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A CAD - System engineering interoperability by Enriching CAD database with functional information

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Abstract-The functional aspect of the parts and assemblies is the engine that generates constructive solutions that satisfy customer requirements. When specifying design solutions, the designer always thinks in terms of function to be satisfied. However, this information is immediately lost once the design solution is validated. In this context this paper will first contribute to the enrichment of the “computer aided design, (CAD)” modeler database by integrating data related to product functions. Then, it will enrich the data related to assembly constraints by the fit aspect. It would be useful if the designer can specify, when creating an assembly constraint between a shaft and a hub (either through bearings, bushings or by direct contact), the type of constraint fit (tight, loose or uncertain). This information will be necessary, for example, when automatically generating assembly or disassembly drawings.

The main objective of the proposed paper is the development of two applications. The first application named “computer aided design part function, (CAD PF)”, used for the enrichment of the parts database by the part function. The second one named “computer aided design adjustment constraint type, (CAD ACT)”, used for the enrichment of the database of assemblies by the type of constraint adjustment during their creation. These tools will be modeled by the graphical “system modeling language, (SysML)” and will be implemented using FreeCAD “Applications Programming Interfaces, (APIs)” which is an open source application.

Keywords: *CAD, Function, Workbench, FreeCAD, Adjustment, CAD data, SysML.*

I. INTRODUCTION

The process of designing a product starts with an idea to finish with a product ready to be manufactured and then used in industry. A

complex product used in automobile sector or aeronautic had many requirements. The manually requirements verification seems to be impossible. It needs to be automatized. In addition, in sub-assemblies identification many approaches are based on fit matrix notion to decide whether a part belongs to a sub-assembly or another. Fit matrix is manually generated. So the idea of helping the system to generate it automatically is interesting. The objective of this paper is to develop an approach that allows to automatically generating the allocation matrices for requirements verification and

validation, also to automatically generate the fit matrix for sub-assemblies identification. According to Farin et al. the current use of “computer aided design, (CAD)” tools presents a revolution in modern industry. Commercial and Open Source packages are motorized with geometric modelling kernel which is responsible for generating geometric forms within these systems [1]. Companies developing “computer aided design, (CAD)” software are concentrating their efforts on user interfaces by opting for ready-to-use geometric modelers [2]. The geometric modeler is the heart of a “computer aided design, (CAD)” system; however, this kernel gives the possibility of developing CAD applications [3]. They are used to resolve many problems based on data extraction. Gouta et al. had developed a new tool named CADLAB which extract part and assemblies database in two different formats:

Excel and Matlab [4]. Also, Belhadj et al. are interested with the same theme for “assembly sequences and disassembly sequences, (AS/DS)” determination [5]. This approach is based on the identification of sub-assemblies especially for mechanisms with a very high number of parts. Wang et al., Li et al. and Giri et al. Yu et al. are interested with the same topic.

CAD systems outputs are usually technical drawings or digital files that will be used in CAM manufacturing or CAE [6-9]. The success link between CAD/CAM systems is defined by the efficient method of processing a decomposed object from the CAD database and reconstructing entities for downstream applications [10]. In order to enrich geometric CAD models, Raphael et al. presented a methodology to enable the translation of STEP schema and its instances to Ontology Web Language OWL Onto-STEP [11]. Similarly, Daniel et al. developed an approach which establishes a method to enrich a CAD model by integrating information such as maintenance intervals of parts, costs of parts, or also index numbers for the complexity of installation [12]. In order to ameliorate the communication between “Model-based systems engineering, (MBSE)” and CAD system, Brahmi et al. proposed an approach using the SysML profile. This profile presents the whole CAD assembly structure and the architecture generation to identify the internal assembly architecture. But, until now they need an automatic database extraction tool to translate the mechanical assembly information into SysML [13].

This paper aims to contribute in CAD enrichment to enhance CAD/CAM interactions, sub-assemblies identification based on fit matrix and CAD/system engineering interaction based on allocation matrix generation. Firstly, it offers a system that enrich part database with functional information such as the function, the number...These information are used to automatically generate the allocation matrix. Allocation matrix serves in engineering system, it's used to validate part requirement. Secondly, this paper offers a sophisticated system that enrich assemblies database with other functional matrix such as fit type and tolerance interval in shaft-hub

assemblies. These information are used to automatically generate the fit matrix. This matrix serves for CAD sub-assemblies identification and to improve the accuracy of manufactured products for CAD/CAM applications.

