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Evaluation of the Freeform Feature of Solid works Parametric

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Abstract: Evaluation the freeform feature of Solid Works Parametric by investigating the capabilities of this CAD system and its advantages in the requirements of very complex designs. A heuristic evaluation and actual modeling of a case part (detergent bottle) was then carried out in Solid works Elements to determine the capability of the freeform feature of this CAD program. The study revealed that the freeform feature in solid works Parametric reduces modeling time, gives the designer more flexibility and control over the shape of the model, and allows for creation of complex shaped models. the freeform feature in Solid Works is a bit rigid and is mainly regarded as a general-purpose shape editing tool. For instance, the feature lacks the redo function hence limiting user control and flexibility. The designer is also required to create the initial model before editing it using the freeform feature. Therefore, the freeform feature in Solid Works is not suitable for creating models from scratch.

Index Terms*:* Freeform feature, surface modeling, Solid model, complex shaped models, case part (detergent bottle)

I. INTRODUCTION

Software makers have undergone an innovative and time-consuming process to come up with software packages that have features that enable designers and engineers to design almost anything. These programs have different capabilities, different level of user friendliness, different features and specialty among other aspects. Although most CAD programs have numerous functions and capabilities, these differences make it difficult for the users to select the most suitable CAD program for a particular application[1]. One of the most fundamental applications of CAD programs is geometric modeling. Geometric modeling in CAD applications has undergone significant development from 2D projections (drawings), to wireframe models, to surface models and finally to solid models. This continuous improvement has been done in order to enhance geometric representation of physical features. For instance, 2D projections are not sufficient because technical skills are required in order to understand the drawing and mistakes always occur either during drawing or interpretation. More so, they do not allow for later applications like finite element analysis.

Similarly, wireframe models are not sufficient because they do not contain the object's mass and volume information. In addition, wireframe models cannot be used to represent complex surfaces that characterize the current products in the market. On the other hand, surface models provide detailed information of the object's surface. When surface models are rendered, they show the actual appearance of the design [2]. Surface models are therefore used to describe complex geometries like those found in cast and forged parts. Surface models are also applied in automobile industry, ship building industry, consumer products, and aeronautical industry among others. Unlike surface models, solid models have extra information about the model's mass and volume. This information allows designers to perform mass calculations, analyze the model, carry out simulations and generate CNC codes. A lot of research has been done on the various forms of geometric modeling. However, surface modeling and solid modeling have received more attention because of their numerous applications. For instance, in the automobile, aerospace and other consumer products industry, surface models are used by designers and engineers to achieve the desired function of a product. The increased need of complex freeform surfaces especially in automobile, consumer products and aerospace industry has led to advancement in the available CAD systems in order to meet the designers requirements.

II. METHODOLOGY

There has been an extensive researches done on regular-shaped features. However, product designers are currently in demand of complex freeform features to enable them meet complex design requirements. Freeform features offer a faster and a more intuitive modeling approach and guarantee a high quality design. Designers and manufacturers all over the world are currently relying on freeform modeling programs to create and manufacture outstanding products in a very short time. Due to the increase in complexity of current designs, designers and engineers require more advanced freeform modeling systems in order to express their creativity, innovation and design ideas in much shorter production cycles. It is therefore necessary to develop a credible basis for evaluating the capability of the freeform modeling systems. This will serve as a guideline for the potential users when selecting the most suitable system. In addition, a thorough discussion of the various capabilities of the freeform feature will enable the users to maximize the use of this feature in the respective CAD software.

In this research, the factors to consider when selecting the most favorable freeform modeling software will be presented with emphasis on Solid Works Parametric. This will also involve the evaluation of the freeform feature in this CAD program. The evaluation process will be based on available literature, heuristic evaluation and personal experience. This will be accomplished by selecting a case part (detergent bottle) and modeling it in Solid works Parametric.The program will then be compared in terms of capability, ease of use, added features, efficiency and effectiveness, available support services (available tutorials), user interface, system requirements, and ability to re-use the feature (freeform feature recognition).

