So, it is necessary to simplify the models before simulation. In this paper presents an automatic CAD model suppression approaches. First part of this paper deals with a Rule based approach to simplify the features for that the rules are generated with help of expert's knowledge and suppression has obtained in Knowledge ware a special tool available in CATIA V5. Second part presents a Hybrid method approach to simplify CAD model. The implementation of algorithm on Open Cascade Platform is also presented. Finally estimate the effect of using this approach on CAD model. It shows that computational time is reduced with minimal changing the exactitude of results.

Keywords: Simulation; CAD Model; FEM; Rule Based Approach; Hybrid Approach; Suppression

I. INTRODUCTION

Computer simulations play a vital role in design, research, development, prototyping and validation of mechanical products. It indeed to reduce the risk and inefficient in product testing. For example: UNO III vehicle design, in that when we began the UNO III redesign, for rider safety it was clear that manually tuning controllers and testing on the actual vehicle would be inefficient and risky. Instead they used computer simulation to model and simulate the UNO III mechanical systems.



Figure 1: Simulation of UNO III vehicle redesign

During real-world test, things move so fast it is impossible to understand everything that is happening. In simulations however, we can freeze time and inspect every aspect of the model to get a clear picture of how mechanics are behaving. We focus on the dynamics of the microscopic world and on realizing simulations that capture maximum complicity using minimum computation time and cost [1].



Figure 2: Virtual model and simulation of military vehicle

Engineering models today are mainly developed with a 3D computer Aided Design Software [2].

If we run a Finite Element Analysis (FEA) on a part with hundreds of small features as often leads to computational time will be very large and poor quality mesh and hence may lead to affect analysis result. Then, it automatically increased the cost of labour [3].

In order to get accurate result in a timely manner, one must utilize simplified models. The simplified models are used in many simulation domains: dynamic analysis of bogie for forestry machines [4]; modeling and simulations of dicycle [5]; Thermo mechanical simulation of aerospace structures [6]; virtual modeling and simulation of military vehicles [7]; Optimization of vehicle structure [8], etc.

Related Work

Atul Thakur et al. [9] had studied that the existing model suppression techniques that are useful for the physical based simulations and it can be classified them broadly into four main categories based upon the type of suppression operators used in respective techniques. ie, surface entity, volumetric entity, explicit feature and dimensional reduction.

Hamdi Mounir et al. [10] had stated that the Finite element method (FEM) becomes mostly used approach in simulation of mechanical behaviour. The adaptation steps consists in suppression of CAD model geometry by eliminating details holes, chamfers, fillets based on a combination of eliminating details and merging faces. H.Zhu and C.H.Menq [11] had reviewed on B-Rep model suppression by automatic fillet/round suppression. The major shape of the primary features may not be affected by fillet and rounds can greatly change the geometric and topological patterns of the primary features.

R. Ferrandes et al. [12] had proposed an evaluation method of suppression details for finite element modal preparation. If a shape detail removed during the shape suppression process proves to be influence on mechanical behaviour, it can be reinserted on simplified model.

Shuming Gao et al. [13] had proposed a feature suppression based framework to CAD model suppression. CAD mesh model is segmented into regions using the improved watershed algorithm and from features are

recognized based on region level representation using graph based feature recognition method.

R.J.Donaghy and C.G.Amstrong [14] use the medial axis transform (MAT) to carry out the adaptation and the idealization of B-Rep geometry. The MAT method builds the skeleton of a geometrical representation in order to obtain the medial axis.

M.Hamdi et al.[15] CAD/CAE interoperability, an automatic generation of analysis model based on the suppression of CAD geometry is implemented by using CASCADE platform. In order to be independent of CAD/CAM system, the proposed algorithm relies on a neutral file (STEP) to recuperate the data of the part to be simplified to use various tools of simulation; the simplified CAD geometry will be also stored in the STEP format.