II. PROPOSED APPROACH

The proposed approach is composed of two principal steps. The CAD PF plug-in which is a CAD Part Function tool aims to add the part function during the design process. Each part has at least one function to be defined and added to the part data base. CAD PF must be integrated in the design model when the design starts; designer must first specify the part function and can update it by adding secondary functions or modifying the existed function during the design process. On the other hand, the CAD ACT plug-in which is a CAD Adjustment constraint type tool aims to specify the fit type between two parts. As an illustrative example, this paper concentrated on the constraint in an assembly between a shaft and a hole. CAD ACT must be executed in the assembly design process when the designer tries to create a constraint between a shaft and a bore. He must first specify the fit type and the tolerance between them. The output of these tools is the generation of two types of matrices: the Allocation matrix [A] with CAD PF and the Fit matrix [F_{it}] with CAD ACT.

A. Allocation matrix generation based on the part function integration

The proposed tool gets the access to the Part Design workbench and relates its opening with the execution of a new design activity. When a Part Design model is opening, the CAD PF plug-in displays the graphical interface and shows an arborescence of creation that includes a box named CAD PF. If the user reply for the interface needs, the plug-in gets the information and save them in the part data base. This information can be executed and modified any time. Figure 1 illustrates the CAD PF flowchart.

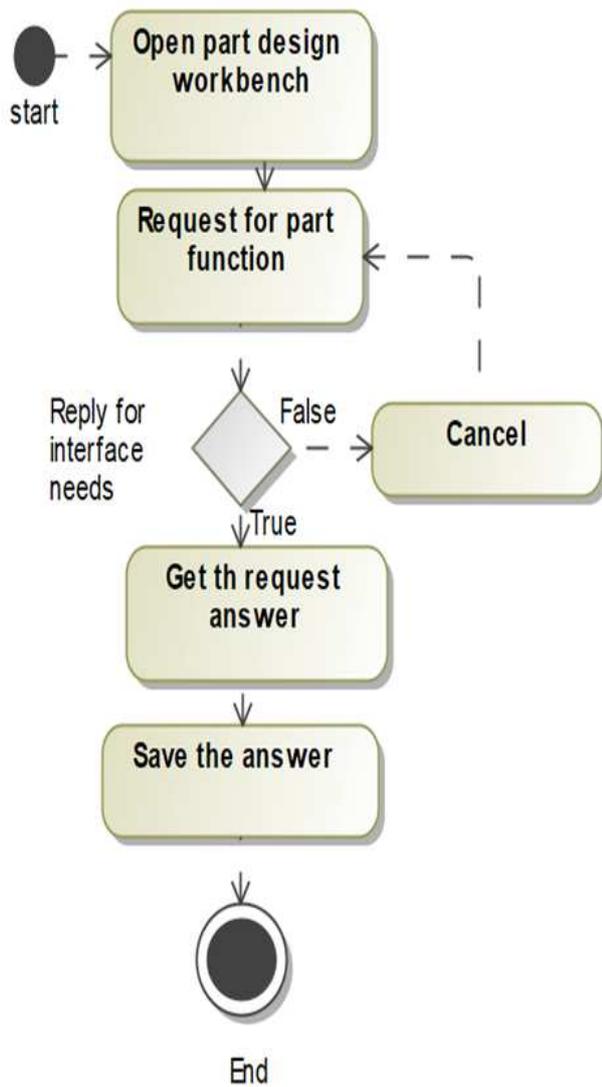


Figure.1. CAD PF flowchart

B. Fit matrix generation based on 3D adjustment technic

The CAD ACT algorithm is presented in the figure 2. It presents the plug-in contribution in the assembly model.

