THE INTEGRATION OF DESIGN AND MANUFACTURING USING A DESIGN-WITH-FEATURES APPROACH FOR TURNED COMPONENTS

by:

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Abstract

This paper describes the work that has been done with an intention to integrate the design and manufacturing functions by developing a feature-based 'front-end' to a CAD solid modeller. This enables designers to express their concepts in terms of manufacturing features and processes, and simultaneously captures this information in a form suitable for an outline process plan.

1.0 Introduction

The Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) technique is the most promising technique in the engineering industry which utilises computers in designing and manufacturing components to increase productivity. The last 20 years has seen a vigorous development of a wide range of computer programs for CAD and CAM to improve the effectiveness in operation and cost of both design and manufacturing functions.

CAD systems represent models in terms of geometric entities such as faces, edges and vertices for Boundary model or in terms of primitives and Boolean operators for Constructive Solid Geometry (CSG) model. However, these entities do not have any meaning in the manufacturing sense. This is because CAM systems require detailed component information in terms of features such as cylinder, taper, undercut, hole, etc., together with manufacturing processes, tolerances and surface finish.

Integrating the design and manufacturing functions pose problems due to the difference in thinking between the design and manufacturing people. Designers always think of designing a new product in terms of its intended function whereas manufacturing engineers think in terms of decomposing a product design into a set of manufacturing operations.

Two approaches have been identified as alternative approaches in integrating the design and manufacturing functions. The approaches are the feature recognition approach and the designing-with-features approach [1].

The feature recognition approach is necessary when the component description from CAD system is not in terms of features but in terms of the primitive shapes. This involves recognising patterns of geometry that are features in the model of an object.

The designing-with-features approach provides the designer with a set of manufacturing features as an alternative to the primitive shapes in the solid modellers. These manufacturing features would correspond exactly to those functional features that the designer thinks of when constructing the model of a component. The geometry of the features can automatically be constructed by defining these features parametrically without require the user to translate the shapes of component into primitives.

The consideration of manufacturing features as an alternative to the primitive shapes for integrating the design and manufacturing functions has led the author in trying to use the designing-with-features approach by developing a feature-based 'front-end' to a CAD solid modeller

2.0 Objective

The objective of the research work discussed in this paper was to develop software suitable for turned components. The software will produce the geometric representation of the component in terms of manufacturing features and processes, and simultaneously captures this information in a form suitable for an outline process plan. Figure 1 shows the main components of the prototype system.

