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ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

PREPARING FOR PART MANAGEMENT BASED ON FEATURE RECOGNITION TECHNOLOGY(AFR) AND STEP FILE

MASTER'S THESIS

Sara OMAIR

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İSTANBUL GEDİK ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (191281008) numaralı öğrencisi Sara Omair'nin "Preparing For Part Management Based On Feature Recognition Technology (AFR) and Step File" adlı tez çalışması Enstitümüz Yönetim Kurulunun 16.11.2021 tarihinde oluşturulan jüri tarafından *Oy Birliği* ile Yüksek Lisans tezi olarak *Kabul* edilmiştir.

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DECLARATION

I, Sara Omair, do hereby declare that this thesis titled as "Preparing For Part Management Based On Feature Recognition Technology (AFR) And Step File" is original work done by me for the award of the masters degree in the faculty of Engineering Management. I also declare that this thesis or any part of it has not been submitted and presented for any other degree or research paper in any other university or institution. (16/11/2021)

Sara OMAIR

DEDICATION

This study is wholeheartedly dedicated to my lovely parents, who have been our source of inspiration and gave us strength when we thought of giving up, who continually provide their moral, spiritual, emotional, and financial support. To my brothers, who were my support every time. To my best friend and relative who shared their words of advice and encouragement to finish this study. And lastly, we dedicated this research to the Almighty God, thank you for the guidance, strength, power of the mind, protection and skills and for giving us a healthy life.

PREFACE

With the name Allah, most gracious, most merciful, who, alone brings forgiveness and light and new life to those who call upon him; and to him is the dedication of this work. I thank Allah for his great loving-kindness, which has guided all of us to say and inspire each other, and which has brought us from darkness to light. All reverence for our holy prophet (peace be upon him) who has directed us to recognise our maker. I also thank all my brothers and sisters who answered the call of Allah and made their decision to be on the right path of Allah. Special thanks to Dr. Mazin Alwswasi at the University Of Technology in Baghdad (UOT). In particular, he was my leader and my teacher to finish my thesis. I would like to thank you for your advice to help me to complete my thesis and to show me how to succeed as a research scientist.

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I would like to thank everyone who reacted to me by giving me information or guide me. I have the deepest gratitude to my family, especially my parents for their dedication and support during my studies. Words cannot describe how my appreciative to my mother and father for all the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far. My thanks to lovely brothers for their support and their response to me every time they were near me when I needed them.

November Sara OMAIR

TABLE OF CONTENTS

Page

LIST OF ABBREVIATIONS

2D : Two Dimensions
3D : Three Dimensions
ACAPP : Automated Computer Aided Process Planning
AFR : Automatic Feature Recognition
B-rep : Boundary Representation
CAD : Computer-Aided Design
CAM : Computer-Aided Manufacturing
CAPP : Computer Aided Process Planning
CE : Cost Estimation
CR : Curve Radius
DBF : Design by Features
GB : Graph-Based
GD&T : Geometric dimensioning and tolerancing
IGES : Initial Graphic Exchange Specification
MSF : Merging Symmetrical Faces
NC : Numerical Control
PDE : Product Data Exchange
STEP : Standard for the Exchange of Product
TE : Time Estimation

LIST OF TABLES

LIST OF FIGURES

Page

PREPARING FOR PART MANAGEMENT BASED ON FEATURE RECOGNITION TECHNOLOGY(AFR) AND STEP FILE

ABSTRACT

In the Parts planning stage, or as it is called computer-aided process planning (CAPP), decisions significantly affect the manufacturing process. Therefore, these decisions must be based on accurate design information from the computer-aided design (CAD) stage. Obtaining information about the features and dimensions of the part at the design stage helps in choosing the appropriate tools to make each feature and shortening the planning time, in addition to relying on this information to estimate the manufacturing time or cost. Industrial parts management requires many tools and methods during the (CAPP) stage.

In this thesis, this information was obtained using feature recognition technology (AFR). A system consisted of several precise algorithms to extract the accurate information for the design using the C Sharp (C#) programming language. Step design files formats were used as input to this system. This system deals with the random information of the step file and infers useful information. Text files are dealt with instead of CAD files because it is more easy and secure in exchanging data between industrial facilities. This system is limited to rotational parts and a certain number of pre-defined features. The process of obtaining feature information and its dimensions contributes to reducing a lot of planning time and a lot of papers and does not require the presence of expertise, as anyone can use the system. And This information was used to estimate the manufacturing time for some features as a case study.

This system can be developed to include a larger number of features, and the process of estimating time and cost can be automatically included in it, in addition to choosing equipment, processes, and manufacturing conditions.

Keywords: *Computer-Aided Process Planning (CAPP), Automatic Feature Recognition (AFR), Step File, Estimating Machining Time.*

ÖZELLİK TANIMA TEKNOLOJİSİ (AFR) VE ADIM DOSYALARINA GÖRE PARÇA YÖNETİMİNE HAZIRLIK

ÖZET

Parça planlama aşamasında veya bilgisayar destekli süreç planlaması (CAPP) olarak adlandırılan aşamada, kararlar üretim sürecini önemli ölçüde etkiler. Bu nedenle, bu kararlar bilgisayar destekli tasarım (CAD) aşamasından alınan doğru tasarım bilgilerine dayanmalıdır. Tasarım aşamasında parçanın özellikleri ve boyutları hakkında bilgi edinmek, üretim süresini veya maliyetini tahmin etmek için bu bilgilere güvenmenin yanı sıra, her bir özelliği yapmak için uygun araçların seçilmesine ve planlama süresinin kısaltılmasına yardımcı olur. Endüstriyel parça yönetimi (CAPP) aşamasında birçok araç ve yöntem gerektirir.

Bu tezde bu bilgiler, özellik tanıma teknolojisi (AFR) kullanılarak elde edilmiştir. Bir sistem, C Sharp (C#) programlama dilini kullanarak tasarım için doğru bilgileri çıkarmak için birkaç hassas algoritmadan oluşuyordu. Bu sisteme girdi olarak adım tasarım dosya formatları kullanılmıştır. Bu sistem, adım dosyasının rastgele bilgileriyle ilgilenir ve faydalı bilgiler çıkarır. Endüstriyel tesisler arasında veri alışverişinde daha kolay ve güvenli olduğu için CAD dosyaları yerine metin dosyaları ele alınmaktadır. Bu sistem, dönen parçalar ve belirli sayıda önceden tanımlanmış özelliklerle sınırlıdır. Özellik bilgilerinin ve boyutlarının elde edilmesi süreci, çok fazla planlama süresinin ve çok sayıda kağıdın azaltılmasına katkıda bulunur ve sistemi herkes kullanabileceğinden, uzmanlığın varlığını gerektirmez. Ve bu bilgiler, bir vaka çalışması olarak bazı özelliklerin üretim süresini tahmin etmek için kullanıldı.

Bu sistem daha fazla sayıda özellik içerecek şekilde geliştirilebilir ve ekipman, süreç ve üretim koşullarının seçilmesine ek olarak zaman ve maliyet tahmin süreci otomatik olarak dahil edilebilir.

Anahtar Kelimeler: *Bilgisayar Destekli Süreç Planlama (CAPP), Otomatik Özellik Tanıma (AFR), Adım Dosyası, İşleme Süresinin Tahmin Edilmesi*

1. INTRODUCTION

1.1 Introduction

All companies operating in the industrial sector enter the field of effective competition with each other when it comes to achieving production in the shortest possible time and thus reducing the cost and effort as a consequence of that. The time includes all of the design time, planning time, manufacturing time, etc., until the product is delivered. Any increase or decrease in time in any stage of production dramatically affects the work of companies and thus affects their sustainability. The design time depends on experience and knowledge. The entry of computing and the possibility of designing with computer-aided design programs or what is known as CAD made the design process faster in terms of time, more accurate, and capable of modifying the design for the purpose of product development (Cosic & Kovacic, n.d.). At the design stage, The product development process needs the knowledge of the manufacturing information, and the only way to know the manufacturing information is to conduct an accurate planning process for the product manufacturing process, while this planning process depends on the design information (Komatsu et al., 2020). Figure (1.1) illustrates the link between the information of each stage (Moshahedi & Mehranfar, 2021).

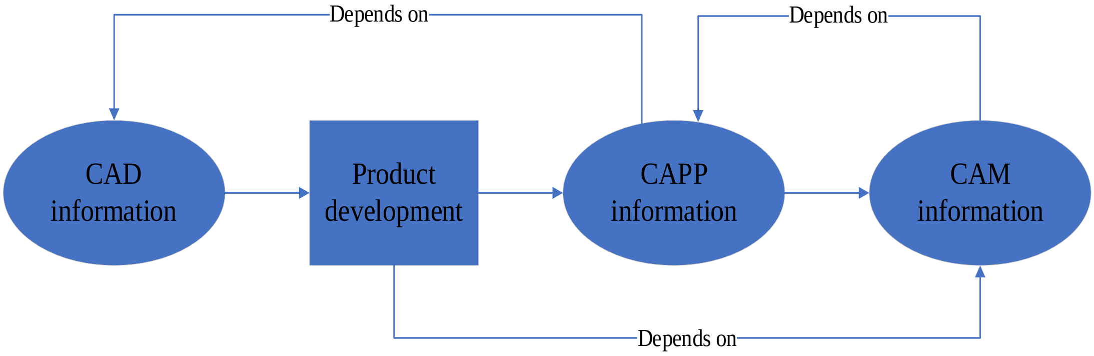


Figure 1.1: The integration of the production process information

In the context of manufacturing, process planning is the determination of the processes and resources required to complete any of the manufacturing processes. These manufacturing processes transform raw materials into finished products while adhering to geometric and technological constraints (Mital et al., 2014). Computer technology was first used for process planning four decades ago (Yusof & Latif, 2014). The planning functions become more accessible and more accurate with the assistance of computer applications. They are referred to as computer-aided process planning (CAPP), which represents the integration of computer-aided design (CAD) and computer-aided manufacturing (CAM). The terms “island of automation” refer to CAD, CAPP, and CAM. They are linked to one another, and their mission is to transfer data regardless of system differences (FAI, 2001). The speed of the planning process determines the period of planning time. The traditional planning process is carried out by experts to achieve the results of its content, which takes a long time and effort; however, when the planning process is automated, it does not require the presence of experts and can be completed in a short time. As mentioned earlier, the planning process needs design information. This information includes interesting engineering or topological characteristics in the part. These characteristics are called features and generally called feature technology (Wilson & Pratt, 1985). The goal of feature recognition (FR) is to use an algorithm to extract higher-level entities (such as manufacturing features) from lower-level elements (such as surfaces, edges, etc.) of a CAD model (Sohlenius, 1992).

Various approaches for automatic feature extraction have been proposed by several researchers. Since these feature extraction processes rely on the internal representation of a specific CAD system, they cannot be applied to other CAD systems (Li et al., 2010). To address this limitation, Some researchers convert the CAD model to a standard neutral file format and then extract the data from that neutral file (Sivakumar & Dhanalakshmi, 2013a). Because neutral files, such as STEP, contain coordinate data in the form of a text file, this technique benefits from generalization and easy feature extraction. To address the problem of extracting data from a CAD model, only a few complex systems for specific applications have been developed (Manoharan et al., 2016). In this thesis, an automated planning system was developed that depends on the feature recognition technology and step file coming from any CAD program, and it is a tool that shortens the planning time and an entrance to estimate the manufacturing time.