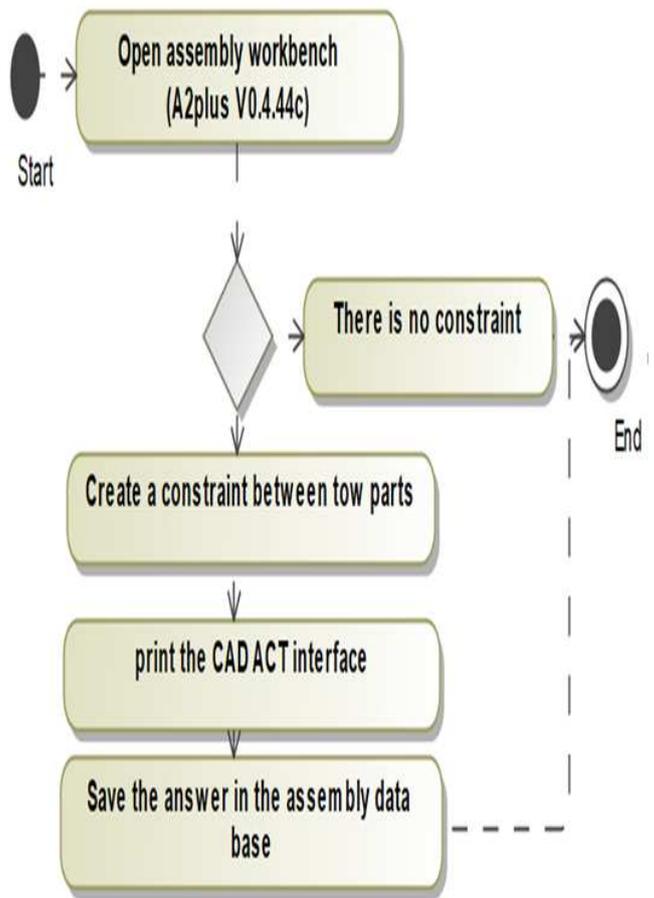


Figure.2. CAD ACT flowchart

If the designer opens the assembly model, the plug-in starts the scan process. When a coaxial or cylindrical constraint is chosen the plug-in executes its interface. The designer must fill the interface with the fit type and its tolerance. When the user saves the information, they will be added to the assembly data base.

III. IMPLEMENTATION AND VALIDATION OF THE PROPOSED APPROACH

A. Implementation

The data-processing implementation of the CAD PF and CAD ACT tools are carried out using the FreeCAD software. The API functions of the CAD system are handled with Python programming language. The CAD generated data enrich the CAD system database with functional information.

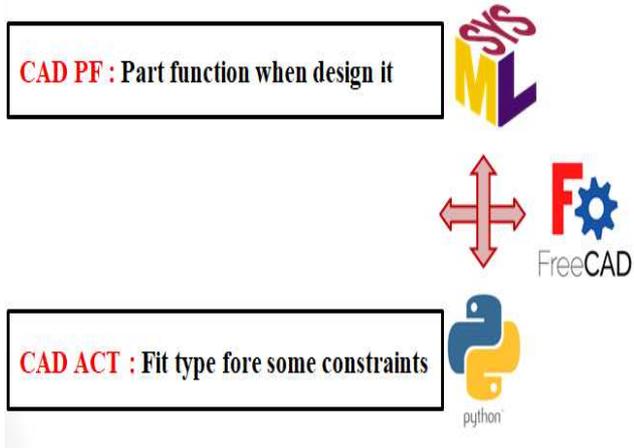


Figure.3. Software used in this paper

The CAD PF and CAD ACT tools are integrated and demonstrated with the open source CAD system FreeCAD and modeled with the “system modeling language, (SysML)”. The integration of the CAD PF and CAD ACT tool with another CAD system can be carried out easily after some manipulations in the implementation. Figure 3 presents the software using during the tool preparation.

B. Validation

The validation example, presented in figure 4, is a Watt machine. It’s a thermal engine that transforms thermal energy to mechanical energy. Because it generates a regular energy it is considered as key of industrial revolution in 1763. This section is concentrated on the function of some parts and the fit type in some shaft-hub assemblies. The system is taken from Traceparts

library: <https://www.traceparts.com/fr>.



Figure.4. Watt machine

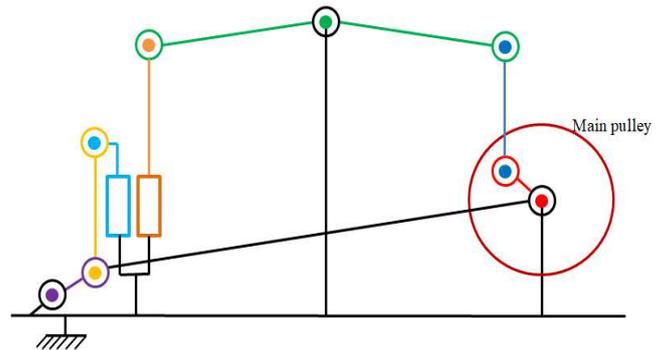


Figure.5. Watt machine kinematic chain

The graphic interfaces developed with the CAD PF and the CAD ACT tools are presented in Figure 6. They take automatically the document name, then; adds the properties defined by the user before to the document database. The CAD PF interface composed of: part name, number, function, function details, standard library and user help. When the part design is executed this interface is displayed.