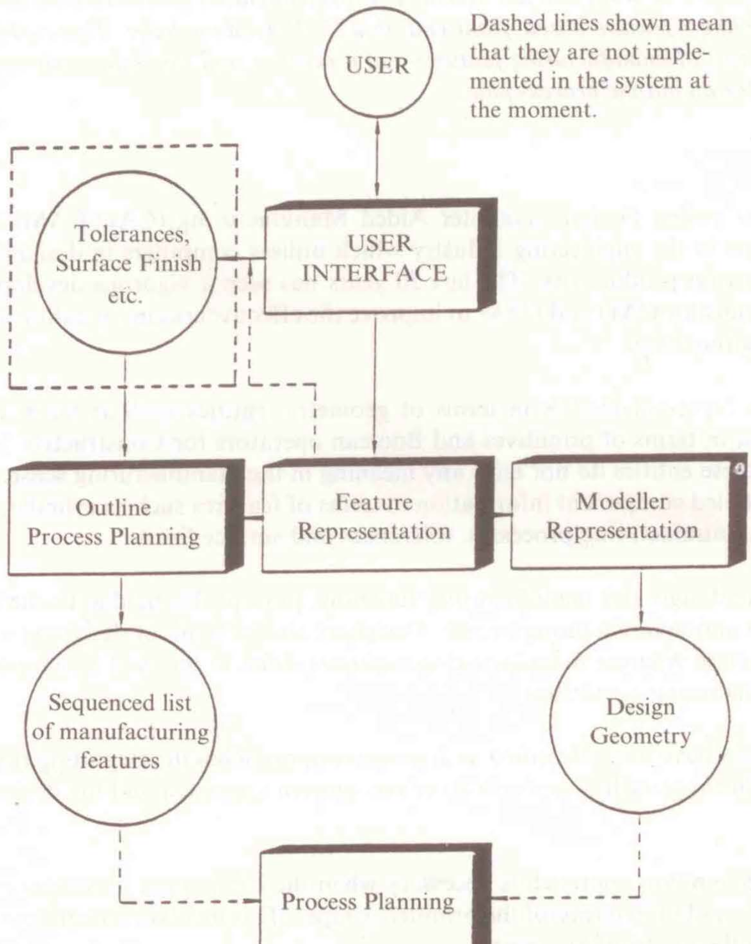

Figure 1: The Main Compenent of the System.

2.1 The Geometrical Specification File

The geometrical specification can be defined as a special program consists of the parameter values of the features which can be used to construct the geometry of the features in the solid modeller.

In creating the geometrical specification file, the user takes a sketched drawing of the rotational machined component consists of a number of features such as cylindrical surfaces, taper, thread and so on, of several dimensions.

The systems asks the user for information about the component material and the shapes of the component in terms of length and diameter. Then the user has to decide in which order the features should be machined. After all the appropriate information has been keyed, the system will ask to save the files.

This file is then used to construct the geometry of the features in the solid modeller.

2.2 An Outline Process Plan File

In addition to the creation of the geometrical specification file, the system generates another file that contains the outline process plan file. The outline process planning can be defined as the determination of a rough draft of processes and tools with the certain feature parameters that are required in order to produce a particular component. This file contains information about the machine tools, cutting tools for machining the features and the parameter values of the features.

3.0 Solid Modeller

BOXER [2], a true solid modeller based on Constructive Solid Geometry (CSG) representation is used in representing the solid model of an object. The BOXER-CSG has been selected to represent the output of solid model not only because a CSG representation provides an effective and compact structure to define a solid object, but also because the 'DIFFERENCE' operation employed to generate the solid model is analogous to manufacturing processes.

3.1 SCOPE

When a shape of a model is frequently required with different dimensions, it is useful to 'hide' parts of definition away.

A 'SCOPE' can be considered as an area where objects and variables can be defined separately from the rest of the definitions and can be accessed from within the scope which they are defined.

There is a special scope where the variables of which can be accessed from any other scope called SCOPE COMMON. This is the scope set on entry to BOXER. The SCOPE COMMON statement can be generated as in APPENDIX I.

3.2 Feature Representation

The technique that has been used in creating the geometry specification and an outline process plan of turned component is Destructive Solid Geometry (DSG) of design-with-features approach. This technique is suitable for the process of removal of a volume of stock material where features are represented in the DSG tree representation which can be used directly by a feature-based manufacturing system.

3.3 Data Structure

The DSG data structure that has been used is quite similar to the BOXER CSG data structure, except that the 'DIFFERENCE' operator in the operator node is used. Each feature corresponds to a cavity volume to be removed by machining. A cavity volume is the solid volume of material to be removed from the stock material by one or more material removal machining operations. When a component is designed using a DSG model, there is an analogy between the modelling sequence and the machining sequence [3]. Figure 2 illustrates the feature representation and the data structure of DSG.