III. RELATED LITERATURE

A. Surface and Solid Modeling

Solid modeling is used to generate solid components of a desired geometry. The solid modeling CAD software is used to create the virtual 3D image of the desired component. This is achieved by systematically joining or cutting a group of features until the desired model is complete. A solid model is a replica of the real component and can be rotated just like the actual component[3].

Surface modeling involves creating surfaces of a predetermined shape using various operations. Surface modeling is similar to solid modeling in the sense that the solid model is achieved when surfaces are connected to represent the object's boundary[2].

B. Ruled Surfaces

Ruled surfaces can either be single ruled or double ruled. A surface is known as doubly ruled if for every point on its surface there are two different lines. Examples of double ruled surfaces are the hyperbolic paraboloid and single hyperboloid. Examples of ruled surfaces are shown in figure 1 below.

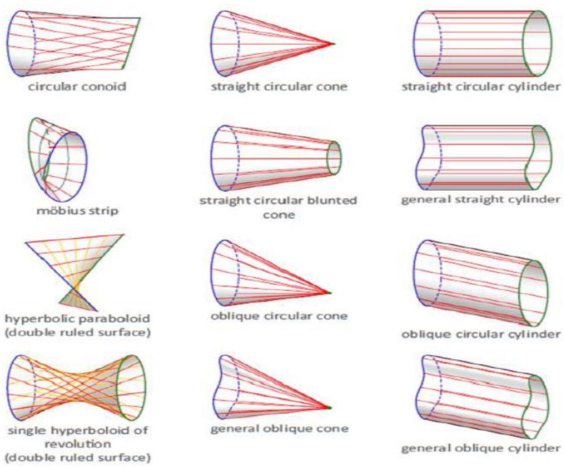

Figure 1: Examples of Ruled Surfaces[4].

C. Surface of Revolution

A surface of revolution is formed by rotating a planar curve about the axis of symmetry at a given angle. The resulting surface is symmetrical. Therefore, this technique is usually used when modeling components that have axial symmetry[5]. Examples of surfaces of revolution are shown in figure 2 below.

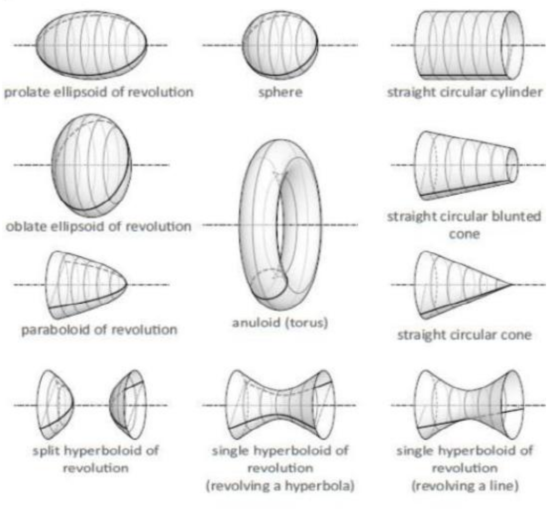

Figure 2: Surfaces of Revolution[5].

D. Freeform Surfaces

Freeform surfaces are usually described by a rectangular set of control points and a mathematical model that defines the surface formation[6]. Modeling a surface by approximation involves generating a smooth shape that approximates the original points. In this case, the surface does not necessarily pass through all the control points. Bezier surfaces and B-spline surfaces are examples of surfaces formed by approximation technique while bilinear surface and Coons Patch are examples of interpolation surfaces[6]. Approximation techniques are usually preferred to interpolation techniques because of the fact that approximation techniques provide a more intuitive feel and are more flexible.

E. Subdivision Surfaces

Modeling using subdivision surfaces begins with the base mesh which is divided into several regions. Subdivision of the base mesh creates new vertices and faces. The continuous subdivision gives more control to each region[7]. To reshape the surface in a particular region, the respective control points are modified. In addition, the control points in the base mesh can be modified to reshape the overall surface. When using subdivision surfaces to create models that have different levels of complexity, the designer does not need to use complex geometry over the entire model but only uses complex geometry in intricate regions of the model[8].