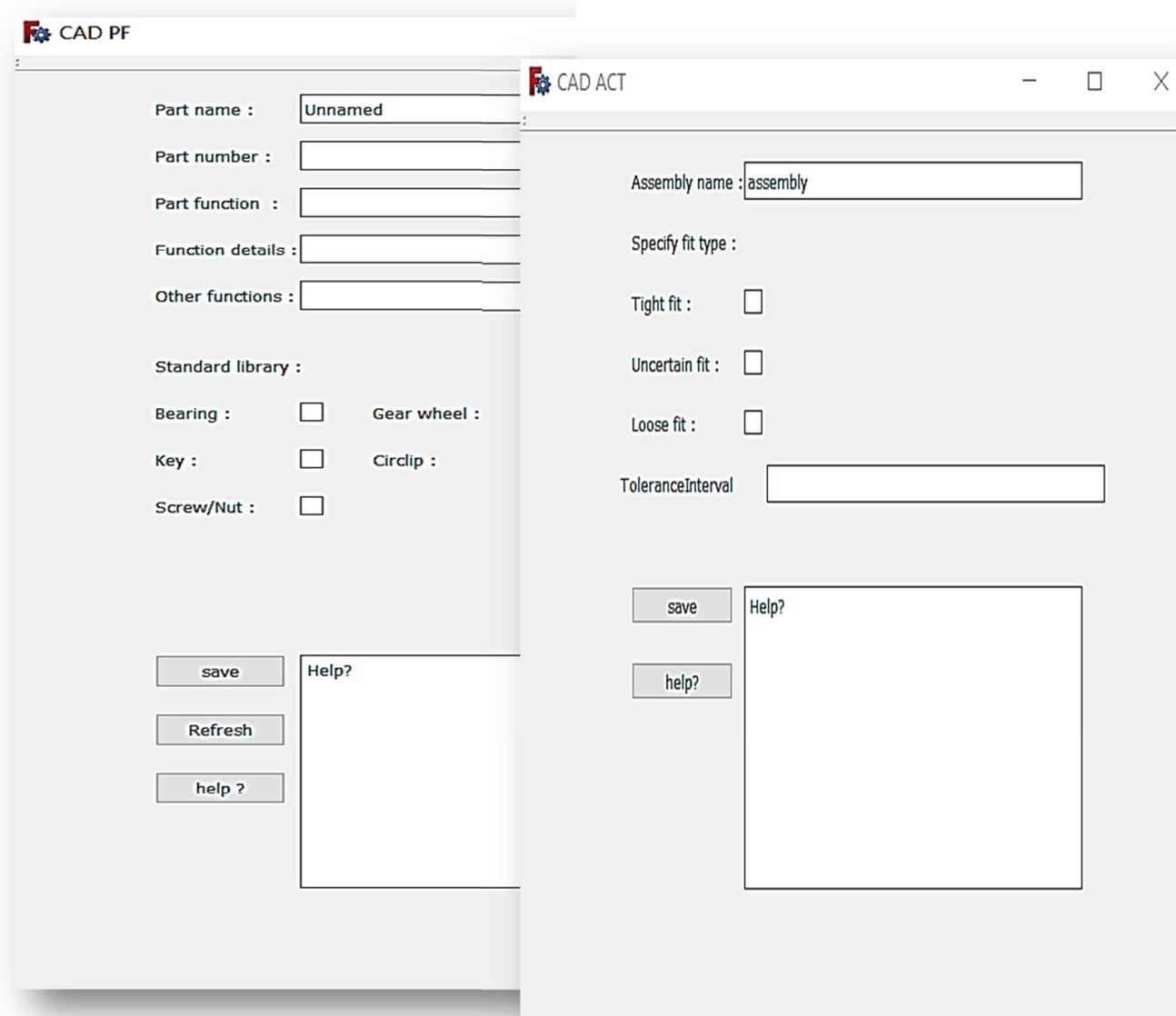


Figure.6. CAD PF and CAD ACT main interfaces

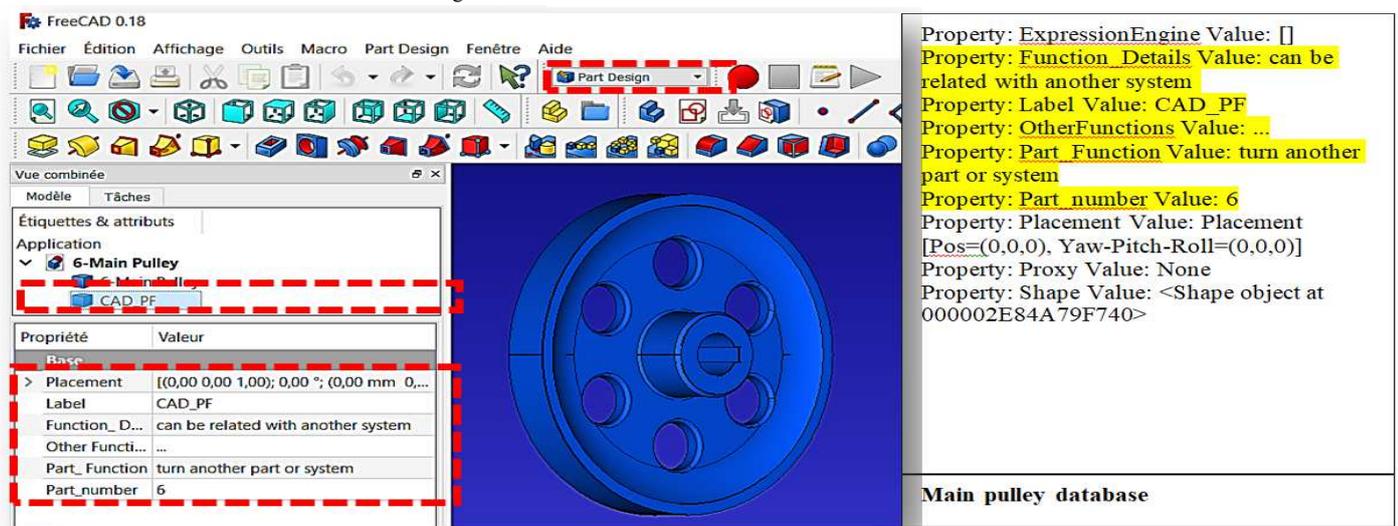