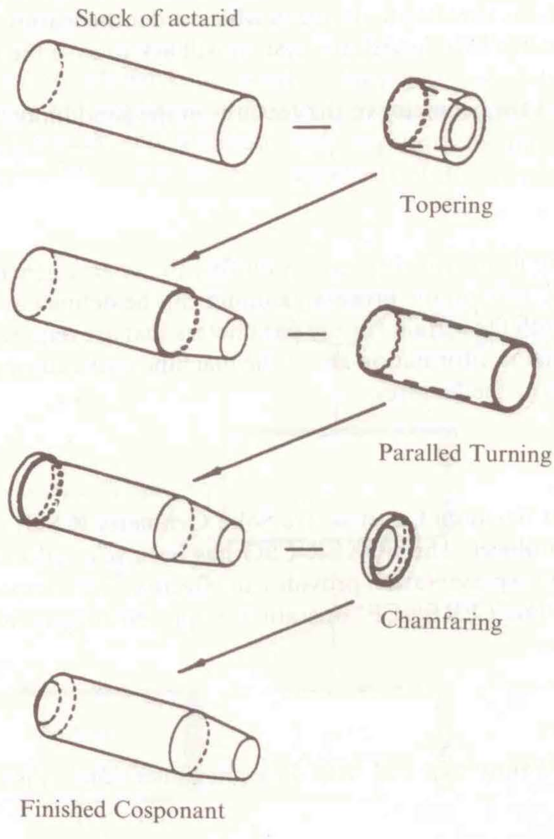

Figure 2: The Feature Representation in DSG Tree Structure.

4.0 System Description

The system that has been developed consists of a main program with subroutines written in Fortran-77 programming language, to run on an APOLLO-DN35OO workstation, under UNIX and AEGIS operating systems. These subroutines consist of a various feature modules and a modification of an existing design and plan module. This software is an interactive program where the input data is entered into the system by means of a user-friendly interactive session, that allows for an easy dialogue between the user and the system. The conceptual design of the svstem is illustrated in Figure 3.