F. Freeform Surface Modeling and Freeform Surfaces

Freeform surface modeling gives the designer the power and innovative flexibility to explore alternative design ideas quickly. Freeform surface modeling also enables the designer to make last minute changes to the initial design quickly. This means that the designer can model any design concept regardless of the level of complexity of the design. Freeform modeling has been the backbone of reverse engineering because it gives the designer the ability to extract product definition parameters from the original design. designers can create essential design modifications and generate alternative designs by editing the product definition parameters[9].

G. Classification of Freeform Features

Freeform surface features have freeform surfaces which do not necessarily enclose a volume. On the other hand, volumetric freeform features are made up several freeform surfaces which must enclose a volume[10]. Various researchers have suggested several ways of classifying freeform features. One of the main methods of classification is the one presented by Poldermann and Horváth (1996)[11]. According to their method of classification, freeform features are grouped into four main categories. These categories include primary surface features, modifying surface features auxiliary surface features and transition surface features. According to the classification by Poldermann and Horváth (1996), primary surfaces describe the overall shape of the model while modifying surface features are used to modify the primary freeform surface features. On the other hand, auxiliary freeform surface features mainly consist of mechanical features like holes and chamfers. Finally, transition freeform surface features are those that are used in the model to ensure that there is continuity between joined surfaces. This classification is shown in Table 1 below.

TABLE 1. Classification of Freeform Features by Poldermann and Horváth

Classification of Freeform Surface features		
Primary Surface Features	Closed	Single curved double curved amorphous
	Opened	Non-isometric Isometric
Modifying Surface Features	Local	Protrusion Depression
	Global	Bend Wave Blending
Auxiliary Surface Features	Holes	Simple Threaded
	Cuttings	Lifted Lowered
	Ears	Single Double
	Fillets	Arc Chamfer
	Ribs	Cross Fix-length
	Slicing	Deformed Non-deformed
Transition Surface Features	Simple	Blended Rounded
	Compound	Blending Rounding

Another important classification of freeform surface features is the method of classification suggested by Zhou, Y., 2010 [12]. According to this method, freeform surface features are classified into two categories namely δ-features and τ-features. This classification is very similar to the one presented by Poldermann and Horváth. Classification of freeform features by Zhou, Y., (2010) is illustrated in Table 2.

TABLE 2. Classification of Freeform Features According to Zhou, Y, (2010)

Freeform Features		
Freeform δ-features	Border	Intrusion (Step-up) Extrusion (Step-down)
	Internal	Intrusion (Cavity) Extrusion(bump)
	N-channel	Intrusion (N-groove) Extrusion (N-rib)
Freeform τ-features	Sharp	Inlet Hole N-gap
	Finished	Inlet Hole N-gap

H. Solid works Features

Solid works is a commercial CAD software package capable of 3D design and simulation. It is also supports surface modeling including freeform surface modeling. The freeform feature in Solidworks enables the user to edit faces of a surface or solid model. This freeform feature is based on NURBS. There are two main methods of freeform modeling in Solid works. The first technique involves creating a freeform surface from solid or surface model. The other technique involves creating a freeform surface from scratch[13].

The designer can easily modify the face of surface model or solid model by creating control curves and control points. The control points are then relocated to modify the face of the model. Surface modeling in Solid works is found under INSERT menu.

The freeform feature in solidworks is mainly used to modify the shape of a model without redefining the original curves. However, it is sometimes used to model a complex shape without using complex curves. This freeform feature in solidworks is mainly regarded as a general-purpose shape editing tool. This feature allows the designer to push or pull specific points on the surface to create a desired shape without creating any curves. This is achieved by defining control curves and control points which are relocated to obtain the new shape. One advantage of this feature is that the designer can see the effect of relocating the control points in real time and make necessary changes. A solid works surface modeling workbench is shown in figure 3 below.

