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SHEET METAL ASSEMBLY DESIGN METHODS ANALYSIS

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Abstract: *This paper analyzes some design methods (from simple to complex) regarding time and problems encountered. The aim is to quantify the advantages of parametrized design based on parameters, relations, and design switches, either using solid activation/deactivation or profile switch. Deactivation of features is not recommended as it could lead to errors later on. This study is meant to find a way to avoid the method of feature deactivation, use the curve parameter type instead and check the method's failure possibilities. The results reveal the success of the method and its limitations in SMD. The curve parameter method seems robust mostly when used in PD and GSD.*
Keywords: *design, parametrization, skeleton, geometries, curve, assembly.*

1. INTRODUCTION

Product development today is increasingly focused on time-saving and reuse to achieve good products with low cost in less time. Even if the projects increase in complexity over time [1], the need to reduce costs and time brings the need to reuse as much as possible from old projects regarding design and lessons learned. In this sense, the engineers must have a compromise between design methods which helps achieving the design very quickly and design methods which make the model reusable in order to save time when updates will be needed In this sense, the engineers must have a compromise between design methods that help achieve the design very quickly and design methods that make the model reusable in order to save time when updates will be needed. For early phases, when the product is just presented as a concept, or when the product is very simple as a geometry, engineers might choose the quick design methods if they do not need to develop a parametrized model. When the product is subject to a development process that includes further simulations and testing that could bring modifications, then the model must be built in a way that will be easy to modify later. This thinking is applicable in many industries where mechanical parts are needed.

2. STAGES OF METHODS

Over time, the modelling methods were the subject of analysis. The best modelling method can only be decided by the engineer analyzing the customer needs, the functional requirements and the time plan. The skeleton-based model can be considered a smart modeling method that uses parametric CAD software to achieve an assembly that can be modified without the need to open each part and search through the tree history. In [2], it describes the skeleton method as sensitive when it comes to complex assemblies but sees it as useful in terms of time (25% less time used in development). The skeleton method is based on a skeleton part linked to the whole assembly and is made to control the principal features that could be subject to change. The skeleton part is like an abstract part of the assembly based on parameters and wireframe information (sketches, lines, points, etc.) [2, 3].

Some considerations say that the scope of the skeleton is to validate the requirements from the early stages of the design [4]. Those considerations are sometimes in contradiction with what customers ask today. When some customer asks for a request for a quotation with a very short deadline, there is no time to organize an assembly model well. Still, as soon as possible, it is recommended to have an organized and easily modifiable model. The skeleton must contain the most essential information related to requirements and model morphology [3]. Also, the skeleton is part-oriented and brings advantages in top-down and bottom-up design [5].

3. CASE STUDY

The analysis was based on a simple sheet metal assembly model of a horizontal clamp, which was designed using more methods in the CATIA CAD software.

The first method was the one using the Part Design (PD) workbench. This method is, at first glance, the simplest one we can think of, as PD is more intuitive, uses simple geometries, and enables the building of any kind of complex geometries. PD is usually used for machined, cast/moulded, or 3D-printed parts but can also be used for other chosen manufacturing processes.

The second method to design the clamp assembly was using Generative Shape Design (GSD) workbench which is usually used when the designed parts have even thickness, for parts with complex shapes, automotive parts with class A shapes, injection blow molding parts or others. Compared with PD, the saved time in GSD was 29,4%. The most important reasons are that the needed sketches are smaller in GSD and less operations are necessary for GSD to obtain a sheet metal because of the even thickness.

The common problem of building one of the parts in PD and GSD was when needed to obtain the clamp body part whose sides are to be bent until they get in contact. In PD and GSD, the 2 sides of the part in contact will join, and the 2 contact surfaces will not be visible. For this, a designed distance of 0.02 mm was introduced. The clamp body part is visualized in Figure 1.

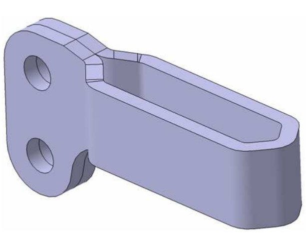


Fig. 1. Clamp body part

The dedicated workbench for sheet metal parts (Generative Sheet Metal design—GSM) does not offer an advantage in terms of time. The difficulty came from the stamping needed for the clamp handle, which took approximately 30% of the time spent and affected the total time by 19.2% compared to PD. The clamp handle part can be visualized in Figure 2.