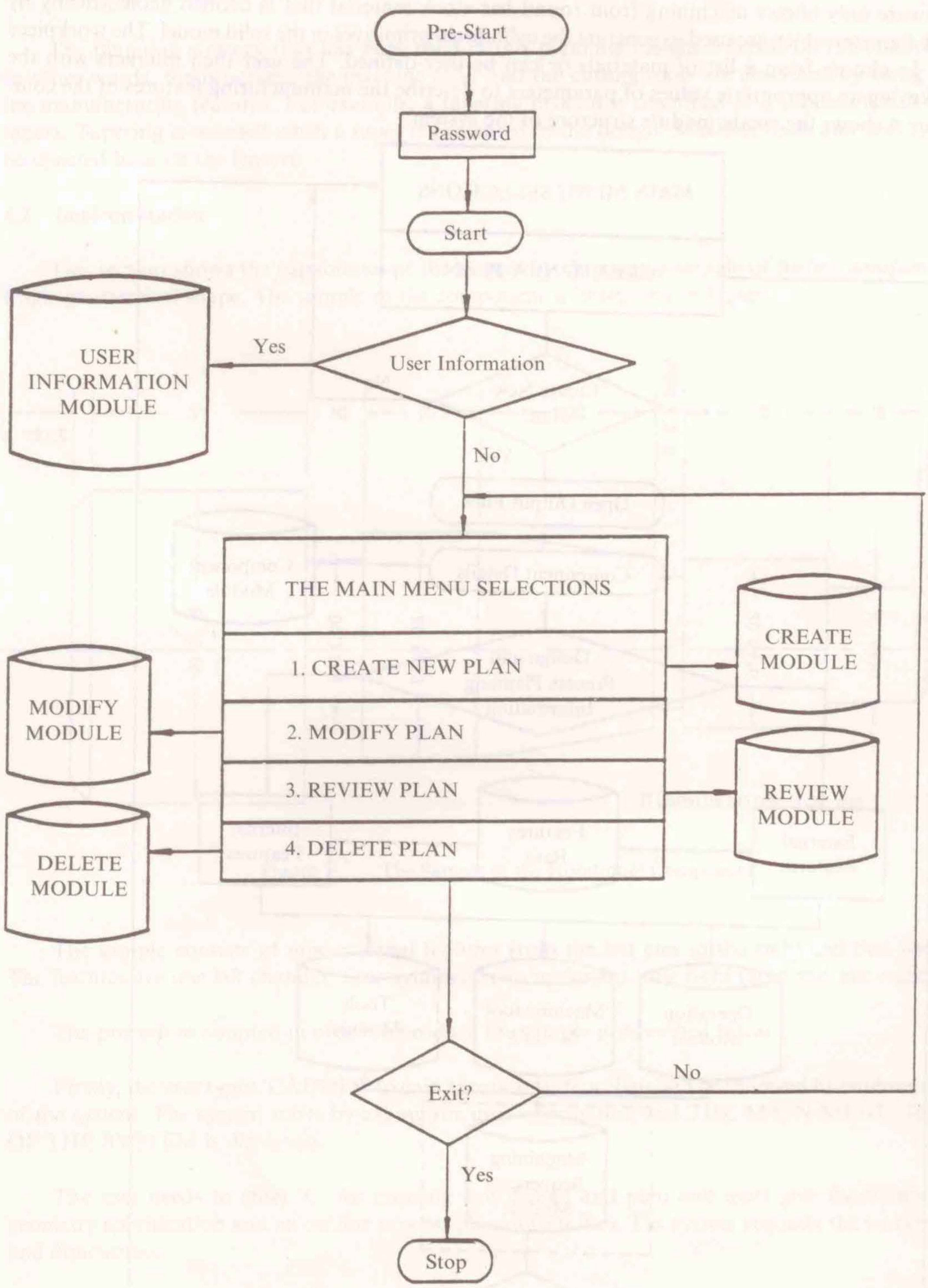

Figure 3: The Conceptual Design of the System.

The software only allows machining from round bar stock material that is defined geometrically by its length and diameter which are used to generate the cylindrical primitives in the solid model. The workpiece material can be chosen from a list of materials or can be user-defined. The user then interacts with the software by keying an appropriate values of parameters to describe the manufacturing features of the component. Figure 4 shows the create module structure of the system.