1.2 Purpose of the Thesis

In general, the primary goals and objectives of any manufacturing process are as follows: management of total manufacturing time, increase in Material removal rate (MRR), i.e., productivity, reduction in machining cost without sacrificing product quality, and increase in profit or profit rate, i.e., profitability. All of these goals are commonly and significantly governed by the total machining time per piece (Papadakis, 1969).

This work mainly aims to develop a CAPP system that reduces the planning time and facilitates the process of estimating machining time per piece based on the system's outputs. The outputs are information that is considered essential in managing the manufacturing process. These outputs are very accurate because they are taken from the design directly after converting it to a text format in the form of a text file and using the feature recognition technology (FR) in analyzing the design information, which prevents any information from being lost. Therefore, it can be said that the purpose of this research is to establish possible links between 3D drawing/features and necessary production times. Establishing this link between the two phases and make the process planning task fully automated in itself contributes to (Planning, 2001):

1. A shorten to planning time.
2. Reduce the effort made between the CAD stage and the CAM stage.
3. Make this transition stage fully automated and does not require human intervention.
4. It is not necessary for experts to be present in planning the manufacturing process.
5. It creates consistent and accurate plans.

This planning function must be given more consideration in order to achieve the goals mentioned above.

Knowing the manufacturing information at an early stage should have many positive consequences in addition to estimating the manufacturing time, including:

1. It assists decision-makers in setting priorities in the event of a large number of product offerings simultaneously (Cosic & Kovacic, n.d.).

2. It's Shortening product development time by knowing its features while still in the design stage and correcting it to increase productivity (Rosenthal & Tatikonda, 1992). Being able to make crucial design modifications during the design phase (rather than during the production cycle) saves money since the cost of making design changes after the start of the product development cycle increases significantly with time (Whitney, 1990).

3. Knowing the manufacturing information and making appropriate planning for the manufacturing process helps reduce wasted time in the CAM stage.

4. Manufacturing data recognition is critical in DFM (design for manufacturing) methodologies. DFM is the simultaneous consideration of design requirements and manufacturing constraints in order to identify and solve manufacturing challenges during product design, thus reducing the lead time for product development and improving product quality (Gupta et al., 1997).

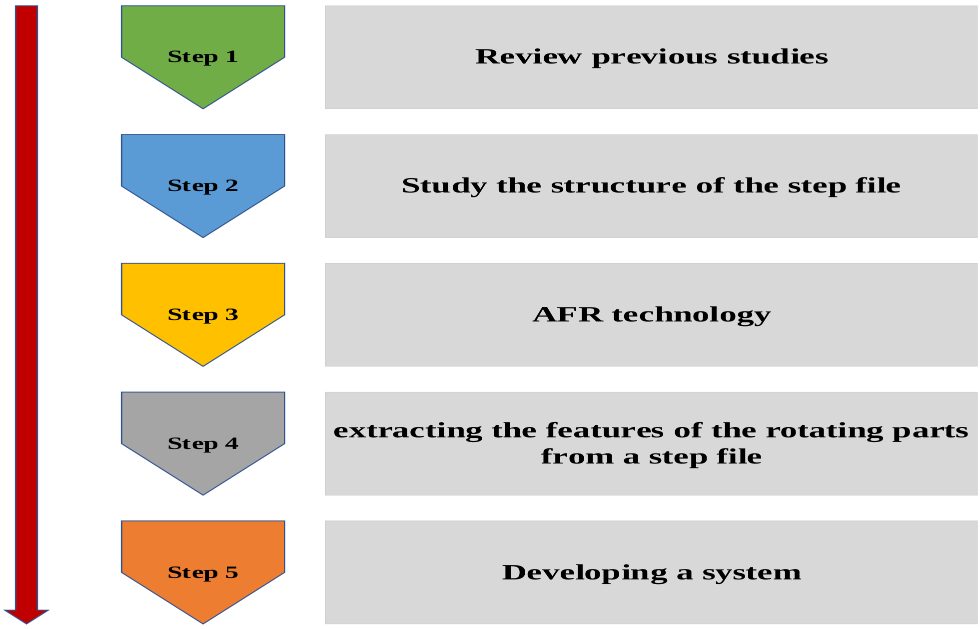


Figure 1.2: Workflow of the thesis

To achieve these goals, the following steps must be taken:

1. Review previous studies and acknowledge or criticize them.
2. Study the structure of the step file and derive a suitable method for its analysis.
3. Use (AFR) technology and focus on features of rotating parts.
4. Work out a strategy for extracting the features of the rotating parts from a step file.
5. Developing a system in C-Sharp language based on all of the above by making appropriate algorithms.

1.3 Literature Review

Time management, in general, is a planning process to control the time allotted to perform a specific function or activity (Rosenthal & Tatikonda, 1992). In order to manage the time of any manufacturing activity, computer-aided process planning (CAPP) must be performed. The (CAPP) relies on many techniques, the most important of which is the feature technology. As a result, According to experts, CAD/CAM integration by AFR and CAPP systems is essential for small and medium-sized manufacturers to succeed (M. Al-wswasi & Ivanov, 2019). This section will introduce previous studies linking (CAPP) to time management and the importance of feature technology in managing the (CAPP) time of the manufacturing process.

1.3.1 CAPP

This means that manufacturers must produce the product in a timely and cost-effective manner while maintaining acceptable quality. In order to carry out a production order successfully however the machines, tools and fixtures that will be used, as well as the length of time that each production step will take, must first be determined. It's worth noting that acceptable quality might not be the best quality, and the desired time period is also not usually the shortest, but the lowest cost is always preferred. As previously stated, process planning is used to generate this information. Process planning has traditionally been handled manually and based on experience.

- The scarcity of competent personnel to make machined parts, as in the past, is one difficulty affecting modern manufacturing.
- Manual process planning comes with its own set of problems. If the planners' judgment and experience are different, they may disagree on the optimal or best mode of production. There are several process plans for a single component in most sectors, resulting in inconsistent processes and extra paperwork.

A computer-assisted approach can be used to solve this problem. The use of computer-aided design (CAD) systems for geometry modeling has been going on since the 1960s (Ismail et al., 2002). By using computer-aided process planning, the process planner can focus on other tasks. Systematic application of computer-aided process planning in a wide range of sectors has been proven.

As a result of these technologies, planning time can be halved, from days to hours, and significant savings in money can be realized (Niebel, 1965). Numerous industries began researching this topic in the late 1960s and early 1970s. Computer-aided systems for report production and plan storage and retrieval dominated the early attempts to automate process planning. As long as they are used effectively, these systems can save a process planner nearly 40% of their work time (Planning, 2001). Yusof & Latif, 2014 provided a current survey with a graphical representation of CAPP’s past, present, and future for easy understanding.

Order of activities and appropriate resources are major issues on a "macro" scale, whereas "micro" process planning is concerned with the characteristics of each operation, time estimation, as well as the selection of tools and fixtures as required (ElMaraghy, 2007). The current work aims to obtain all the design information that enables us to estimate the time. Therefore, the present work is considered a micro-planning process.

Process planning narrows the scope of the planning to the production of a single part. The steps in the process planning Regardless of the order, (Planning, 2001):

1. Geometry Analysis.
2. Stock Selection.

3. Gross Process Determination.
4. Setup and Fixture Planning and Design.
5. Process Selection.
6. Process Detailing.
7. Plan Analysis and Evaluation.

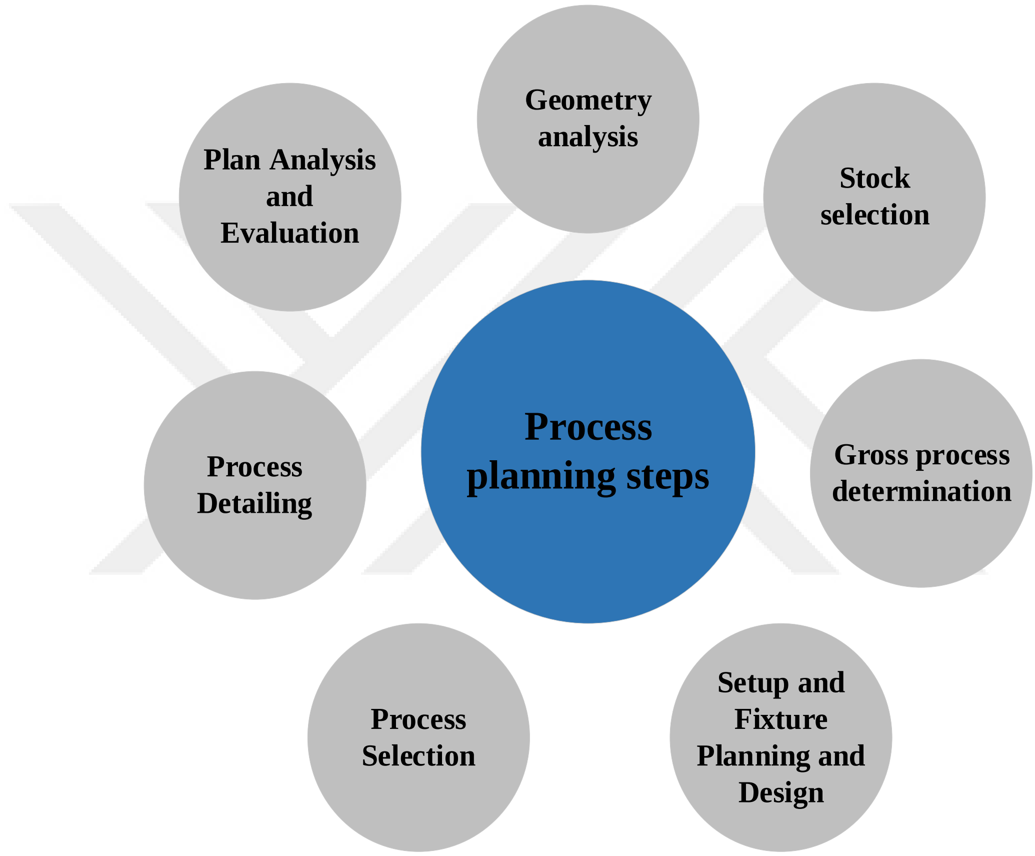


Figure 1.3: Process planning steps.

In general, process planners work in the order that they are introduced. The planning process, on the other side, is iterative. Geometry analysis, for example, is the first step. The planning process cannot begin without first knowing the geometry of the part. When choosing procedures or instruments, geometric reasoning is necessary to develop one's grasp of geometry. The iterative nature of setup planning and strategy selection is another example. The outcome of one has an impact on the other's outcome, and vice versa.

The tools used in computer-aided process-planning systems to carry out these stages are discussed in this section. They assist the human planner in creating process plans. The majority of these technologies have already been implemented in real-world process-planning systems. (Planning, 2001).

1. Group Technology.
2. Process Mapping.
3. Process Capability Analysis.
4. Cost Model.
5. Tolerance Charting.

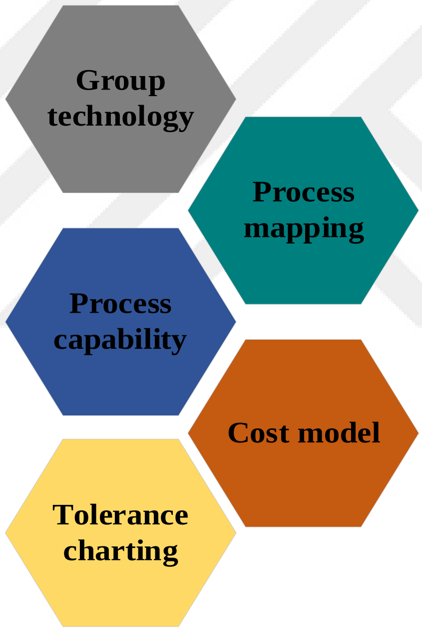


Figure 1.4: Process planning tools.