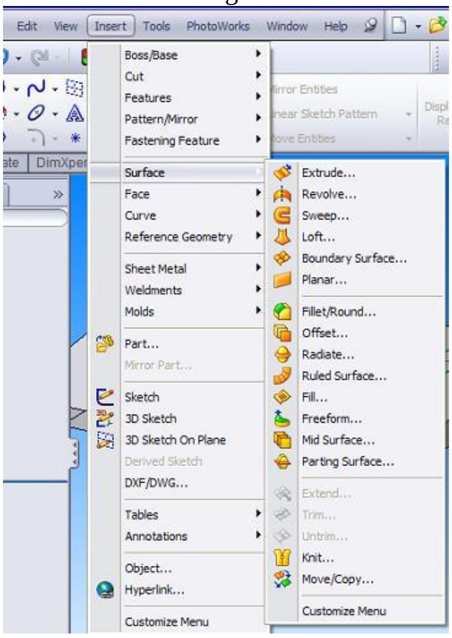

Figure 3: A Solid works surface modeling workbench

I. Heuristic Evaluation

A heuristic evaluation of a CAD system is usually carried out by having an experienced CAD user looking at the interface of the selected software and identifying the weaknesses and strengths of the interface. Heuristic evaluation is the best tool to analyze CAD software when time is limited. It is also important to note that even though heuristic evaluation appears to be simple, it requires a considerable level of expertise. However, developed a general checklist with guidelines that can be followed to easily carry out a heuristic evaluation on the user interface of any software[14]. These guidelines are usually regarded as rules of thumb when conducting a heuristic evaluation of an interface. These guidelines will be used in the tutorial part of the solidworks, as a general and comprehensive evaluation of the software's freeform features. The main guidelines are described in short, as follows.

1. **Provide Feedback (Visibility of System Status)**

   A good system should always provide some feedback to the user to clarify what the system is doing. This feedback should be provided in the shortest time possible. Examples of a form of feedback are an hour glass, progress bar, direct manipulation and a visible change on the display to show that the system has changed it state in response to the user's input[14].

2. **Match between System and the Real World (Speak the Users' Language)**

   A good CAD software system should communicate to the user in a language that the user understands instead of using system oriented terms. The form of communication should be in worlds, phrases, symbols and concepts that the user is conversant[15].

3. **User Control and Flexibility**

   A good CAD system should not confine users in a situation that has no clear exits. To enhance flexibility and control, each CAD application should have clearly marked exits. It is common for even experienced CAD users to accidentally select the wrong function.

4. **Consistency and Standards**

   Every word, phrases, and actions among other features should conform to the industry's conventions. There should be a single way of performing certain functions instead of having several icons that are used to execute the same function. However, shortcuts and commands are exempted from this principle[15].

5. **Recognition Rather Than Recall**

   A properly designed CAD system should reduce the user's memory load. This is due to the fact that human beings have a limited short term memory and may not recall information from one dialogue to another.

6. **Flexibility and Efficiency of Use**

   A CAD system should have the ability to accommodate different levels of skill. Novices usually find stepwise execution of various functions to be appropriate but experts find such steps to be time consuming. To achieve this, CAD programs should have shortcuts and commands that are not visible to the novice. The system should also allow the user to customize templates to enable the user to control the level of expertise.

7. **Aesthetic and Minimalist Design**

   All dialogues in a CAD system should only have information that is required by the user. All messages below an icon should also be as short as possible. Information that is least required by the user should be avoided to prevent reduction in visibility[16].

8. **Provide Sufficient Error Messages**

   The error messages should be expressed in plain language with no codes and should address the specific error and suggest possible solutions. For instance, a warning sign should be linked to a list of warning signs showing the time of error, it's likely cause and possible solutions.

9. **Error Prevention**

   Although errors cannot be totally prevented, the system should be designed to prevent frequent occurrence of errors. This can be achieved by ensuring that error-prone conditions are minimized[15].

10. **Help and Documentation**

    It is very important to give help and documentation and a good CAD system should have simple and brief help and documentation. Help and documentation should also be easy to search specific to the user's task and provide specific actions to be taken.

IV. DISCUSSION

as evaluation of Freeform Feature in Solid works, this section comprehensively describes the process of modeling a bottle in Solid works. Although Solid works has freeform modeling capability, it is only limited to simple shapes. For this case, most parts of the model were created using conventional modeling techniques such as revolve, extrude, sweep, fillet and cut among others. However, freeform modeling was used to modify the shape of the handle to enhance aesthetics and ergonomics.