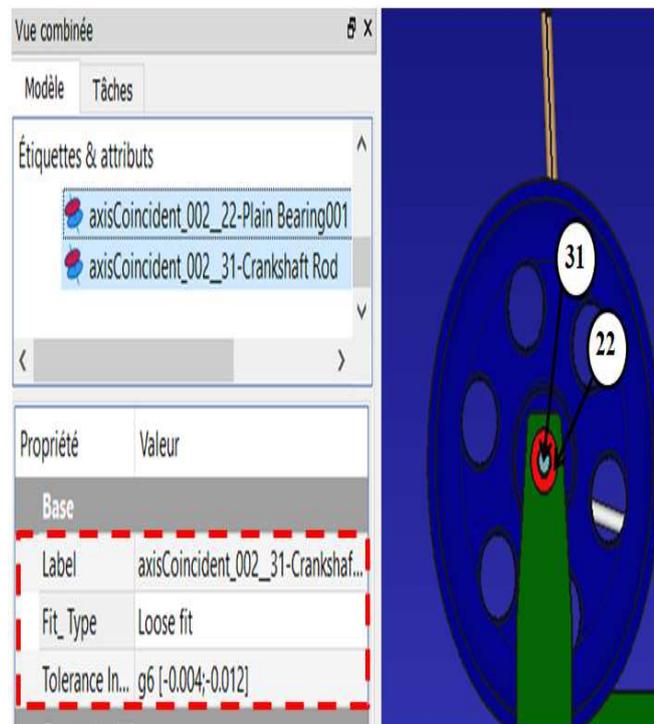
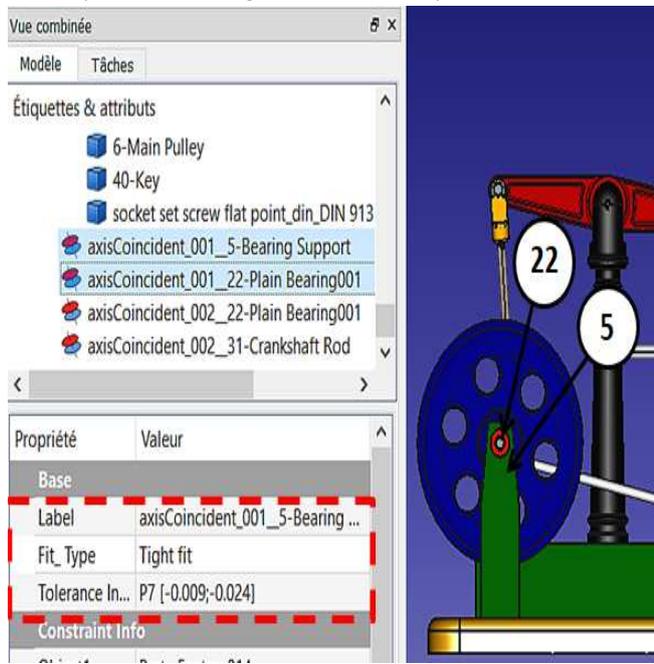
Figure.7. Application of CAD PF on Main pulley and its database extraction