Oussama Jaider et al. [16] had described a new approach to eliminate the undesirable in interpretations of features, according to manufacturing rules and metal removal principals. Automatic Feature Recognition (AFR) has played a crucial role linking CAD activities and computer aided process planning (CAPP).

Bob Evans et al. [17] had stated that the interference of machine learning as decision tree induction to derive process control rules and participation of experts knowledge to do the best. They recently applied a machine learning strategy known as decision tree induction to derive a set of rules.

Jiawei Han and Micheline Kamber [18] looks at rule based classifiers, where the learned model is represented as a set of IF-THEN rules. They then studied the ways in which they can be generated; either from decision tree or directly from the training data using a sequential covering algorithm.

A.Sheffer [19] reported that, face clustering is a technique to cluster the faces in the input model. The clusters thus formed represents the region of intersects that may be considered for suppression. There are three main steps followed in this approach: face clustering, finding the collapsible faces and suppression.

Satoshi Kanai et al. [20] had described that the CAD systems and assembly models tend to have a huge number of parts and very complex inner structures. For

achieving the light weight and strengthened parts, the inner structures of housing such as rib or bosses have very complex geometries. In order to simplify this complex geometry: Remove invisible technique is used. In this paper utilizes two different approaches to simplify the cad model. The first approach is knowledge based. In this approach the knowledge is gain from experts demo's and encoded that data as suppression rule. It is also called as a rule based approaches. The rules shows that whether the feature /part that should be considered for suppression or not.

The second approach is using hybrid method of suppression. In this approach consists of following phases. The phase A consists of step of pre-treatment of CAD model. The phase B consists in identifying details for details for suppression. The phase C consists of allows suppression and reconstruction of simplified model. For this approaches the open cascade platform is utilized.

II. METHODS AND MATERIAL

In this session has been divided into two main phases. First phase consists of knowledge based approach and second phase leads to suppression by hybrid approach. The overview of this approaches are discussed below.

1. Overview of Knowledge Based Approach

The proposed approach is to design an automated tool to identifying the features capable for suppression. The overall approach for generating a CAD suppression using rule based approach as shown below.

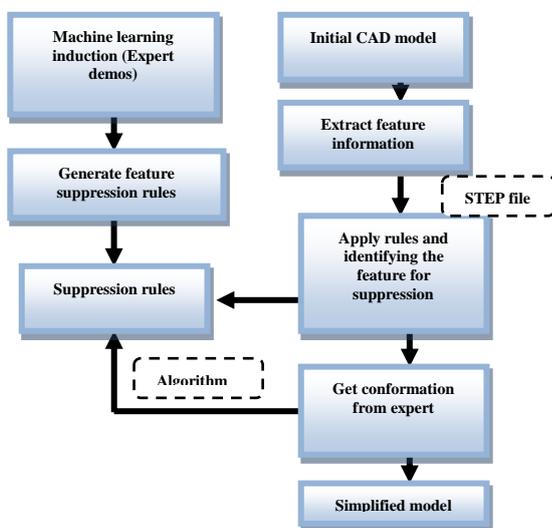


Figure 3: Overview of rule based approach

First, the experts knowledge is captured from demo and suppression rules are generated form statistical induction learning techniques [21].The generated CAD model is converted into neutral format (STEP) and then rules generated are expressed as a binary decision tree. The decision to suppress or not, on a feature depends up on the analysis content and application. Using that knowledge gained from the expert and the decision rules are generated for suppressing the CAD model for FEA simulations. For suppression we considered following.

1.1 Machine Learning: Rules for Suppression

Rule 1: Based on feature type only we concluded whether model is suppressed or not. Feature like holes, fillets, chamfers are suppressed.

Rule 2: Based on feature dimension only whether model is suppressed or not. Small dimensions are leads to suppress.

Rule 3: Instead of absolute dimensions, the relative dimensions of features are considered as suppressed or not.

Rule 4: Boundary and load conditions are important factors that also taken to be consideration for suppression or not.