The first step of the modeling process involved started the workbench and importing the required picture into the sketch using the sketch tools i.e. (Tools>Sketch Tools> Sketch Picture). The outline of the picture was then sketched and used to model the bottle. For instance, the cap was modeled by revolving a sketch contour around an axis. On the other hand, the remaining body was created by extruding a sketch contour. The fillet feature was then used to make the edges smooth and round. The sketch picture is shown in figure 4 & the model of the bottle is shown in figure 5 below.

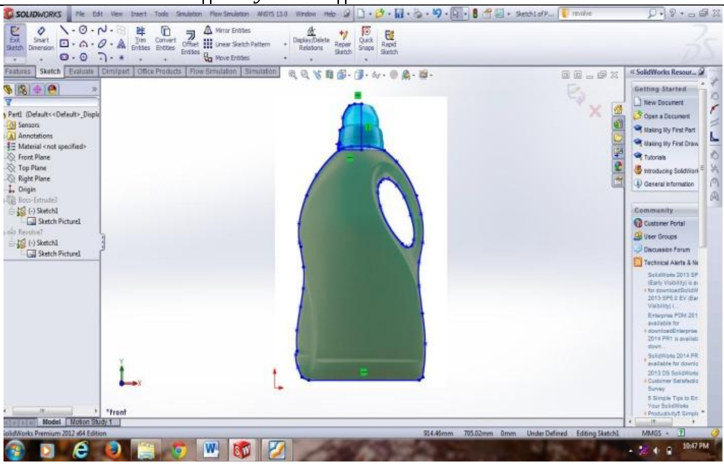

Figure 4: Sketch Picture in Solid works

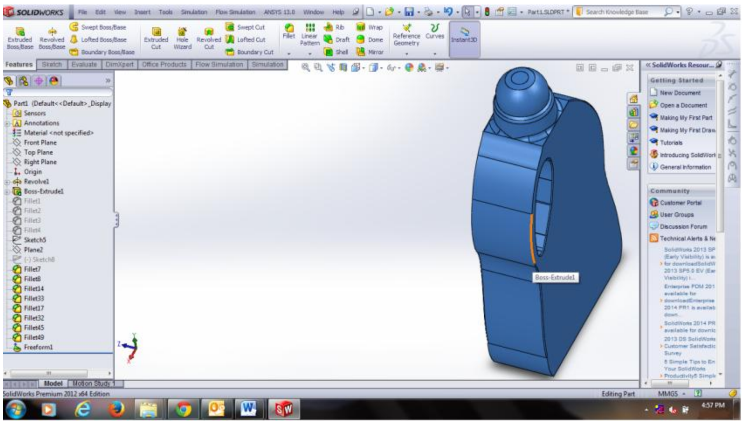

Figure 5: Model of the Bottle in Solid works

It is important to note that the freeform feature could not be used to provide a smooth surface finish on the main body of the bottle. An attempt to use the freeform feature to improve the overall surface of the bottle generated an error message (Freeform feature cannot deform this face. The boundary may be too complex: try using split to divide the face into smaller faces).

The freeform feature was used to modify the shape of the handle in order to provide a comfortable grip. The handle is shown in figure 6 and 7 below.