There are two types of the computer-aided production process: variant and generative. The computer uses table lookup algorithms to acquire designs for related components using the variation approach. Process planner makes adjustments to plan and generates a variant that fulfills the specific criteria of the planned component. Creating and revising standard plans is the responsibility of the process planner. According to this methodology, each component is designed from scratch, without reference to any previous blueprints. Many generative system functions are performed in a generative manner. Humans are used in the planning loop to complete the remaining functions.

There was a description of agents for conceptual design and planning integration by (Feng, 2005). In a knowledge base, Feng recorded characteristics such as shape and material as well as limitations, surface condition and shape intricacy as well as their mappings to probable production processes and resources. Information can be shared between agents/systems using the Agent Communication Language, which Feng designed. Denkena et al., 2007 have proposed a comprehensive component manufacturing system planning model based on an integrative technique that blends technological and business aspects. For component manufacturing process planning, these models provided as a foundation for the development of decision support and knowledge management templates and capabilities to help in cutting and abrasive process planning. Manafi et al., 2017 described one way to extract manufacturing data for computer-aided process planning systems by translating design data into manufacturing data, including calculating tool approach direction and defining reference faces. M. Al-wswasi & Ivanov, 2019 uses a STEP AP203, AP214, or AP242 file as a system input for an intelligent interactive AFR (SI-AFR) approach for identifying rotational part features. C# code was used to extract geometrical and topological information from a STEP file, building a database with a set of 54 predefined features while still intelligently learning how to detect new characteristics and integrating them into the dataset.

1.3.1.1 Variant approach

Planning strategies were initially digitized using a technology known as variant process planning. A presumption that process plans for similar items will be the same should be avoided at all costs. When used as a tool, a computer can be used to help locate similar plans that can be retrieved and edited to match the needs of certain portions. The following functions are included in a variant process planning system (Planning, 2001):

- Family formation
- Standard plan preparation
- Plan editing
- Databases

Variant process-planning systems are relatively simple to construct. However, they are accompanied by several difficulties (Yusof & Latif, 2014):

- The components that will be planned are restricted to previously planned components.
- Even the most experienced process planners must adjust the basic plan to meet the particular component.
- The plan's specifics cannot be produced.
- In the absence of additional process planning, variant planning cannot be used in an entirely automated manufacturing system.

Saeidi et al., 2019, developed CAPP-based variant software for feature recognition and extraction of cylindrical parts to provide raw data for CAPP systems. However, except for cylindrical part feature extraction, this program created the process planning program semiautomatically using the extracted feature data. Following recognition and extraction of features, the parts were classified and compared with the newly created database features, and one or more process planning programs were suggested. The new parts are also saved for later use in the program database.

1.3.1.2 Generative approach

Generic process planning is the second type of computer-aided planning. An automated process plan generator for new components can be described as such. Using information from a manufacturing database, A process plan can be generated without human intervention using the generative approach. An operation sequence can be generated for each component based on a design model. The following critical functions are included in a generative process-planning system (Number et al., 2012):

- Design representation
- Feature recognition
- Knowledge representation
- System structures

The following are the benefits of the generative process-planning approach (AMAITIK, 2005):

- It quickly generates consistent process plans.
- It’s just as simple to plan new components as it is to plan existing ones.
- It has the ability to link to an automated production facility and deliver extensive information on control settings.

Kretz et al., 2011 implemented a methodology for Generative Process Planning based on ISO Standard 10303. There was also a feature library based on the ISO 10303 application protocol 224, which they provided. Using the Qt framework, the presentation layer provides a user interface for the CAD module to create and customize product features. As a result, Deja & Siemiatkowski, 2018 developed a feature-based system for generating process sequences, which includes the assignment of machine alternatives.

The proposed system in this work is considered generative since it does not require human intervention. It only needs to receive the design in a form that it can accept. This system will extract design features and information that can be relied upon in the process planning in an automated or manual manner.

1.3.2 Feature technology

Feature technology can aid in the effective integration of design and manufacturing information, allowing for the collection of more manufacturing data during the design phase and the prediction of time consumption for future manufacturing phases. When it comes to integrating CAD and CAM, feature-based models have traditionally been used. There are two primary techniques. (Hu et al., 2015):

1. Feature recognion.
2. Feature-based design

In the feature-based design method, features are introduced immediately into the design stage of a part's creation. Designing the feature information is possible in both techniques. It is possible to use the feature data for both part representation and process planning.

1.3.2.1 Feature-based

CAD data can be represented as features in a feature-based model. Designers consider features to be functional elements. Design features are frequently distinct from manufacturing features. Ou-Yang & Lin, 1997 provide an estimator for the fabrication cost of a design, based on the shapes and precision of its features, in order to help a designer with little knowledge of the fabrication process estimate the fabrication cost early in the design process in order to avoid excessive costs later on in the production process. It was proposed by Yepez et al., 2021 to create an intelligent system that automatically delivers maintenance instructions at the product and component levels by using feature-based product identification. A framework for knowledge-based decision-making, robust reverse engineering, CAD model feature detection, product identification, and maintenance plan generation was developed as part of the research. An intelligent plan for the maintenance operation is generated when the recognized product is linked to the knowledge-based system given.

1.3.2.2 Feature recognition

To integrate CAD with CAPP, manufacturing feature recognition is essential. With the help of feature recognition, designers can highlight product functionality and make the most of it. This feature recognition system can identify the product's production features (Regli et al., 1995). Wang, 1990 Most proposed feature recognition systems rely on data from a solid model. Even while a solid model has all of the topology and geometry, it lacks important information such as measurements and tolerances. As a result, the solid model's recognition results may be disappointing (Wang, 1990). Recognizing details in 2D geometrical curves or text is more difficult compared to a solid model (You, 1998).

Owusu-Ofori & Chen, 1990, developed systems capable of recognizing features in rotational part drawings. As a result of their work, Dong & Wozny, 1991 were the first to use a frame-based reasoning method for machining features extraction for computer-aided process planning. Using this method, they were able to construct volumetric characteristics from surface features and perform a tool accessibility study. MEERAN, 1992, Was the first to use an expert system to identify features in drawings of non-rotating parts. Three groups of characteristics were used in his work: As a result, there are three different sorts of functionalities: simple functions, interacting functions, and general functionalities.

IGES files generated by CAD/CAM software were analyzed by Basu & Kumar, 1995 to extract key product model data information. Nodes and elements are the only mesh entities that are evaluated in this attempt. Using a simple code, a general-purpose IGES translator for preprocessing in a finite element or boundary element based analytic environment can be quickly created with minimal effort. A propose by You, 1998 that an automatic transfer system might recognize linear sweeping characteristics in 2D engineering drawings of non-rotational elements. A set of identification rules is used to identify features in the swept profiles after they have been derived from drawing views. Perng, 1988 suggested a two-stage approach for reconstructing the solid model using orthographic views and recognizing features in the initial solid model. J Gao et al., 2004 Discusses the use of constraints to define the hole-series feature model from data retrieved from a design database. In addition, feature interactivity was examined, and a feature-based strategy for generating hole-series machining features was presented. Lau et al., 2005 created an intelligent computer-integrated system for dependable design feature recognition in order to achieve automatic process planning. According to Mok & Wong, 2006, properties of plastic products can be divided into three hierarchical levels: primitive characteristics; complex characteristics; and high-level complex characteristics. Graph-theoretic and logic-based methodologies are combined in the suggested strategy. For automatic extraction of primitive and sophisticated characteristics of plastic parts, the authors provide enhanced multi-attributed adjacency graph (EMAAG) and feature-interaction feature graph (FIFG) approaches. For sheet metal components, Farsi & Arezoo, 2009 offered a feature identification module and a design adviser system. In this method, the features of sheet metal components are retrieved automatically from a 3-D model. These are object-oriented data. Visual Basic was used to construct the system in SolidWorks 2008.

Sunil et al., 2010 introduced a hybrid approach for identifying interacting features in prismatic machined parts using B-Rep CAD models (graph + rule-based approach). he created a feature identification system for prismatic parts that detected all variations of simple orthogonal features. Tarsitano et al., 2015 created a database with a definition of the features and linked it to a CAD modeler without specifying how they should be found. This database optimization significantly reduces the time complexity of feature finding, resulting in an acceptable time. Niu et al., 2015 shown how to leverage a database engine and CAD modeler to locate instances of entities that satisfy the predicates that make up features, as well as how to turn a declarative feature description into a SQL query. According to the researchers' findings, the time required to detect features increases with model size and feature count. The next chapter will elaborate on the concept of feature recognition, and its role in the proposed system will be addressed.

1.3.2.2.1 Feature extraction from step file

Increasing productivity requires computer-aided systems to have strong data exchange and system integratio. As a result, a neutral format for exchanging product data between manufacturing components has been developed (Ismail et al., 2002). STEP is an international standard for defining a product’s physical and functional characteristics in a complete, unambiguous, and computer-readable manner throughout its lifecycle. The problem with the STEP file, which was used in standards and specifications as early as 1984, is that the standard does not specify the sequence of instances in a STEP file.

Bhandarkar & Nagi, 2000 developed a standards-based system for extracting form-features. It uses a STEP file to define the geometry and topology of a part as an input and output. For process planning based on form features, a STEP file is used. The CAD data translator was built by Chao & Wang, 2001 to convert multiple file types to STEP format. With the STEP Translator, CAD/CAM users may effortlessly exchange their design files. Ismail et al., 2002 devised a method for extracting and recognizing cylindrical type features in STEP files. A compilation of manufacturing data such as length, radius, and Cartesian point is the product of this process. For the development of a STEP file-based feature recognition system, D Sreeramulu & Rao, 2008 presented an automatic feature recognition methodology. The proposed approach is intended for 3D prismatic parts built with any STEP-generating CAD software. JAVA software is used to implement the geometric data extraction algorithm, which was created to extract geometric information from the STEP file. The different features of the part are recognized using a feature recognition algorithm, such as the slot, pocket, etc. Using the B-rep database as input, the geometric reasoning approach is used. Using the STEP file as a feature extraction tool, Sivakumar & Dhanalakshmi, 2013 aimed to connect CAD, CAM, and CAI. NC codes for a CNC machine were developed using the feature information to build the desired parts. Sivakumar & Dhanalakshmi, 2013 created a system that extracts the manufacturing feature information from STEP files for cylindrical parts using a simplified and generalized methodology. The extracted information is used to generate controller-specific NC codes. Experimenting is done by turning cylindrical parts with generated codes and inspecting them with a CMM. Venu et al., 2014 suggested a new hybrid approach for the recognition of machinable features of prismatic parts with multiple features on distinct faces, which is encoded in the STEP AP 203 file format. The Java Standard Data Obtain Interface is used to access STEP AP 203 product model data (JSDAI). A two-stage technique is used to recognize features. A simple orthogonal feature can be recognized using the syntactic pattern recognition method in the first stage of the process. As a second stage, the graph-based method is used to identify any residual features that were difficult to recognize using the syntactic pattern recognition method. Jaider Oussama, Elmesbahi Abdelilah, 2014 Using STEP AP203 as a starting point, They devised a method for identifying rotatable parts' independent and interconnected properties. There are three steps to the process. STEP's geometric and topological data must first be extracted in the first step of the process. First, the data is taken from many sources, such as satellite images, and then it is processed to find turning features. It then creates all conceivable combinations of interacting features based on the features that were identified.