Rule 5: Feature lies close to the load application cannot to be suppressed.

Rule 6: concentrate on feature formed by offset, mirrored and used as a reference, of other features. Because it leads to deleting of overall component or access denied or redefined over other features.

1.2 Inductive Decision Tree

Inductive decision trees have proven to be a successful tool within the numerous fields and these are proven to be advantageous in improving the accuracy or efficiency of the system

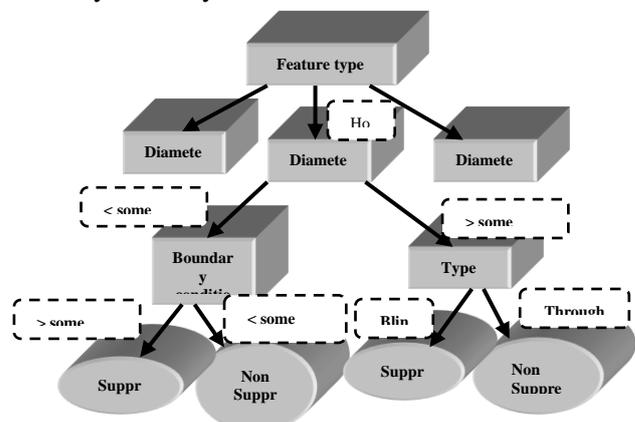


Figure 4: Decision tree for feature suppression

The above is an example of a representative decision tree for suppressing a hole feature considering attributes diameter, minimum distance to the boundary condition feature, and the geometric type. The left node is the node that should be executed if the condition is true. The right node is the node that should be executed if the condition is false.

Example algorithm for the above flow chart for suppression of holes using decision tree induction as shown below.

1.3 Algorithm for feature suppression

Algorithm: Rule 1

```

if feature type ==hole
get diameter value (min)
    then (DIAMETER (D) <5)
if boundary condition. Distance (d) <5
    then
    The feature leads to be suppressed
Else The feature could not be suppressed
End if
End if

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Algorithm: Rule 2

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if feature type == hole
    get diameter value (min)
    then (DIAMETER (D) <5)
if Hole type == blind
    then The feature is to be suppressed
else
if Hole type ==through
    then The feature could not be suppressed.
End if
End if
End if

```

1.4 Implementation and validation on example

Implementation of Approach

The data processing implementation of suppression approach was carried out on CATIA V5 software. In that the API development's platform: "Knowledgware". Knowledgware a special tool developed for 3D applications of CAD-CAM

multiplatform. This platform is installed by using API toolkit installer and it is based on visual basic language.

Example of Validation

In this section, one example of validation will allow validating the principal functionalities of the suppression algorithm. (Fig 5) presents Bogie SF200. The part Bogie selected because they have a broad variety of mechanical parts in terms of its forms, the boundary conditions and also the details which they contain.

In this first the STEP file format is encoded and details of the feature are obtained. After that the 3D model is extracted from neutral STEP file in Knowledgware API platform. Below Fig presents the illustration of the principal stages to pass from a CAD model of the Bogie SF200 (Fig 5), imported CAD model from STEP file (Fig 6), shows that operation performed in rule editor (Fig 7), shows that check editor performance (Fig 8), shows knowledge inspector checks the rules (Fig 9), shows Remove features language browser and finally (Fig 10), shows simplified model.