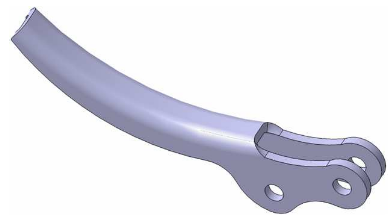


Fig. 2. Clamp handle

The following method used a GSM workbench in a parametrized model, which was designed to obtain the updates without activating/deactivating solid features but changing the sketches using rules and curves. Some of the features to be controlled/parametrized can be observed in Figure 3. A skeleton part was used to control five parameters inside the assembly. The first attempt was creating a curve parameter, intended to assign different sketches depending on the input values of a parameter in the skeleton. This skeleton parameter refers to the distance between the fixing points, which came with a need to increase the part profile area on one side. The rule did not work as intended because a sketch could not be used as a parameter but only as a parameter activity whose type is Boolean and does not fit the curve type parameter.

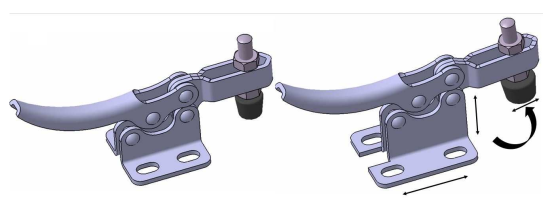
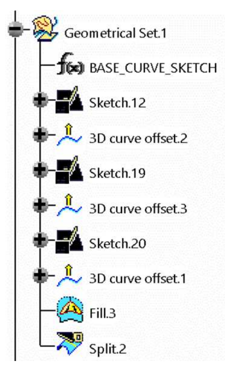


Fig. 3. Features to be controlled/parametrized

Trying to solve that, GSD was used locally to obtain 3D curve offsets from the two variants of the profiles. A curve parameter was created and introduced in a rule made to assign one of the 2 3D curve offsets. The rule did not throw any

error, so the impression was that it would work. Because a so-called 3D curve type was assigned to the curve parameter (even if everything was physically on one plane), the curve parameter could not be used to create a sheet metal wall.
Also, the curve parameter could not be projected on the plane in any way except by creating a sketch. To be able to have an automatically constrained sketch, a surface was created and then projected in the sketch. This last try also worked. As all these steps seemed too complicated for such a simple part, it was also tried to use the curve parameter directly to create a surface feature. It worked without additional surface creation/edit and projection in sketch. So it seems that only GSM is not recognizing a curve to which was assigned a 3D curve type, but is practically a 2D one.

The rule can be found together with the features in Figure 4. This fourth method took 12.3% more time than the traditional GSM one and 89.1% more than the GSD one.



if `External Parameters\DISTANCE_BTW_FIXING_PTS` ==13mm
{BASE_CURVE_SKETCH =`Geometrical Set.1\3D curve offset.3` }
else if `External Parameters\DISTANCE_BTW_FIXING_PTS` >13mm
{BASE_CURVE_SKETCH =`Geometrical Set.1\3D curve offset.2` }

Fig. 4. Curve parameter rule

The last method was also considered a parametrized one using GSM but was based on the activation/deactivation of solid features instead of using a curve parameter to switch the profile. This method is not preferred in general. Experienced engineers always advise not to have deactivated features when a part revision is released. The reason could be that sometimes more engineers could work on the same product, and they will not know why those geometries are deactivated. Even if the software warns the user when the feature is linked to a rule, errors might happen and that feature could be deleted by someone who considers the feature unnecessary.

Nevertheless, the last method is a simpler one, thinking that it is easy to pick one geometry or the other. The problem appears in dress-up features when, meanwhile, the geometry is deactivated, and the edges/faces are moved due to parameters update. Then, when the geometry is activated again, it will not find its references (edges, faces) and will throw an error. At that moment, the engineer will need to spend additional time to find and relink the edges or faces, which could happen at each update. Used in this case study, this method took 9.7% more time than the traditional GSM one and 84.8% more than the GSD one.

4. RESULTS

The best results in terms of time were achieved in GSD, which also achieved the lightest assembly document in terms of size.
GSM almost doubled the design time with insignificant differences from the parametrized ones, thinking that the parametrized models have an additional part as a skeleton and additional features/sketches/relations.

One thing to consider is also the order of using the methods because some of the steps were repeated, which could have given an advantage to the last methods. The values for the time spent on each method can be found in Figure 5.