1.3.3 Time management

As mentioned in the previous paragraph, CAPP has a crucial role in linking CAD and CAM, and that an effective CAPP system can reduce the lead time. Reducing the time limit gives companies and industrial institutions the opportunity to break into the market and the product is still in the growth stage. (Chincholkar, 2002) enumerates some of the benefits of achieving the goal as follows:

1- Reducing the time limit reduces the time required for product development.

2- Reduce early design and development costs.

3- The company guarantees its market share for being the first to introduce the product.

Brookes & Backhouse, 1998 As the manufacturing process shortens and more products must also be brought into the market more regularly, address the importance of monitoring product introduction performance. Time-to-market measures, such as average concept-to-launch time, time for each development phase, average over-run and percent of products over-running, average time between product re-designs, and product performance measures, such as product cost, technical performance, quality, return on sales, market share, and design performance, are some of the performance measures that can be used to evaluate time-performance. They give case studies that examine product performance in a variety of business environments. Chincholkar, 2002 used performance indicators like production cycle time and throughput to explore the relationship between a product design and a certain manufacturing system.

1.4 Hypothesis

Some software tools have successfully lowered the barriers between design and manufacturing (Gupta et al., 1997). Manufacturing systems are exceedingly complicated and incorporate a wide range of complicated research issues. This project focuses on the creation of an expert system that detects part features and manufacturing information automatically. This system assumes to make the CAPP process fully automated in the manufacturing process of rotational parts for time management. In order to develop the part model, the designers used CAD software. To be effective, the process-planning system must be able to interface with the current CAD system. This system accepts CAD designs as input, however they are not in their regular state. It should be transformed into a format that is easily readable and exchangeable. A data exchange format like IGES or STEP can be used to input data into the system. This study will make use of ISO 10303, a new worldwide standard for exchanging product data, also known as STEP. All engineering information for part features and positioning is extracted from a step file. The feature recognition from the file format of the design may be complex, but it is more efficient and accurate, and it facilitates the exchange of files between institutions.

In this thesis, an algorithm will be created to analyze this file in a way that includes several steps, at the end of which the desired results are achieved, which are supposed to be:

1. Knowing the design features.

2. Other important design information, such as dimensions and tolerances, should be known.
3. Based on the previous two points, these results can be used to estimate the manufacturing time.
4. Reducing planning time by quickly discovering accurate design information.

This system automatically will provide information on manufacturing guidelines to designers during the initial design process that reduces costs and cycle times, and this effectively contributes to achieving their goals. This process is done by software that will be developed in the C# programing language.

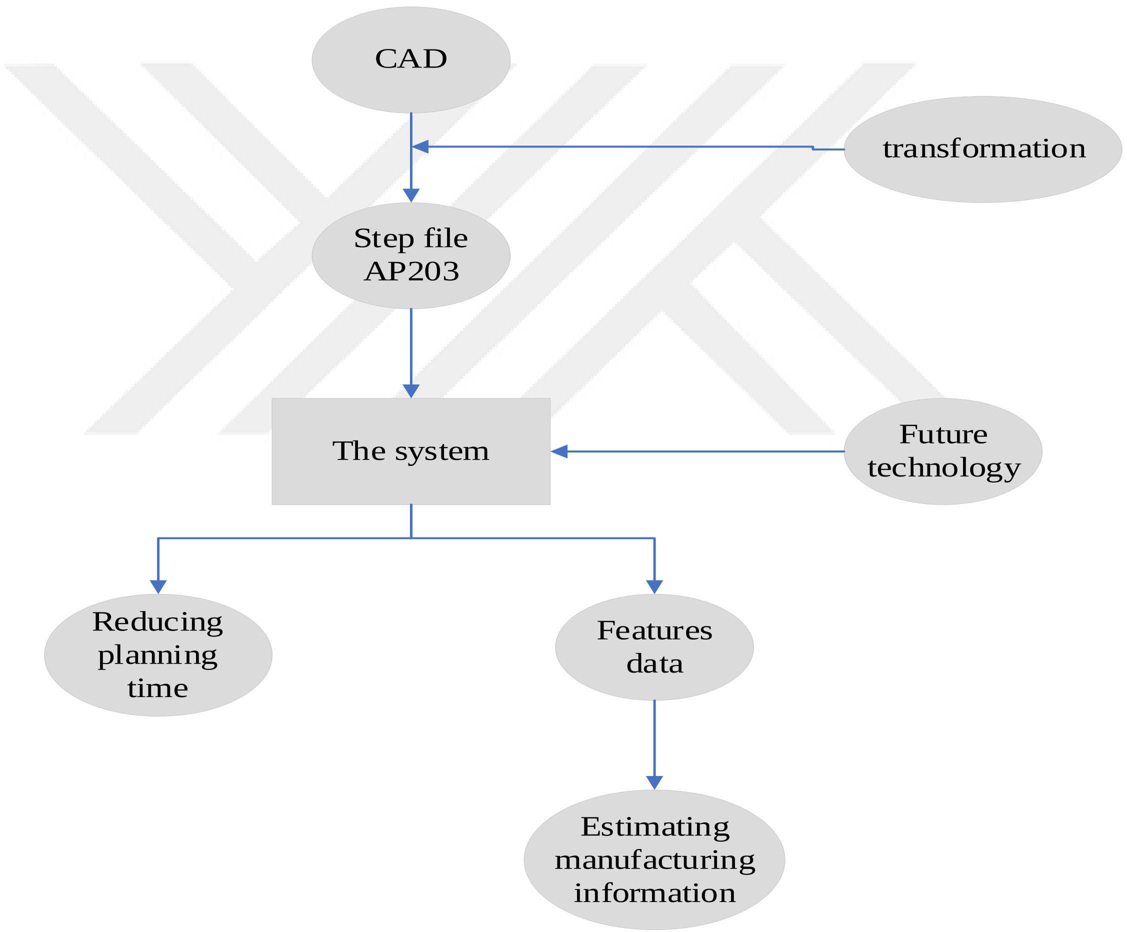


Figure 1.5: The inputs and outputs of the proposed system.

2. STEP FILE STRUCTURE

2.1 Introduction

The CAPP's objective is to choose the appropriate processes, tools and automatically produce operation sequences and instructions to build the part while taking surface roughness, Geometric Dimensioning and Tolerancing (GD&T) and economic and technological precedence restrictions into mind. To fulfill this task, CAPP needs to be able to extract and detect manufacturing information such as machining characteristics straight from a 3D solid model (Jaider Oussama, Elmesbahi Abdelilah, 2014). By connecting low-level geometric entities created in CAD systems such as points, lines, and curves, these features must be extracted and converted into high-level manufacturing features such as holes, grooves, and pockets. All AFR techniques can be used to perform this extraction automatically (M. G. Al-wswasi, 2019). To share design information between multiple computer-aided design (CAD) systems and downstream applications like computer-aided process planning (CAPP) can be a problem, however. It's a problem because each CAD system has a different database structure for storing information about geometric features of parts, and there isn't a unified standard that can be used by all systems to address this issue (M. Al-wswasi & Ivanov, 2019). As a result, various file formats for exchanging product model data have been presented in order to save and transfer design information. The product data exchange (PDE) formats can provide both geometric and topological information. IGES (Initial Graphic Exchange Specifications), STL (Stereo Lithography), DXF (Drawing Exchange Format), and STEP are some of the most used formats.

The availability of extensive geometrical and topological data supplied by PDE standards has motivated developers to use feature technology to link design and manufacturing systems (Dowluru Sreeramulu et al., 2016). It allows everyone engaged in the design, manufacture, marketing, and distribution of a product and its components to contribute, access, and share product data (Jaider Oussama, Elmesbahi Abdelilah, 2014).

Indeed, the use of CAD exchanging files is thought to facilitate automatic data transmission across several platforms, resulting in successful CAD/CAPP/CAM integration.

2.2 Step File

As the IGES and STEP formats have grown, DXF and STL files have become obsolete and no longer have any use. IGES can be utilized to represent the design and topology of a product model. This structure, on the other hand, does not support the life cycle and is difficult to comprehend. Thus, a new worldwide standard for the transmission of product model data, STEP (ISO 10303), is designed to enable product models throughout their entire life cycle, overcoming the limits of IGES file format and other neutral file formats interchange.

Step (ISO 10303) is an internationally recognized method of documenting and exchanging information about products throughout their lifecycle, from design to manufacturing to quality control to support (M. Al-wswasi & Ivanov, 2019). As an example of boundary representation data, the text file contains shells, faces, edge loops and vertices, as well as surface geometric data like cones and toroidal shapes. It also contains curve geometry like lines and circles as well as B-shaped polygons and ellipses (Jaider Oussama, Elmesbahi Abdelilah, 2014).

While several PDE standards have been utilized in various AFR systems, the STEP file has gotten special attention since it offers features that no other format can. When it comes to products, the STEP file transmits both geometric and non-geometric data throughout the product's life cycle. The feature extraction procedure makes it easy to recover part feature dimensions and locations from a STEP file (Sivakumar & Dhanalakshmi, 2013a). As a result, better data sharing across CAD/CAM systems is predicted with the STEP file.

STEP AP 203, STEP AP 214, and STEP AP 242 are some of the most widely used STEP application protocols (Xie & Xu, 2006). The AP203 STEP format is a “general” STEP format. AP203 provides the geometry, topology, and configuration management data for solid models of mechanical parts and assemblies. Colors and Layers are not managed by this file type (Venu et al., 2014).

2.3 Step File AP203 Structure

The STEP AP 203 file is a text file that is language-based. It contains Entities and strings that describe the representation of a product (M. G. Al-wswasi, 2019). It is separated into two parts: "HEADER" and "DATA" as shown in figure (2.1).