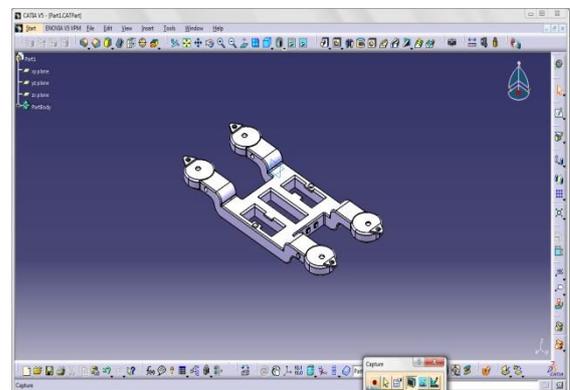


Figure 5: Imported CAD model from STEP file

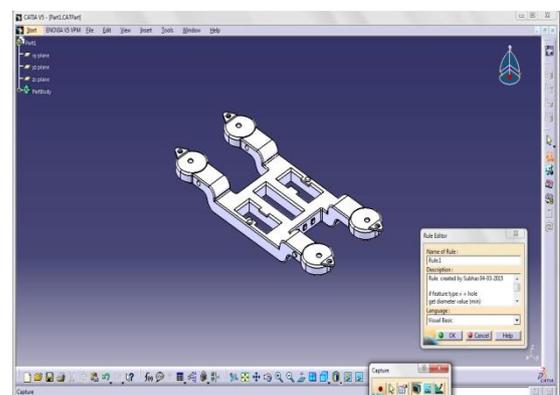


Figure 6: operation performed in rule editor

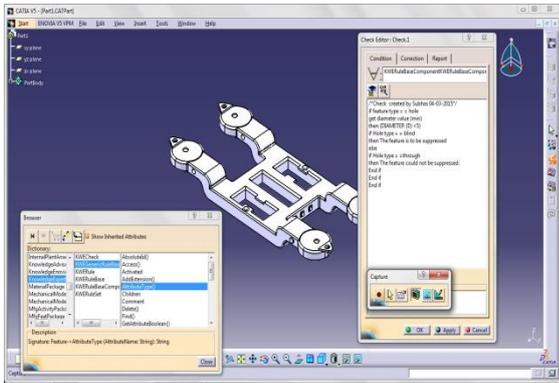


Figure 7: Check Editor Performance

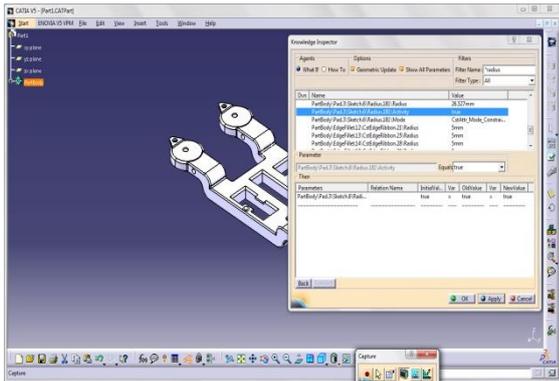


Figure 8: Knowledge Inspector Checks the Rules

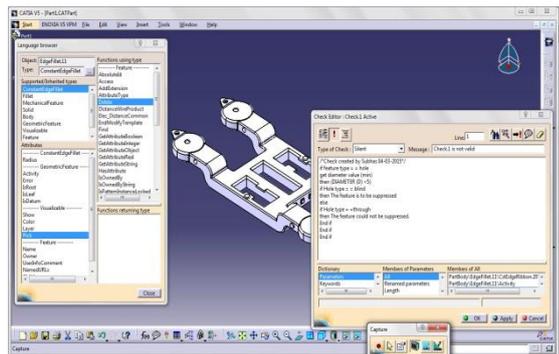


Figure 9: Remove Features

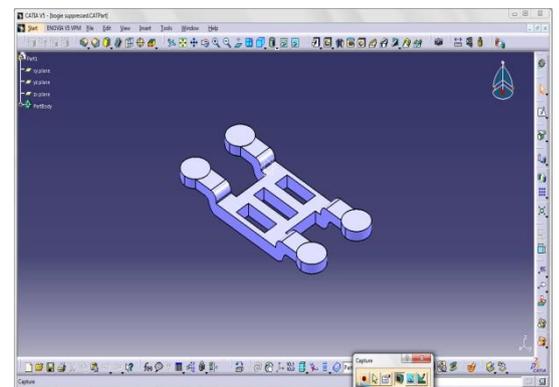


Figure 10: Simplified Model

2 Overview of Hybrid Approach

In order to be independent of the CAD-CAM systems, the proposed algorithm relies on a neutral file (STEP) to