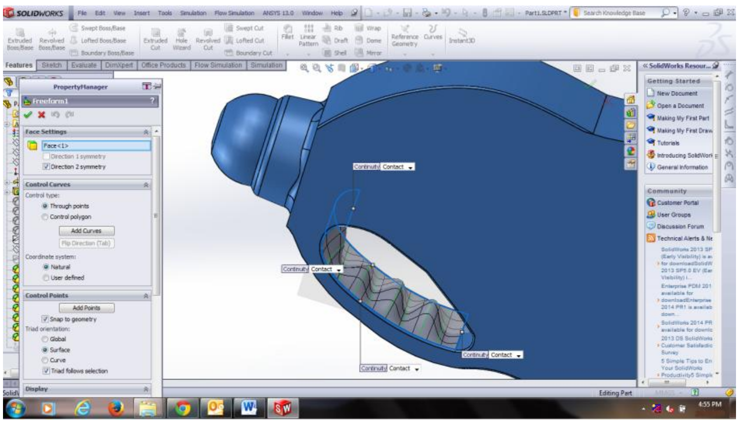

Figure 6: Freeform Modeling of the Handle

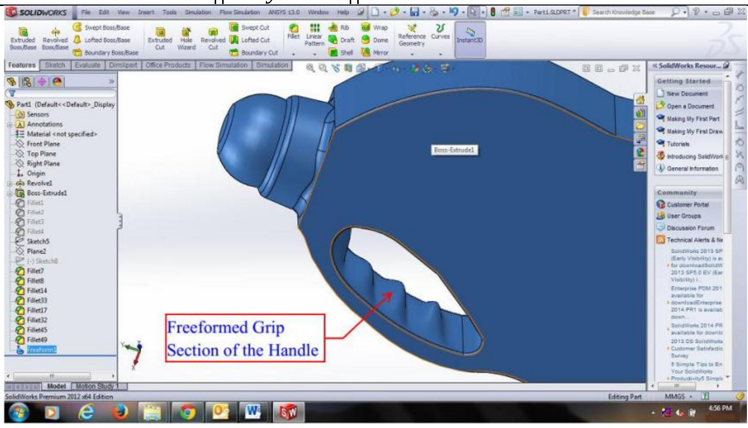

Figure 7: Free-formed Grip Section of the Handle

V. FINDINGS

The results of the above analysis is discussed comprehensively. These are the results for both heuristic evaluation and actual modeling of the detergent bottle. Heuristic Evaluation of the Freeform Feature in Solid works by main guidelines which described above.

1. Provide Feedback (Visibility of System Status):

The freeform feature of solidworks does not work in isolation but is supported by other workbenches including the sketch workbench. When importing a picture into the sketch workbench, the system indicates that it is carrying out a certain function. The system also provides feedback when it fails to execute a certain function. For example trying to import a picture of an unsupported format results to sufficient feedback is shown in figure 8 below.

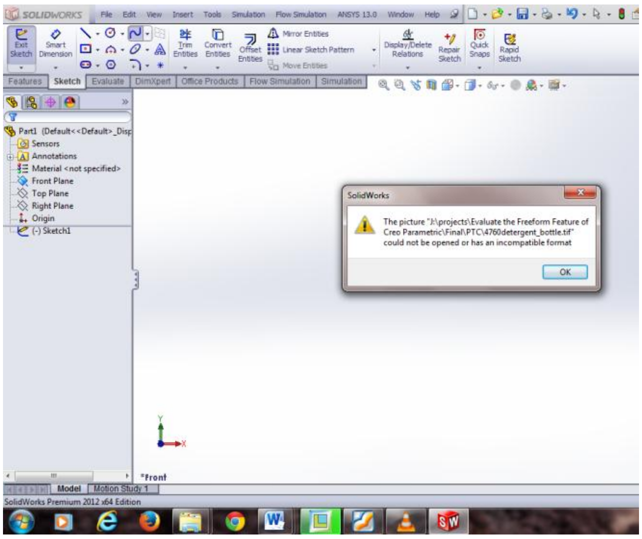

Figure 8: Feedback in Solid works

2. Match between System and the Real World (Speak the Users' Language):

When in the freeform environment, the system displays information in English explaining the function of every command executed. However, the language used cannot be edited because it is set during installation. The user can also view the function of every icon by simply passing the curser over the icons.

3. User Control and Flexibility:

The freeform environment is very poor in terms of user control and flexibility. This environment only has an undo function but lacks the redo function. This makes it extremely inflexible. This is very undesirable for novices because they can be forced to repeat lengthy operations if they mistakenly selected an undo function. However, the system has clearly marked exits. On the basis of user control and flexibility on a scale of 0-10, this feature can be given a rank of 3.

4. Consistency and Standards:

All phrases and appearance of icons in the freeform environment satisfies the industry's standards. There is also no repetition of icons on the toolbar within the freeform environment. This consistency is also in other Solid works modules.