The CAD ACT interface is composed of: fit type (tight, loose, uncertain), tolerance interval and user help. Currently, the plug-in executes automatically the CAD ACT interface when a coaxial or cylindrical constraint is selected.

They are automatically executed and linked directly to the design and assembly models. The

proposed algorithms, after some manipulations, can be adapted to other CAD systems. Also, data generation is fully automated.

The designer must simply enter the required information for fields requested by the implemented plug-ins. All the added data are always recoverable.



| Vue rapport | |
|---------------------|------------------------------|
| <u>Fit_Type</u> | <u>Tight fit</u> |
| Label | axisCoincident_001_5-Bearing |
| Support | |
| Object1 | Part_Feature014 |
| Object2 | Part_Feature002 |
| SubElement1 | Edge16 |
| SubElement2 | Edge78 |
| ToleranceInterval | P7 [-0.009;-0.024] |
| Type | axial |
| directionConstraint | aligned |
| lockRotation | False |
| <u>Fit_Type</u> | <u>Tight fit</u> |
| Label | axisCoincident_001_22-Plain |
| Bearing001 | |
| Object1 | Part_Feature014 |
| Object2 | Part_Feature002 |
| SubElement1 | Edge16 |
| SubElement2 | Edge78 |
| ToleranceInterval | P7 [-0.009;-0.024] |
| ToleranceInterval | |
| Type | axial |
| directionConstraint | aligned |
| lockRotation | False |
| <u>Fit_Type</u> | <u>Loose fit</u> |
| Label | axisCoincident_002_22-Plain |
| Bearing001 | |
| Object1 | Part_Feature017 |
| Object2 | Part_Feature014 |
| SubElement1 | Edge20 |
| SubElement2 | Edge18 |
| ToleranceInterval | g6 [-0.004;-0.012] |
| Type | axial |
| directionConstraint | opposed |
| lockRotation | False |
| <u>Fit_Type</u> | <u>Loose fit</u> |
| Label | axisCoincident_002_31- |
| Crankshaft Rod | |
| Object1 | Part_Feature017 |
| Object2 | Part_Feature014 |
| SubElement1 | Edge20 |
| SubElement2 | Edge18 |
| ToleranceInterval | g6 [-0.004;-0.012] |
| Type | axial |

Figure.8. Application of CAD ACT and Assembly database extraction

In the figure.8 it is a plan bearing between the shaft and the hub. It is a rotating shaft case, so the bearing (22) is mounted with tight fit on the support (5). A $\phi P7$ fit was chosen. The tolerance interval depends to the bore diameter. For a 12 mm diameter, the tolerance interval on the support (5) is [-0.009;-0.024mm].The Plain bearing (22) is mounted with loose fit on the Crankshaft (31). A $\phi g6$ fit was chosen. Therefore the tolerance is [-0.004;-0.012mm].

Tool validation is realized with another data extraction code that extract some parts and assemblies database. The code execution results are presented in figure.8.

IV. CONCLUSION

This paper offers pertinent tools that enrich the CAD system database with functional information. The first, named CAD PF can add the component function. The second, named CAD ACT can add the fit type and the tolerance interval for some constraints. This work aims to automatically generate the allocation matrix witch is very important to verify and validate the system engineering requirements. For this, the intervention is made to integrate the notion of the part function in CAD systems database. Also to automatically generate the fit matrix witch is vital for the subassembly identification.

In future work, an export of these tools to other CAD systems is envisaged such as CATIA and SolidWorks. CAD PF can be useful in the automatic generation of the allocation matrix. CAD ACT can be used in automatic subassembly identification using the fit matrix. Also, a comparative study will be done to compare these results with other results to present the benefit of this work in terms of time saving and use simplicity.

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