recuperate the data of the part to be simplified. To use various tools of simulation, the simplified CAD geometry will be also stored under the same neutral format (STEP). The overview diagram for hybrid approach is shown below. It consists of three main stages in simplifying of CAD model. This original vision enables designer to visualize the least influential zones (high order of criticality) on the computation results, giving him the possibility either to inter-actively eliminate the entities which have high order of criticality, or to appeal to automatic algorithms of elimination.

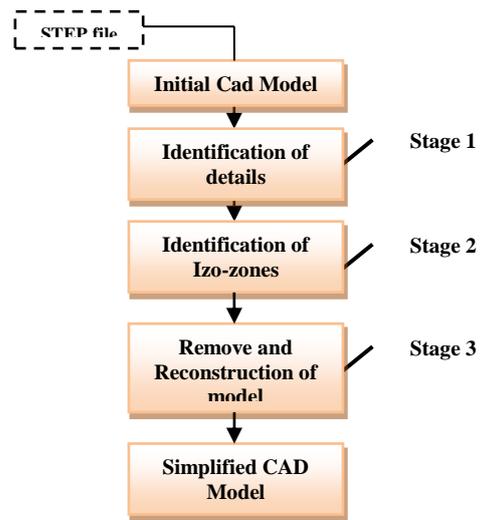


Figure 11: Overview of hybrid approach

2.1 Stage1: Initial CAD model

The stage (1) of the algorithm consists of a phase of identification of details. The structured information relates to the faces, wires, the edges and the vertex which includes the geometry model of the part.

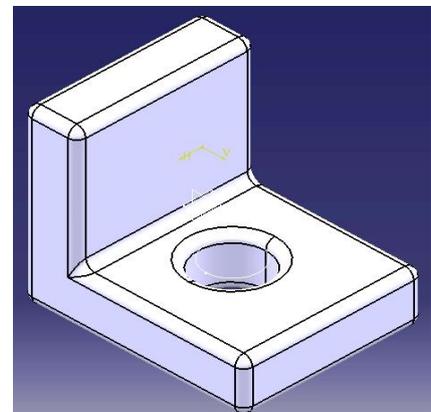


Figure 12: Initial CAD model

2.2 Stage2: Identification of details

The stage (2) consists in identifying the Iso-zone for elimination. That implies the implementation of algorithms of identification based on feature recognition. The result of this phase is a representation of Iso-zones targets for elimination. These Iso-zones are entities (edges, faces, chamfers, fillets, and rounds) colored according to a gradient of criticality.

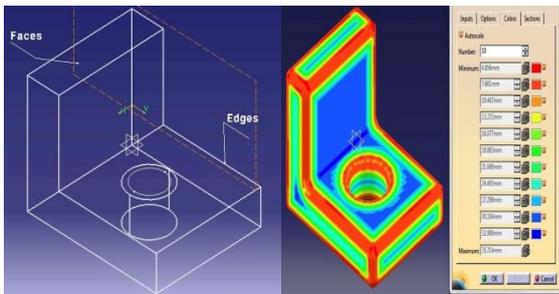


Figure 13: Identification of details(edges, faces, Izo-zones)

2.3 Stage3: Remove and Reconstruction of model

The stage (3) consists in removing the identified details, then in rebuilding the geometrical model after suppression. The result of this phase is a simplified CAD model whose elementary topology is valid. At the exit of the algorithm, the designer has at his disposal a simplified model recorded in format STEP for a simulation by finite elements.