5. Recognition Rather Than Recall:

The freeform environment is not well designed to minimize the need for memorizing. Although the icons are self-explanatory, the manipulation of the freeform surface requires skills and experience. Novices are required to remember how to set the control points and curves because the system does not explain the required procedure. In addition, novices may not know the function of various items in the information table. The information table is shown in figure 9 below. There are also no dedicated icons for executing functions in this environment. However, after using this feature the user may not need to memorize the procedure in future. The system also displays the basic steps for accomplishing various tasks at the bottom left corner of the active window.

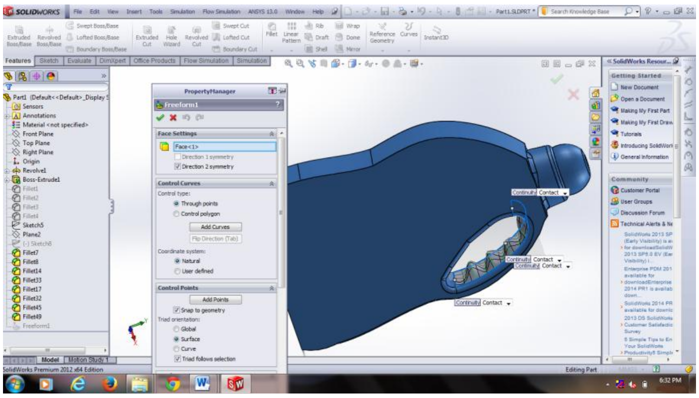

Figure 9: The Information Table used to Control to Execute Freeform Modeling

6. Flexibility and Efficiency of Use:

The freeform feature of solidworks does not support various levels of skill. Novices may find it hard to locate and move control curves and points in order to create the desired shape. The feature is therefore suitable for skilled CAD users. Basing on flexibility and efficiency of use, the system can be given a value of 6.

7. Aesthetic and Minimalist Design:

The freeform environment in Solid works is compact with minimum information. Only necessary information is displayed such as the labels for every icon. Extra information is provided in form of a drop down list.

8. Provide Sufficient Error Messages:

When using the freeform feature of Solidworks, all errors are reported in form of a text message that gives the source of error and how to correct the error. For instance, when the user intends to use this feature to edit a model with a complex boundary an error message is displayed explaining possible solutions to the error. The message is also displayed in a language which the user understands. A sample error message is shown in figure 10.

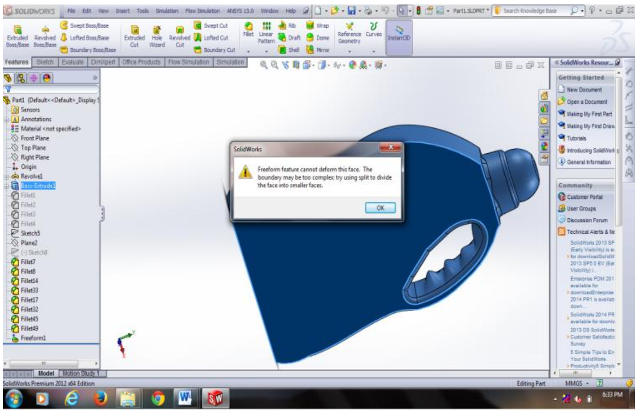

Figure 10: Sample Error Message is Solid Works

9. Error Prevention:

There are no clear strategies to prevent frequent occurrence of errors in the freeform environment of solidworks.

10. Help and Documentation:

There are several forms of help and documentation within the freeform environment of solidworks. The user can search within the knowledge base, community form and tutorials.

VI. CONCLUSIONS

The main aim of this paper was to evaluate the freeform feature of Solid Works Parametric. A comprehensive literature review was carried out to understand freeform modeling concepts. A detergent bottle was selected as the case part and was modeled in Solid Works Parametric. There was also a heuristic evaluation of the interfaces of these CAD program. The freeform feature in solidworks is rigid and is regarded as a general-purpose shape editing tool. This is because it lacks the redo function and requires the user to create an initial model before editing it using the freeform feature. It is important to note that some of the information used in this paper is based on available literature and the researcher's personal point of view. The research also focused only on one case part but varying the case part can yield different results.

Solid works parametric require improvements in order to make freeform modeling more attractive. The makers of Solid works should improve the capability of its freeform feature.

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