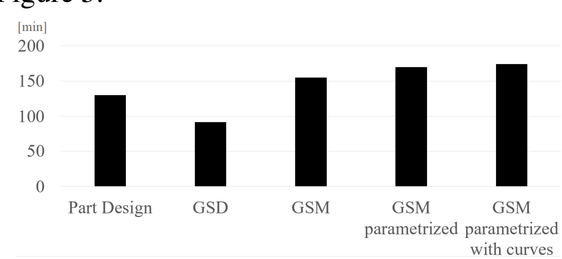


Fig. 5. Time spent

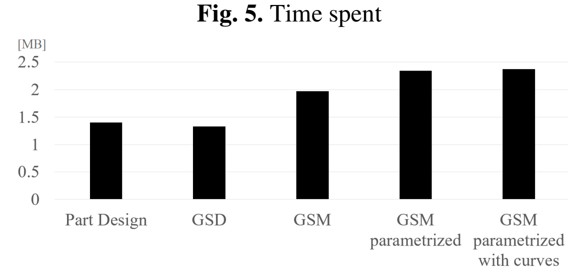


Fig. 6. Assembly size

Figure 6. presents the size of the assembly for each design method, and a substantial increase in the GSM workbench can be observed.

5. CONCLUSIONS

The study shows that except for cases where something could not be achieved in PD or GSD workbenches, these two are to be used. There is no advantage of using sheet metal design except for the fold/unfold features. These can be used anyway using the recognize command to convert the model built in another workbench into a sheet metal one.The study also shows that, when needed/ worthwhile, parametrization does not necessarily add a significant amount of time to the preliminary design, thinking that there will be more time gained later. It was also proven that there is a method of switching designs/geometries without the need for solid features deactivation, and there is no significant difference in time/size. This method refers to the usage of curve parameter type as a robust method which removes the need of feature deactivation and later issues due to undesired deletion deactivated geometries by users that do not know about how the model was structured.

As further research, the curves parametrization method used in GSD or PD workbenches will be verified to see if there is a possible significant improvement in terms of model stability, design robustness and time. The small difference detected in regards of time and file size seen in the actual case study, but without parametrization is to be rechecked in order to find out if it increases with design complexity and including the parametrization/configurable design.

6. REFFERENCES

[1] Kolossváry, T., Feszty, D., Dőry, T., Jintao, C., Shan, H., Wen, T., *Systems engineering in automotive product development: A guide to initiate organisational transformation*, Journal of Open Innovation: Technology, Market, and Complexity, Yun J. J., Vol. 9, Issue 4, ISSN 2199-8531, December 2023

[2] Bin, H., Pengchang, Z., Ningfeng, Z., Jintao, C., Shan, H., Wen, T., *Skeleton model-based approach to integrated engineering design and analysis*, The International Journal of Advanced Manufacturing Technology, Nee A.-Y., Vol. 85, pp. 1105–1115, ISSN 1433-3015, November 2016

[3] Jałowiecki, A., Kłusek, P., Skarka, W., *Skeleton-based Generative Modelling Method in the Context of Increasing Functionality of Virtual Product Assembly*, Procedia Manufacturing, Vosniakos G.-C., Vol. 11, pp. 2211-2218, ISSN 2351-9789, September 2017

[4] Ostrosi, E., Bluntzer, J-B., Stjepandic, J., *A CAD Material Skeleton-Based Approach for Sustainable Design*, Transdisciplinary Engineering for Complex Socio-technical Systems – Real-life Applications, Pokojki J., Vol. 12, pp. 700-709, July 2020

[5] Demoly, F., Roth, S., *Knowledge-based parametric CAD models of configurable biomechanical structures using geometric skeletons*, Computers in Industry, Chiong R., Vol. 92–93, pp. 104-117, ISSN 0166-3615, November 2017

Analiza metodelor de proiectare a ansamblurilor de tablă

Acest articol conține o analiză a unor metode de proiectare (începând de la simplu la complex) în ceea ce privește timpul și problemele întâlnite cu scopul de a cuantifica avantajele proiectării parametrizate bazate pe parametri, relații și schimbarea modelului utilizând activarea/dezactivarea solidelor sau schimbarea profilului. Dezactivarea caracteristicilor nu este recomandată deoarece ar putea introduce erori mai târziu. Acest studiu este menit să găsească o cale de a evita metoda dezactivării caracteristicilor utilizând în schimb parametrul de tip curbă și să verifice posibilul eșec al metodei. Rezultatele dezvăluie succesul metodei și limitările sale în SMD. Metoda parametrului de tip curbă pare robustă mai ales atunci când este utilizată în PD și GSD.

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