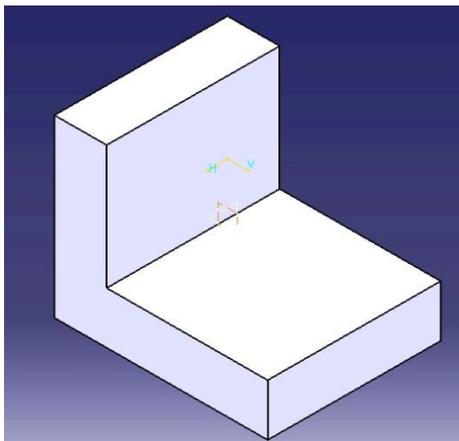


Figure 14 : Remove and Reconstruction of model

2.4 Implementation and validation on example Implementation of approach

The data processing implementation of suppression approach was carried out on open CASCADE platform.

Open CASCADE a special tool developed for 3D applications of CAD-CAM multiplatform. This platform available freely in open source on internet and it is based on C++ language encoding.

Example of Validation

In this section, one example of validation will allow validating the principal functionalities of the suppression algorithm. Fig presents Bogie SF200. The part Bogie selected because they have a broad variety of mechanical parts in terms of its forms, the boundary conditions and also the details which they contain.

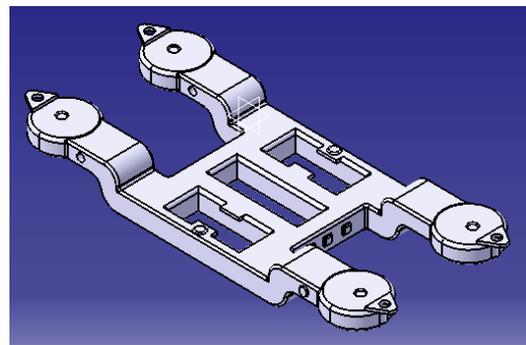


Figure 15 : Initial CAD model (STEP FORMAT)

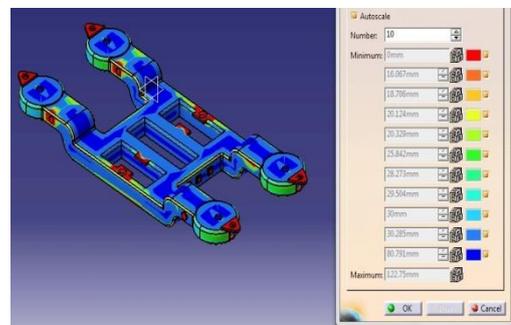


Figure 16 : Identification of Izo-zones

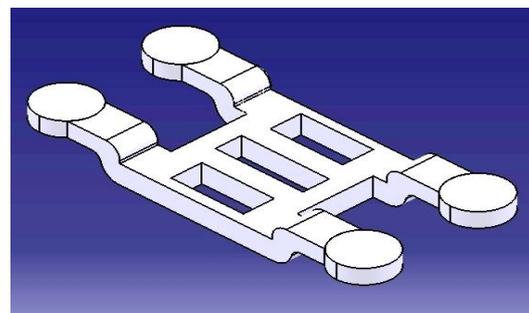


Figure 17 : Simplified model

III. RESULTS AND DISCUSSION

The below figures shows that the analysed models using ANSYS 14.0. Fig (18) shows analysis of original model it has an equivalent Von-mises stress of **1.8745e5 Max** and analysis time taken as **38 s**. Fig (19) shows analysis of simplified model using knowledge based approach it has an equivalent Von-mises stress of **1.4891e5 Max** and analysis time taken as **16 s**. Fig (20) shows analysis of simplified model using knowledge based approach it has an equivalent Von-mises stress of **1.4236e5 Max** and analysis time taken as **12 s**.