In general, ISO-10303-21 is the keyword that starts the STEP text file and is ended with the keyword END- ISO-10303-203. However, all the other data need not come in a common format.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION (( 'STEP AP203' ),
  '1' );
FILE_NAME ('cylindrical.STEP',
  '2021-02-07T22:36:46',
  ( '' ),
  ( '' ),
  'SwSTEP 2.0',
  'SolidWorks 2016',
  '' );
FILE_SCHEMA (( 'CONFIG_CONTROL_DESIGN' ));
ENDSEC;

DATA;
#1 = EDGE_LOOP ( 'NONE', ( #136, #5 ) ) ;
#2 = CARTESIAN_POINT ( 'NONE', ( 32.23588457517412600, 0.0000000000000000000,
60.53599254523973600 ) ) ;
#3 = DATE_AND_TIME ( #32, #36 ) ;
```

Figure 2.1: Part of the step file showing its sections.

The file name, creation date, company name, and programmer name are all included in the HEADER section. The essential geometrical and topological product data are represented by the entity lines in the DATA section. In the DATA section, each entity instance starts with "#," followed by a unique integer, entity name, and related data. Associative data can be strings, numbers, Booleans, or even a pointer to another entity instance in the file.

The geometrical and topological product data are organized using a hierarchical structure, as shown in Figure (2.2).

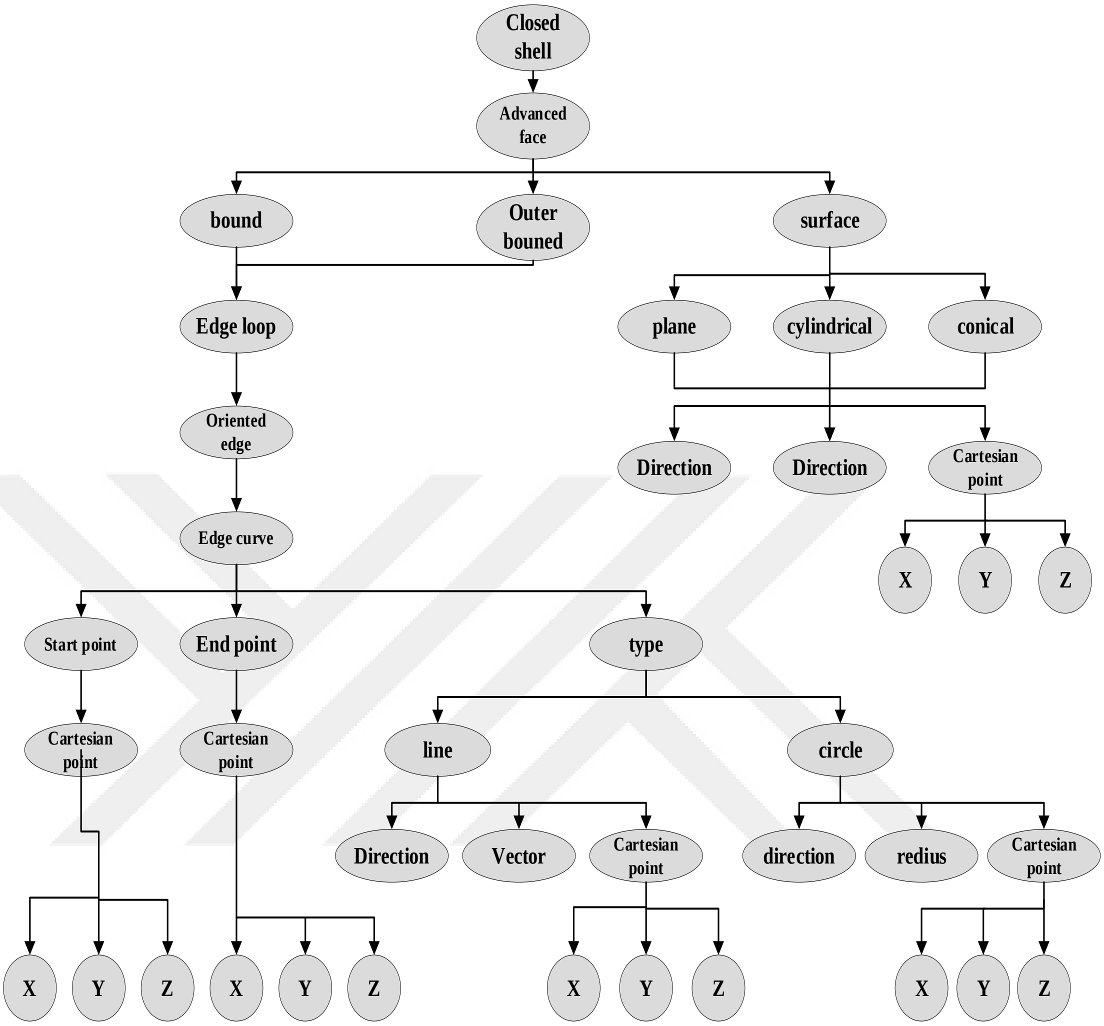


Figure 2.2: STEP AP 203 file structure

Source: (M. G. Al-wswasi, 2019).

The shell is the greatest level of description in this hierarchy, as it is a topological item that describes a 3D region by merging a number of faces along edges. The cylinder in Fig. is a “CLOSED SHELL,” and the STEP AP 203 file for it has 175 entity lines in the DATA section.

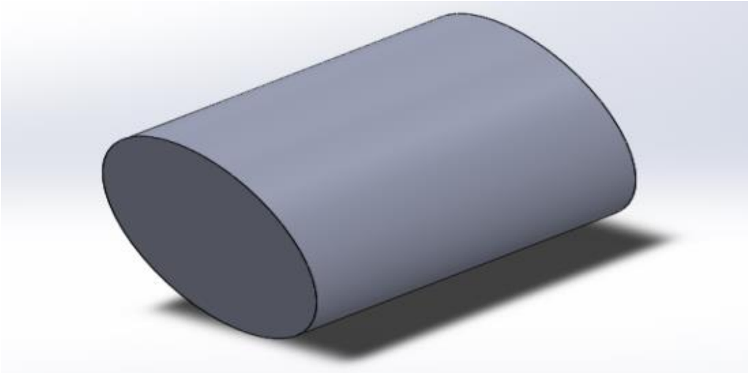


Figure 2.3: A cylindrical part.

The data arrangement in the physical text file does not appear in a hierarchical sequence, despite the fact that the STEP file has a hierarchical structure and represents the entity lines in a systematic manner. As a result, the top-level of the hierarchy, the "CLOSED SHELL" node, is not always present in the first line of entities. In reality, it might be anywhere in the DATA portion between the beginning and the end. This assertion is true for all levels of data. For example, the cylinder in figure (2.3) has a closed shell in the line with #62.

#62 = CLOSED_SHELL ('NONE', (#140, #23, #100, #152)) ;

The faces in a STEP AP 203 file represent the second level of description. Faces are topological entities that define a loop-bounded part of a surface that forms a CLOSED SHELL by sharing an edge with precisely one other face. A face is defined in a STEP file through geometric and topological entities, as shown below.

#140 = ADVANCED_FACE ('NONE', (#92), #61, .T.) ;

A face in the STEP file can be a plan, a cylinder, a cone, etc.

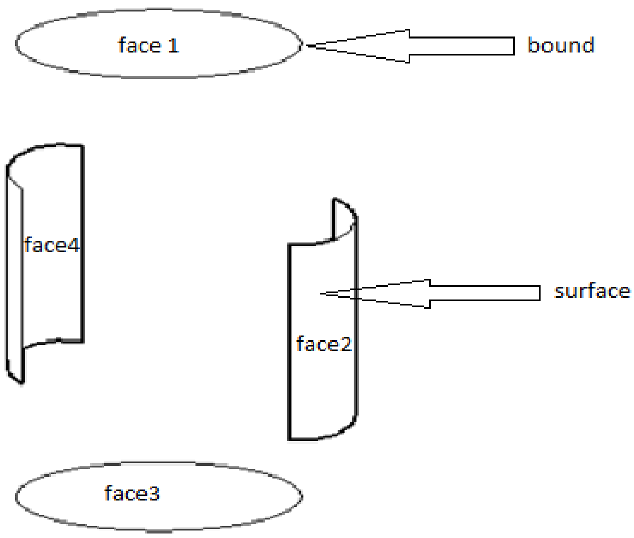


Figure 2.4: How is the cylinder represented from the point of view of the STEP file.

Figure (2.4) shows the cylinder's four faces, as well as the edges and vertices of the initial face #140. In order to specify the bounds and surface of each face, two pointers must be utilized. The bound is always represented by the first pointer, while the surface of the face is represented by the second pointer. The ADVANCED FACE object closes with a Boolean flag indicating whether the loop direction is aligned with or against the surface normal (Bhandarkar & Nagi, 2000).

#140 = ADVANCED_FACE ('NONE', (#92), #61, .T.) ;

Bound

According to the information in figure (2.2), this can be two sub-types: face-outer-bound and face-bound, which define an outer edge-loop and an inner edge-loop of a face, respectively. A face-bound is a loop of connected edges that are used to bound a face, and each face may have one or more bounds. The cylindrical shape, for example, has only face-outer-bound.

#92 = FACE_OUTER_BOUND ('NONE', #165, .T.) ;

However, the plane surface of the shape in figure (2.5) has a face-bound and a face-outer-bound.

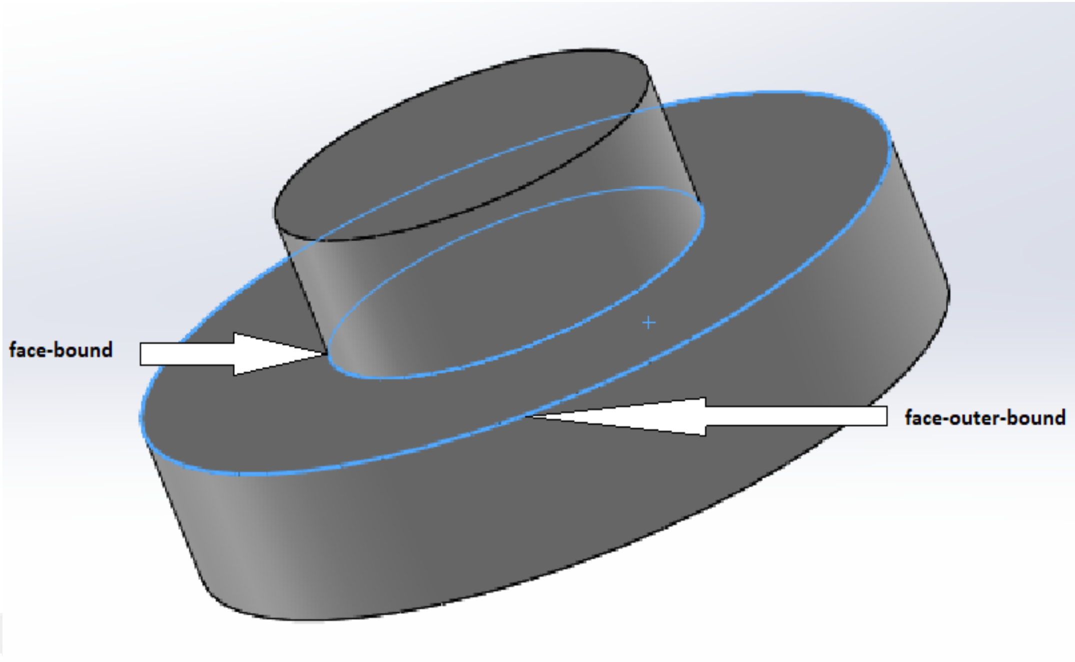


Figure 2.5: The face-bound and the face outer bound in one face.

There is always one "EDGE LOOP" sign, regardless of the type of bound. A closed path of oriented edges around a face with the identical start and endpoints is called an edge loop.

#165 = EDGE_LOOP ('NONE', (#79, #151, #71, #46)) ;

Another (original) edge is used to generate an oriented-edge. It holds information on the Boolean flag's direction (orientation). Edges can be defined as a line, a circle, or a B-spline curve with ellipse knots. As a result, the orientation of this Boolean flag can be reversed from the beginning to the end vertex.

#79 = ORIENTED_EDGE ('NONE', *, *, #7, .T.) ;

Each oriented edge corresponds to a single "EDGE CURVE," a topological entity with a beginning and an endpoint.

#7 = EDGE_CURVE ('NONE', #131, #95, #123, .T.) ;

Edge curve description is a geometric entity with fully defined geometry. A line, for example, has a start point vertex, an endpoint vertex, a vector, and a single direction, whereas a circle has a radius and two directions, as well as a start point, endpoint, and center point vertices. A vertex-point is a point that defines a vertex's geometry. The following records provide the start and end vertex points, respectively:

#131 = VERTEX_POINT ('NONE', #146) ;

Where #146 is a pointer to the vertex point's coordinates. A Cartesian point is the lowest level of the STEP hierarchy, and it specifies a vertex in Cartesian space using the axes x, y, and z.

#146 = CARTESIAN_POINT ('NONE', (32.23588457517412600, 0.0000000000000000000, 0.0000000000000000000)) ;

Surface

A face type is identified by its surface, which is able to only accept a single prospect, such as planar, cylindrical, conical, or toroidal.

#61 = CYLINDRICAL_SURFACE ('NONE', #35, 16.11794228758706300) ;

This section contains information varies depending on the type of surface. A cylindrical surface, for example, is described as "AXIS2 PLACMENT 3D2," that is specifies a reference vertex on the surface, a direction, and the radius of the surface.

#35 = AXIS2_PLACEMENT_3D ('NONE', #59, #6, #60) ;

The x-axis and z-axis directions are defined with regard to the part's global coordinate system, and a Cartesian-Point is an Address of a point or vertex in Cartesian space. The normal of planar and spherical surfaces, as well as the axis of cylindrical, conical, and toroidal surfaces, is represented by the local z-axis.

#59 = CARTESIAN_POINT ('NONE', (16.11794228758706300, 0.0000000000000000000, 60.53599254523973600)) ;

#6 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#60 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000));

2.3 Summary

The product is recognized from CAD models using feature recognition technology (Yepez et al., 2021). STEP is one of the international PDE standards and the most utilized in developing AFR and CAPP systems because it has the ability to transfer rich information of a product through its lifecycle. Robust process planning necessitates the use of technologies like step file and feature recognition, and these study areas are expanding at a rapid pace. Industries can use these tools to make production decisions since they are effective and powerful.

While most CAD systems provide geometrical and topological information through PDE files, such as STEP APs 203, 214, and the most recent 242, they do not provide information on part features. Many AFR systems have been created to ensure that the interface between CAD and CAPP is as efficient as feasible because CAPP is feature-based. Much of the present research incorporates new technology and tools to aid with planning. The use of STEP files in AFR systems, on the other hand, does not overcome the following constraints, limited ability to learn how to recognize a new feature, and restricted recognition of a limited number of predetermined features.

3. AFR SYSTEM

3.1 Introduction

In intelligent manufacturing, integrating CAD and CAPP systems in conventional methods necessitates a significant amount of effort, time, and cost. The contrast between CAD and CAPP systems, in which the former is based on geometrical and topological data, contributes to this disadvantage. The latter, on the other hand, is based on production characteristics. Vertices, edges, curves, surfaces, and relations are included in the former, whereas materials, view, general note, witness line, leader, and associativity entities are included in the latter.

The current intelligent manufacturing trend relies on manufacturing features to carry geometry and topology representation information. They're primarily derived from CAD models and used in subsequent engineering applications. In order to achieve process efficiency and high quality products, it's critical to sequence the manufacturing features correctly (Deja & Siemiatkowski, 2018).

3.2 The Design Importance

The production process begins with the design of the part and the deadline. On the basis of the requirements, an engineering design specification is created. A design model is created throughout the development phase. Traditionally, the design model is a hand-drawn engineering drawing (drafting) or a CAD model created with the use of technology (Harris & Meyers, 2007). Because of this, the majority of CAD/CAM systems in use today include solid modeling capabilities (Ismail et al., 2002).

Designers and manufacturers enter into a contract with the help of a design model. The whole geometry of the intended part, the measurements and tolerances, the surface finish, the material, and the finished material attributes must all be included in the design model. There is a comparison between the finished product and the design model. Only if all of the design model's specifications are met will the product be accepted.

3.3 The System Component

This study proposes a hybrid technique for identifying rotational part machining characteristics. These features were previously represented in the STEP AP203 file format, however they are now lost when the file is transferred to a different format. So in this approach, the feature-recognition module extracts features and information associated with them from the CAD part model and constructs the feature information model.

First, the CAD models will be designed and then converted to text as input to the system. The system accepts STEP AP203, AP214, or AP242 files, created in various CAD packages and represent a part's constructive solid geometry (CSG). SolidWorks is used as the CAD modeler. It was necessary to use the 3D model of the workpiece due to the large amount of geometry and topological information it contains. There are four steps in the AFR system that has been proposed. Before anything else, the text version of the CAD file needs to be uploaded. In the second, a parser is built to reorganize and present geometrical and topological information in STEP files in a machine- and human-readable format. Various strategies are employed to alter the parser's output to make the feature recognizer's job easier. In the meantime, the AFR logic rule-based technique creates a collection of eight predetermined features. Fourth-module analysis compares the part's geometrical and topological data with previously determined characteristics for feature recognition.

3.3.1 Browsing

An interface software built in C# transforms the design model into a step file AP203 format for use by the system's first step in the process. Because it's free, open-source, and has well-structured code that makes it easy to interface to the CAD modeler for building a feature recognizer, Visual Studio was selected as the engine in our system. It's easy to switch optimizations on and off in the code and see how they affect performance.

3.3.2 Parsing

The data arrangement does not appear in a hierarchical sequence in the physical text file, despite the fact that the STEP file has a hierarchical structure and shows the entity lines in an ordered manner. As a result, the file is almost unreadable due to the inability to move from line to line in a sequential manner. Not only for people, but also for computer systems that recognize features, this is unreadable. As shown in the figure().