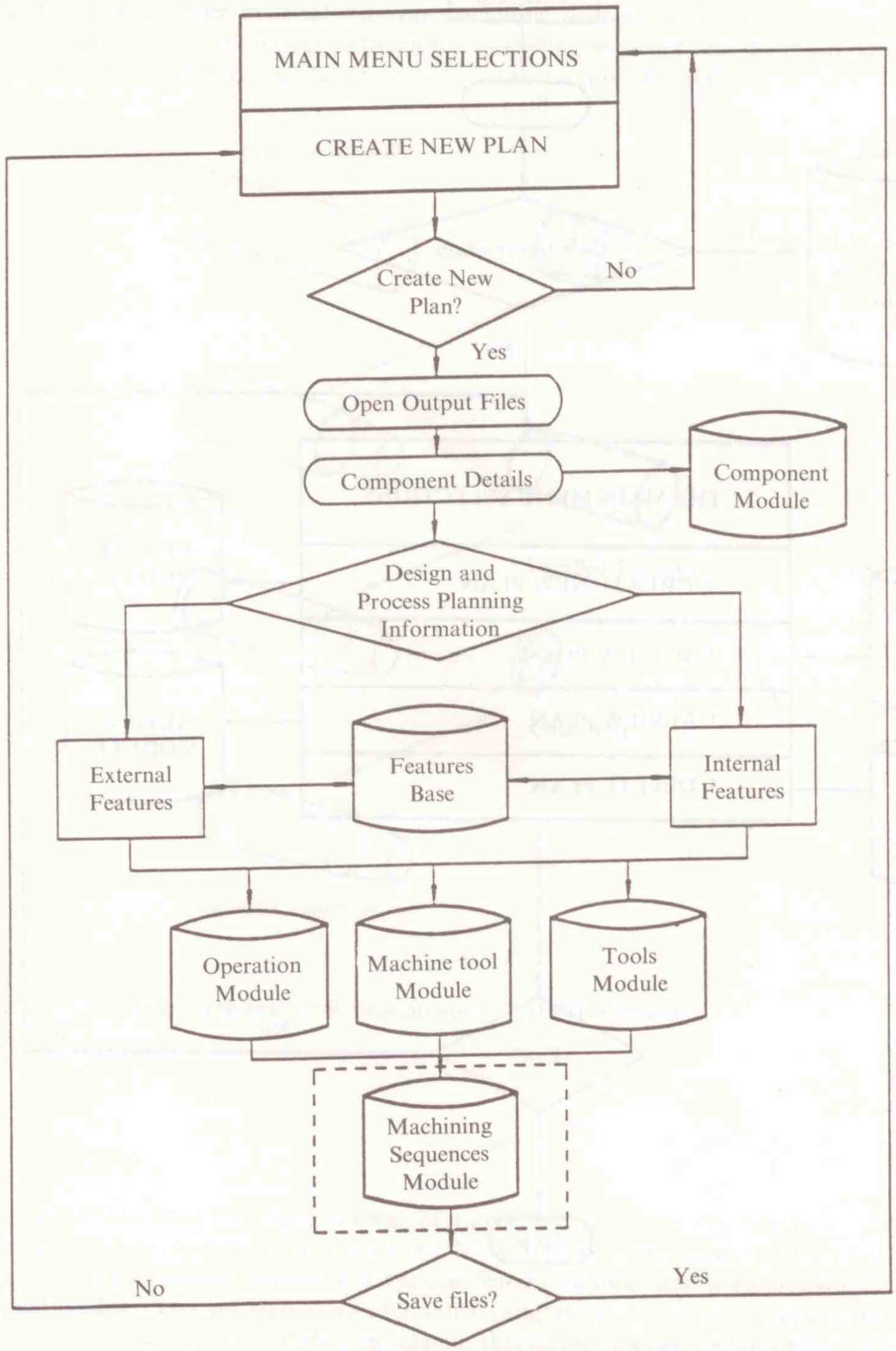

Figure 4: The Create Module Structure of the System.

4.1 Planning Strategy

The planning strategy that has been used in this planning system is based on the features name 14). In other words, the processes, the machine tools and the cutting tools are described by using the name of the manufacturing features. For example, a tapering process is described as a process which can produce tapers. Tapering is selected when a taper is presented in the design. Machine tools and tool types can also be selected base on the feature.

4.2 Implementation

This section shows the capabilities of the system by choosing a sample of turned component having a single geometrical shape. The sample of the component is illustrated in Figure 5.

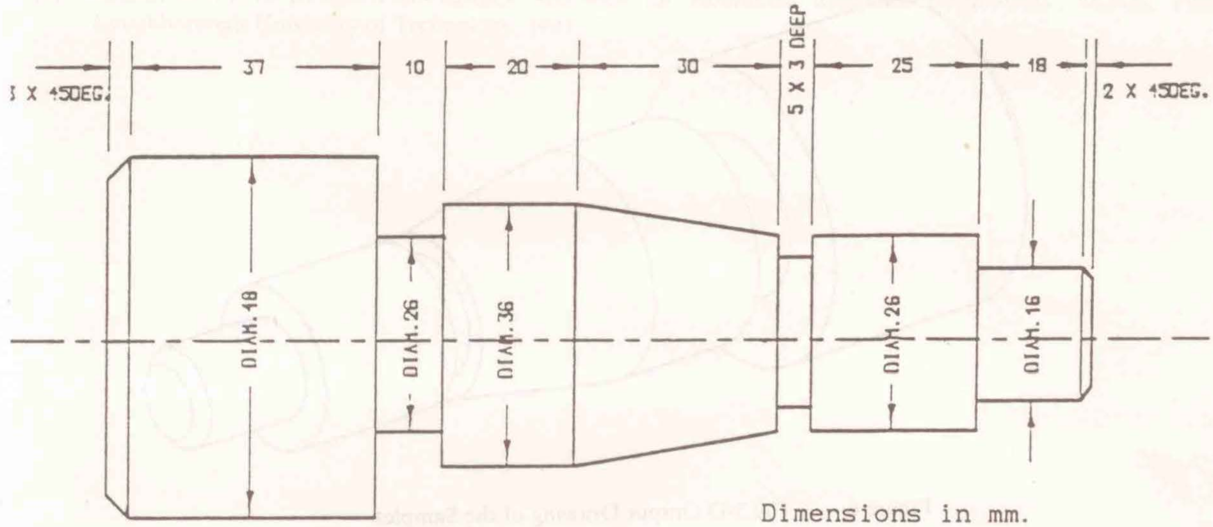

Figure 5: The Sample of the Rotational Component

The sample consists of nine external features from the left end to the right end that need to be cut. The features are one left chamfer, four cylinders, two undercuts, one right taper and one right chamfer.