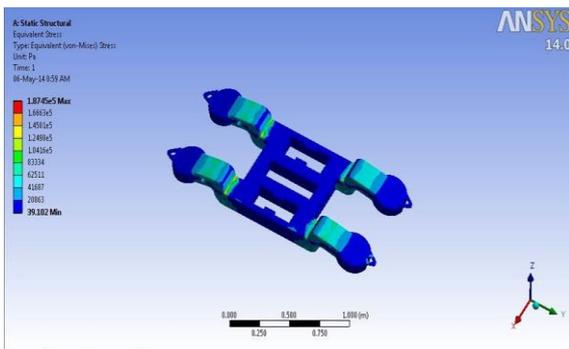


Figure 18 :Analysis of original model

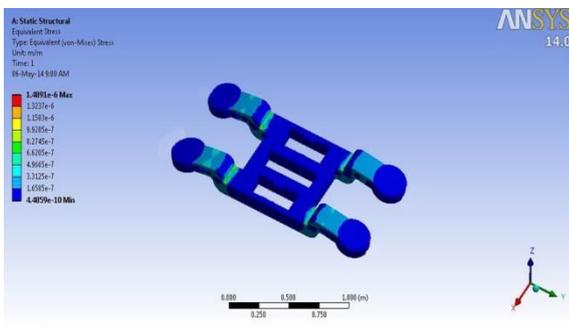


Figure 19 :Analysis of simplified model (Knowledge based approach)

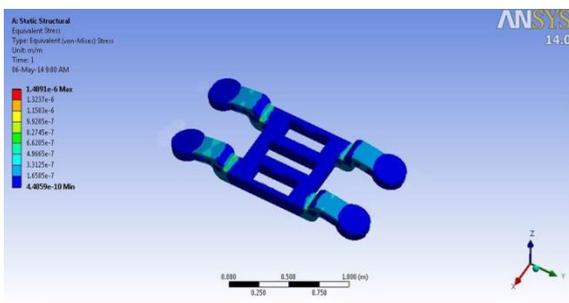


Figure 20 :Analysis of simplified model (Hybrid approach)

The below Chart 1 shows that the comparison of CAD model suppression techniques based on Equivalent Von-

mises stress and chart 2 shows comparison of computation time reduction.

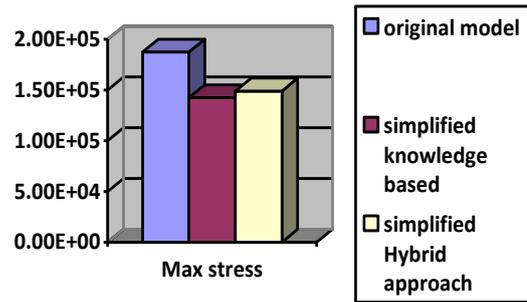


Chart 1: Equivalent Von-mises Stress comparison

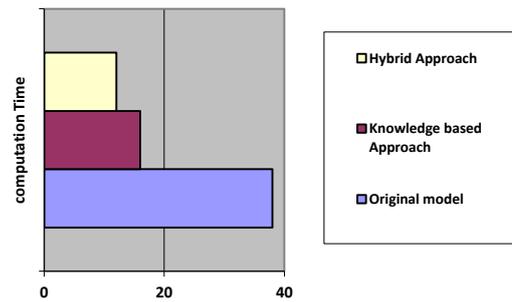


Chart 2: Comparison of Computational Time

IV. CONCLUSION

This paper presents an estimating the effect of suppression algorithm on CAD models for a simulation by finite element method. The algorithm proposed consists on reading the B- rep model of the CAD geometry in order to identify, then to remove the details considered superfluous for mechanical analysis.

The example of validation show that a suitable elimination of the details in a CAD model allows saving a very important time (up to 69%) in the procedure of simulation while keeping a high quality of the computation results. These observations were found by doing simulations by finite elements before and after suppression. This work helps to the industrialists who are interested more and more in preparing CAD models for simulation purposes. Thus, the comparison shows hybrid approach gives acceptable results with minimum error.

V. SCOPE AND FUTURE WORK

This work helps to the industrialists who are interested more and more in preparing CAD models for simulation

purposes. It is fully based on suppression of features like holes, chamfers and fillets.

At short notice, In Future it is important to consider other criteria of suppression such as volumes, size and surface entity based with this suppression technique.

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