```
DATA;

#1 = EDGE_LOOP ( 'NONE', ( #136, #5 ) ) ;
#2 = CARTESIAN_POINT ( 'NONE',  ( 32.23588457517412600, 0.0000000000000000000, 60.53599254523973600 ) ) ;
#3 = DATE_AND_TIME ( #32, #36 ) ;
#4 = AXIS2_PLACEMENT_3D ( 'NONE', #143, #133, #118 ) ;
#5 = ORIENTED_EDGE ( 'NONE', *, *, #14, .F. ) ;
#6 = DIRECTION ( 'NONE',  ( -0.0000000000000000000, -0.0000000000000000000, 1.0000000000000000000 ) ) ;
#7 = EDGE_CURVE ( 'NONE', #131, #95, #123, .T. ) ;
#8 = PERSON_AND_ORGANIZATION_ROLE ( 'classification_officer' ) ;
#9 = MANIFOLD_SOLID_BREP ( 'Revolve1', #62 ) ;
#10 = EDGE_LOOP ( 'NONE', ( #48, #12, #170, #125 ) ) ;
#11 = AXIS2_PLACEMENT_3D ( 'NONE', #145, #160, #72 ) ;
#12 = ORIENTED_EDGE ( 'NONE', *, *, #14, .T. ) ;
#13 = APPROVAL_PERSON_ORGANIZATION ( #115, #126, #105 ) ;
#14 = EDGE_CURVE ( 'NONE', #95, #131, #53, .T. ) ;
#15 = AXIS2_PLACEMENT_3D ( 'NONE', #29, #164, #17 ) ;
#16 =( LENGTH_UNIT ( ) NAMED_UNIT ( * ) SI_UNIT ( .MILLI., .METRE. ) );
#17 = DIRECTION ( 'NONE',  ( -1.0000000000000000000, 0.0000000000000000000, -0.0000000000000000000 ) ) ;
#18 = PRODUCT_DEFINITION ( 'UNKNOWN', '', #138, #93 ) ;
#19 = CC_DESIGN_DATE_AND_TIME_ASSIGNMENT ( #169, #44, ( #18 ) ) ;
#20 = PERSON_AND_ORGANIZATION ( #49, #137 ) ;
#21 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT ( #28, #117, ( #138 ) ) ;
#22 = PERSON_AND_ORGANIZATION ( #49, #137 ) ;
#23 = ADVANCED_FACE ( 'NONE', ( #158 ), #68, .F. ) ;
```

Figure 3.1: The unordered data of the step file.

A parser is needed to reorganize the data so that it is easier to understand. The parser was created using the C# programming language with the purpose of making feature recognition easier. As a result of the work done here, the parser can import STEP AP 203 files and scan all of their lines to identify how many closed shells and faces are there in the design. Before going on to the next face, all of the face's geometrical and topological information is displayed in the order illustrated in Figure (2.2).

When a face is proclaimed, the first bound appears in the following line, which can be either face-bound or face-outer-bound. The edge-loop information is then sequentially presented all the way to the end, which is the Cartesian points, as shown in Figure (2.2).

```
A Closed Shell Has been found
#62 = CLOSED_SHELL ( 'NONE', ( #140, #23, #100, #152 ) ) ;