The procedure adopted in order to produce the sample is described below.

Firstly, the user types 'CADOPP' to gain access to system. This will be followed by entering the password of the system. The system starts by asking for user information and THE MAIN MENU SELECTIONS OF THE SYSTEM is displayed.

The user needs to enter 'C' for creating new design and plan and must give the names of both the geometry specification and an outline process plan output files. The system requests the workpiece material and dimensions.

The FEATURE MENU is then displayed for the user to select the features that should be machined. The features should be machined from the right end to the left end. Since this sample has only external features, only EXTERNAL FEATURES menu is chosen.

The input of the dimensions and the location of the features is prompted for each feature type chosen.

When all the input of the feature has been performed, the user needs to enter the "OO" key to save the files and this will return the user to the MAIN MENU SELECTIONS OF THE SYSTEM for further action.

The corresponding geometric specification and an outline process plan files for the first sample which is carried out by the system is shown in APPENDIX II and APPENDIX III.

The files consist of the operations, the machines and the necessary tools. The corresponding attributes for each feature such as length, diameter, pic, pattern type and so on are also listed. The 3-D output drawing of the sample is shown in Figure 6.

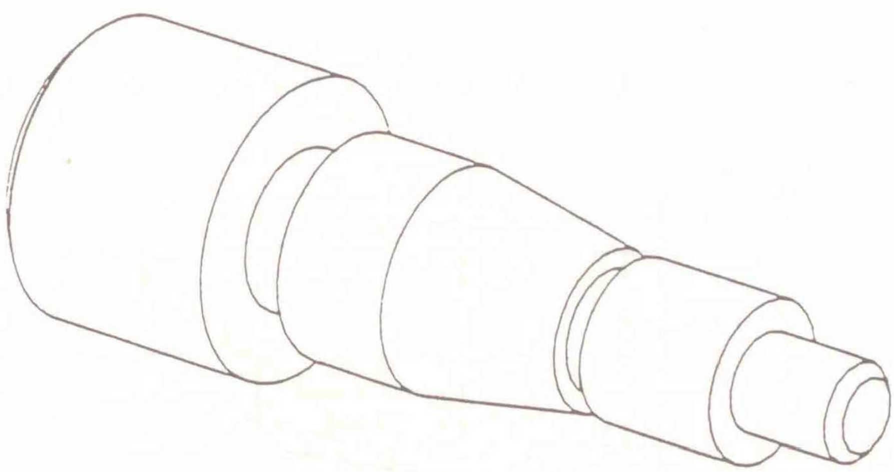

Figure 6: The 3-D Output Drawing of the Samples.

5.0 Discussion

The results [5], have clearly shown that the integration between both design and manufacturing functions can be done by using features. In order to model a component, the system provides the answers concerning the features and their characteristics. This is a definite advantage using this approach. The relationship between features and manufacturing processes can be used to construct the process planning.

However, this approach has arise a constraint in sequencing the manufacturing processes in order to create the process plan. The method of sequencing the processes is based on human expertise. Further research is needed in providing an expert system for sequencing the manufacturing processes.

The system described is limited to the design and manufacturing problems and it should considered that this is an integrated activity which can be done by one person.

6.0 Conclusion

The overall objective of the research is to integrate the design and manufacturing functions by using the design-with-features approach. Although, there has been some earlier research aimed at gathering the information from CAD systems for manufacturing processes, the system that has been reported here creates the geometrical representation of the component and captures information related to the component for manufacturing purpose.

7.0 REFERENCES

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