F1=#140
 #140 ADVANCED_FACE #92 #61
 #92 FACE_OUTER_BOUND #165
 #165 EDGE_LOOP #79 #151 #71 #46
 #79 ORIENTED_EDGE #7
 #7 EDGE_CURVE #131 #95 #123
 #131 VERTEX_POINT #146
 #146 CARTESIAN_POINT X=32.236 Y=0 Z=0
 #95 VERTEX_POINT #108
 #108 CARTESIAN_POINT X=0 Y=0 Z=0
 #123 CIRCLE #37 CurveRadius = 16.118
 #37 AXIS2_PLACEMENT_3D #83 #101 #102
 #83 CARTESIAN_POINT X=16.118 Y=0 Z=0
 #101 DIRECTION X=0 Y=0 Z=1
 #102 DIRECTION X=1 Y=0 Z=0
 #151 ORIENTED_EDGE #43
 #43 EDGE_CURVE #95 #91 #58
 #95 VERTEX_POINT #108
 #108 CARTESIAN_POINT X=0 Y=0 Z=0
 #91 VERTEX_POINT #39
 #39 CARTESIAN_POINT X=0 Y=0 Z=60.536
 #58 LINE #113 #167
 #113 CARTESIAN_POINT X=0 Y=0 Z=60.536
 #167 VECTOR #157 1000
 #71 ORIENTED_EDGE #63
 #63 EDGE_CURVE #38 #91 #89
 #38 VERTEX_POINT #2
 #2 CARTESIAN_POINT X=32.236 Y=0 Z=60.536
 #91 VERTEX_POINT #39
 #39 CARTESIAN_POINT X=0 Y=0 Z=60.536
 #89 CIRCLE #11 CurveRadius = 16.118
 #11 AXIS2_PLACEMENT_3D #145 #160 #72
 #145 CARTESIAN_POINT X=16.118 Y=0 Z=60.536
 #160 DIRECTION X=0 Y=0 Z=1
 #72 DIRECTION X=1 Y=0 Z=0
 #46 ORIENTED_EDGE #30
 #30 EDGE_CURVE #131 #38 #24
 #131 VERTEX_POINT #146
 #146 CARTESIAN_POINT X=32.236 Y=0 Z=0
 #38 VERTEX_POINT #2
 #2 CARTESIAN_POINT X=32.236 Y=0 Z=60.536
 #24 LINE #127 #94
 #127 CARTESIAN_POINT X=32.236 Y=0 Z=60.536
 #94 VECTOR #114 1000
 #61 CYLINDRICAL_SURFACE #35 CurveRadius = 16.118
 #35 AXIS2_PLACEMENT_3D #59 #6 #60
 #59 CARTESIAN_POINT X=16.118 Y=0 Z=60.536
 #6 DIRECTION X=0 Y=0 Z=1
 #60 DIRECTION X=1 Y=0 Z=0
```

Figure 3.2: The result after parser.

3.3.3 Sorting

After paring the data in an understandable way, we notice that the faces are not arranged according to the sequence and Some faces have the same information and may make the process of recognition and extracting features more difficult. Therefore, many algorithms have been proposed to arrange the data and make it more straightforward before entering the feature technology.

3.3.3.1 Merging

The step file expresses the faces in its own way, which is different from the CAD vision. A normal cylinder in CAD is shown in Figure (A), and it consists of three faces, two of which are plane, and the third is cylindrical. While figure (B) shows how the step file expresses the cylinder, it divides the cylindrical face into two parts so that it contains four faces instead of three. These two sections are similar, so there is no point in repeating them in the present work. Accordingly, algorithms have been developed for the purpose of merging similar faces to be stored as one face. This will not affect the desired results.

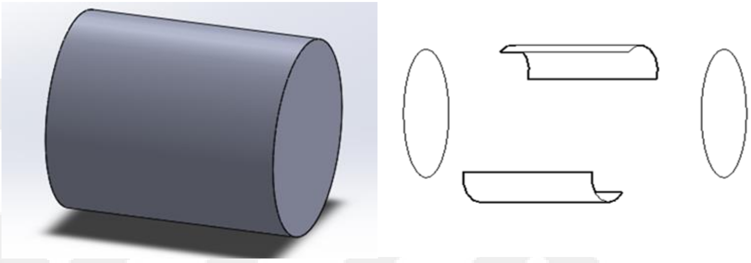


Figure 3.3: The cylinder befor merging.

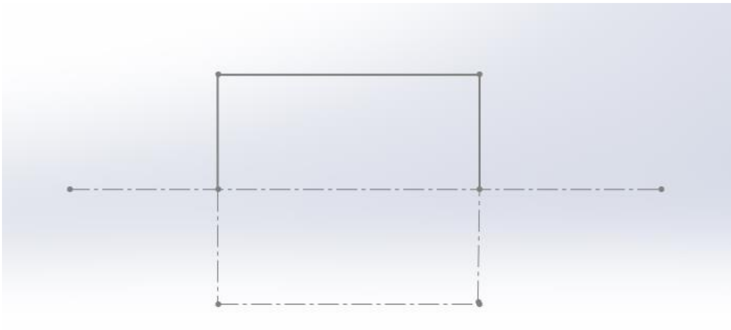


Figure 3.4: The result after merging.

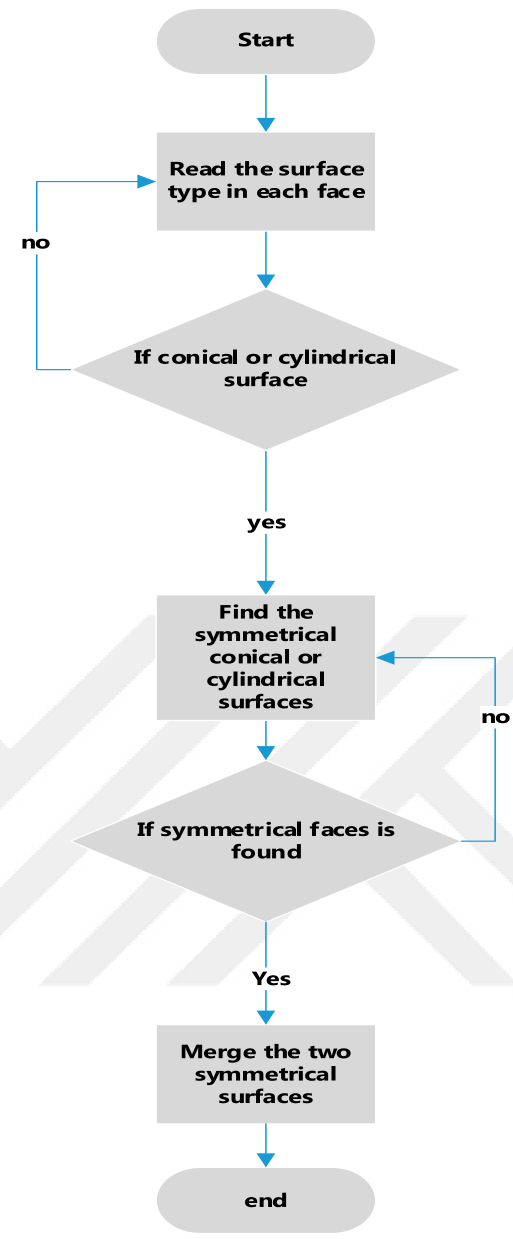


Figure 3.5: The algorithm of merging information of two symmetrical faces.

3.3.3.2 Arrange faces

As mentioned previously, the faces are not arranged in sequence. The intended sequence is the arrangement of the faces through which the z-coordinate passes and from right to left. This is because the coordinate system in the lathe machine is XZ, where X represents the diameter of the piece while Z represents its length.

This system has been adopted in developing an algorithm to sort faces according to their arrangement on the z-axis from right to left. Faces are chosen based on the values of the Cartesian points for each face. Where each face has maximum and minimum z values as shown in Figure(). For plane faces, the maximum z and the minimum z are equal.

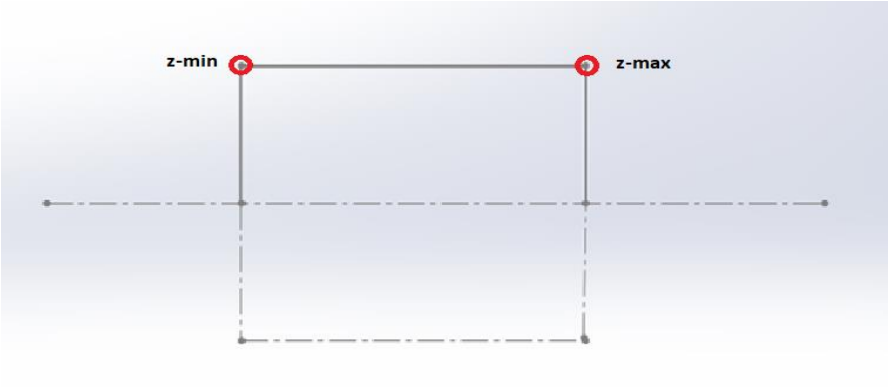
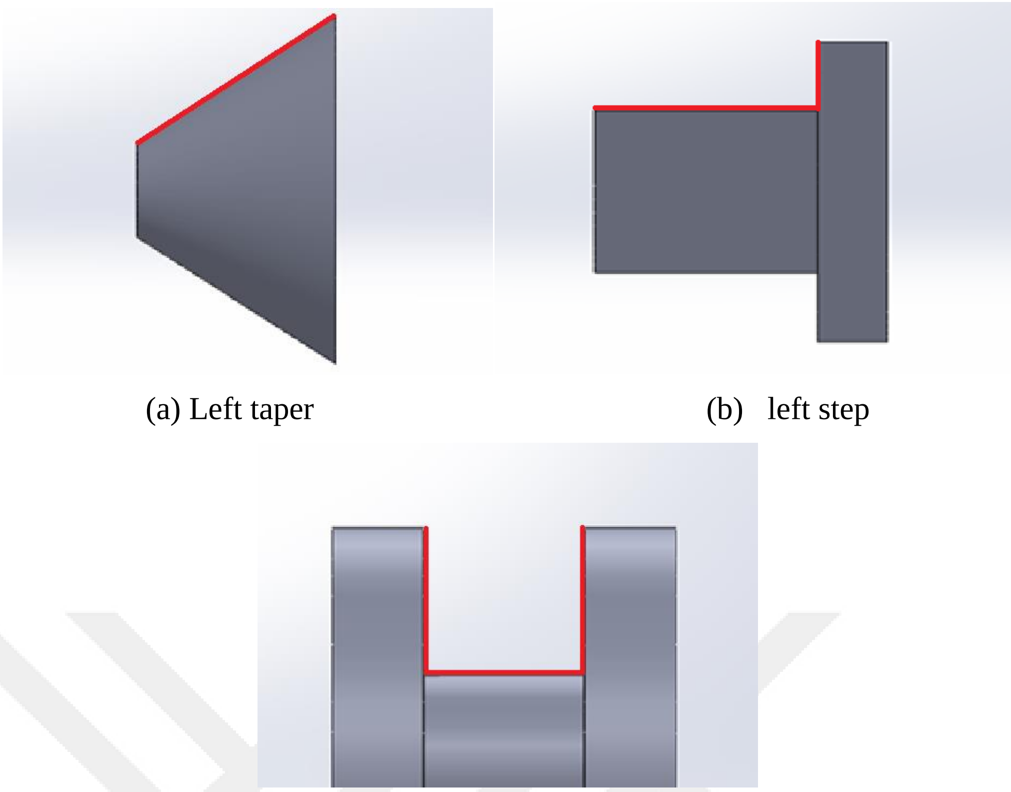


Figure 3.6: The maximum and minimum z of the cylindrical surface.

In any case, the process of sorting faces depends on the maximum z values. Except if there are faces with the same maximum z-values, where the lowest z-values are used to compare the faces in order to rank them. Priority is given to the face with the highest minimum z-values.

3.3.4 Feature recognition

Product data must be transferred between computer-aided design (CAD) and automated computer-aided process planning (ACAPP), using automatic feature recognition (AFR) technologies. This is done by transforming low-level geometric entities from CAD component design models to manufacturing features for CAPP. With the use of features, the qualities of a part may be given meaning, and its geometry can be broken down into easily identifiable and understandable parts. As a result, it facilitates communication between the design and manufacturing teams (Jian Gao et al., 2005). The figure() represents some examples of the features.



(a) Left taper (b) left step

(c) Square groove

Figure 3.7: Some examples about features.

After all the faces have been arranged and filtered, it is easy to recognize the features in the CAD model. For the system to recognize and extract the features of the part, it must have information about each feature in order to be able to capture it. Therefore, this section is divided into two steps that complement each other and cannot be separated: declaring the features and extracting them. The first step is to set the fixed rules for each feature, while the second step is to scan the faces to capture the features to which these rules apply.

3.3.4.1 Feature declarative

In order for the system to recognize the features of the part, it must have a complete definition of the feature, in terms of the number of faces it consists of and the differences between the coordinates of each face. This declarative makes the next step easier.

One feature may consist of one or more faces. In this work, eight features will be declared; two of them consist of three faces, two of them consist of two faces, and the remaining four consist of only one face. Table (3.1) shows these features.

Table 3.1: The features used in this work and its information

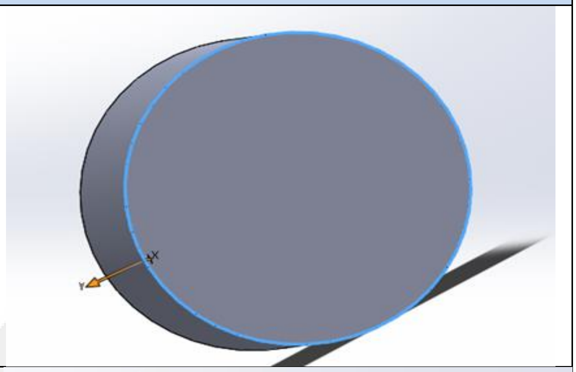
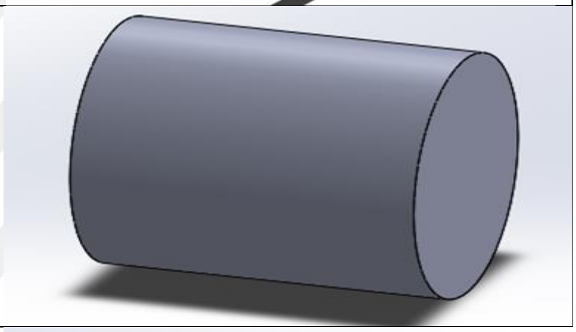
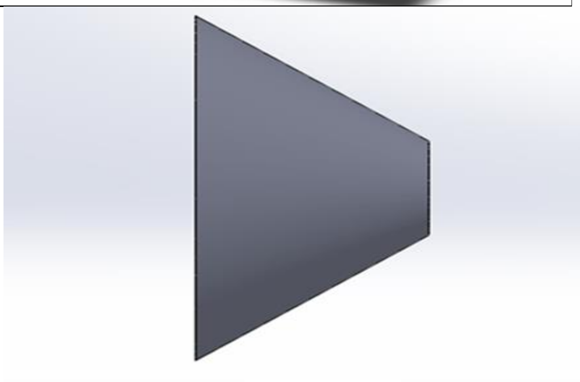
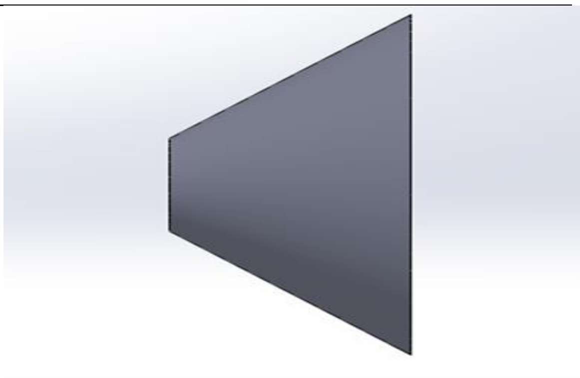
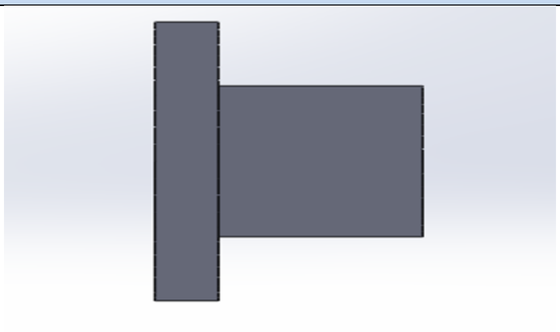
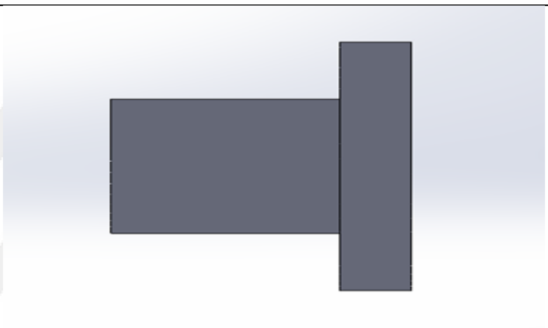
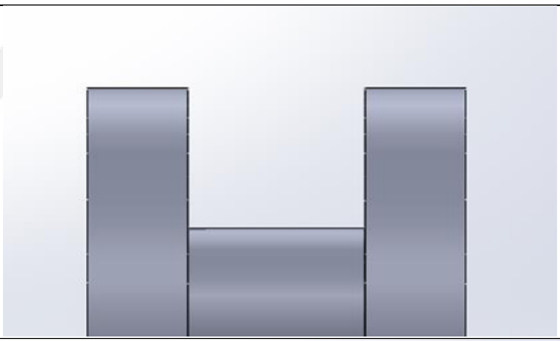
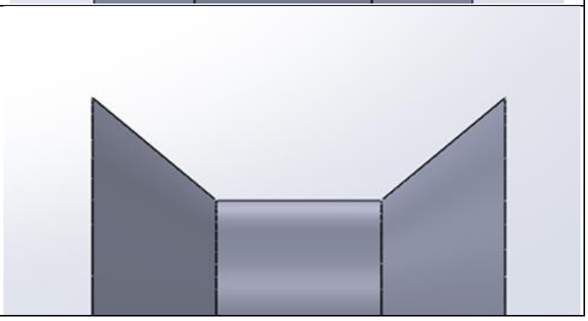
Feature information	Feature shape
Feature name: plane Number of faces: one. 1) Plane.	
Feature name: cylindrical. Number of faces: one. 1) Cylindrical.	
Feature name: right taper. Number of faces: one. 1) Conical.	
Feature name: left taper. Number of faces: one. 1) Conical.	

Table 3.1: (Cont.)

Feature information	Feature shape
The feature: right step. Number of faces: two. 1) Cylindrical. 2) Plane.	
The feature: left step. Number of faces: two. 1) Plane. 2) Cylindrical.	
The feature: square groove. Number of faces: three. 1) Plane. 2) Cylindrical. 3) Plane.	
The feature: wide groove. Number of faces: three. 1) Conical. 2) Cylindrical. 3) Conica.	

In order to define each feature, rules must be established according to the information contained in the feature. These rules depend on the number and type of faces and the values of z and x coordinates for each face. For example, a cylinder is defined by the following rules:

1) The surface type: cylindrical.

2) Z-Max > Z-Min.
3) X-Max = X-Min.

While the right step can be defined by the following rules:

1) The surface type of the first face: cylindrical.
2) The surface type of the second face: plane.
3) Z1-Max > Z2-Max.
4) Z1-Min = Z2-Min.
5) X1-Max < X2-Max.
6) X1-Min = X2-Min.

For a feature to be classified as cylindrical, all of these characteristics must be met on the face. The same programming language (C#) can be used for the purpose of declaring features. These rules will be used as a reference in the next step. It must be noted that the features can be defined in different ways. That is, there is no unique way, and accordingly, the results may differ.

3.3.4.2 Feature extraction

After the features were defined in the previous step, in this step, the system will compare these definitions with the features of the designed part in order to recognize its features. The system is built using the parser's geometric and topographical data. Geometrical information refers to information on a part's geometry, such as the center point coordinates, radii, line lengths, and surface kinds. When it comes to edge loops, inner and outer boundaries, and edge curve generation, topological information is all about those things. The obtained data is organized in the form of a node and stored for use in the stage of identifying the predefined features. This system works in loops. A batch of faces sorted in the previous steps is taken and matched with the defined features. The batch in this system consists of three faces. If they are matched and the feature is found, the loop is terminated and the three faces that make up the feature are announced. Then a new loop starts if the CAD model contains more faces. But if the three faces match feature are not found, two faces are kept and the last one is subtracted. After that, the algorithm compares the fresh batch with the specified characteristics, which include two faces. This process continues until all faces have been covered in the design model. Figure ( ) shows the predefined feature recognition loop.

After the system recognizes the feature, the following information is stored: (i) The name of the feature (ii) The number of features that make the feature. (c) The surface type of each face.

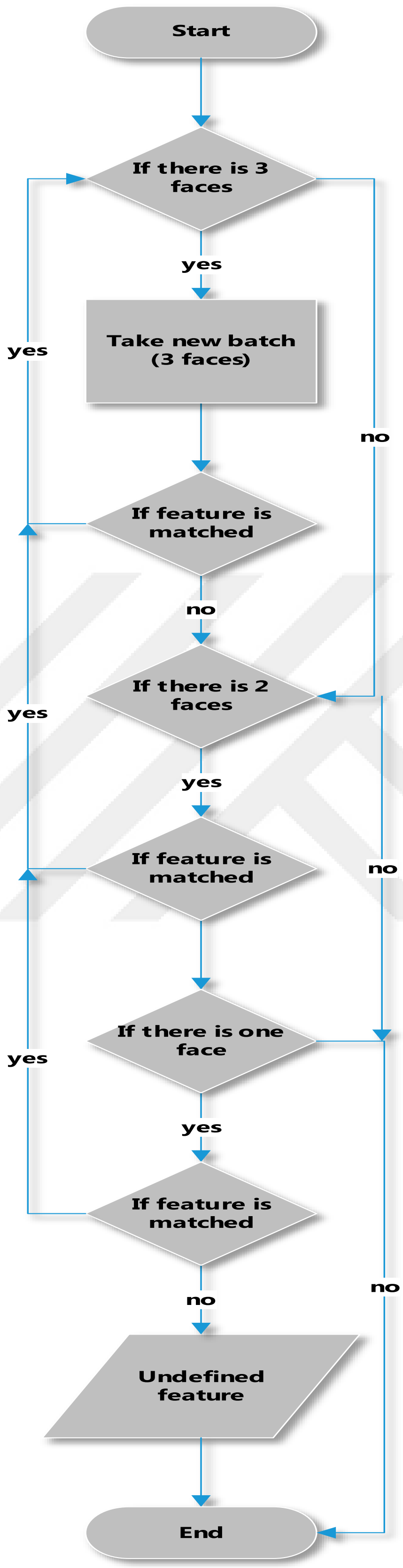


Figure 3.8: The feature recognition loop

3.4 Discussion and Summary

CAD (computer-aided design) and CAPP (computer-aided process planning) are key ideas in the manufacturing business. However, their natures separate them, with the former providing geometrical and topological information and the later requiring manufacturing knowledge, and a link is needed to bridge this gap. Various AFR systems have been created and deployed to link CAD with CAPP using a PDE standard.

This chapter proposes an automatic feature recognition technique for identifying rotatable parts' features. A STEP AP203 file is utilized as an input because of its large capacity for conveying design information to downstream applications such as CAPP. A parser was developed to extract geometric and topological data from a Stage file and forward it to the next step. The retrieved data is then used by the system to aid in the feature recognition process.

4. METHODOLOGY (CASE STUDY)

4.1 Introduction

In order to verify the efficiency of the system, a case study was conducted. The designed model does not exist in the industry, but it was designed for the purpose of verifying the results and showing the capabilities and efficiency of the proposed system in identifying the predefined design features.

4.2 Design Part

The part model is designed using SOLIDWORKS and saved as a STEP file AP203 format. This CAD model contains all of the eight features that were previously described. Figure () shows the details of the designed part. Which consists of a closed shell and a set of predefined features. These features consist of faces, which will be 15 faces in this example as showen in figure().

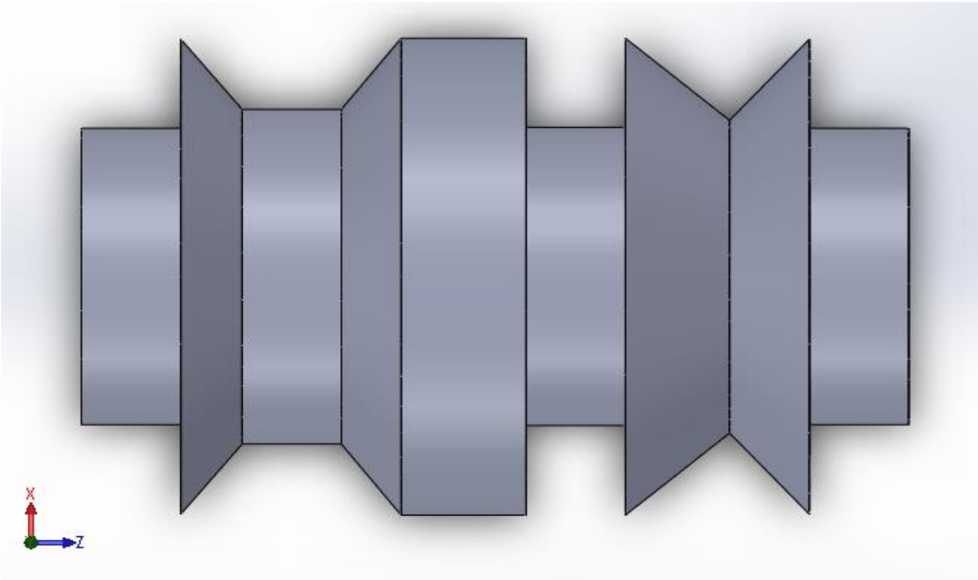


Figure 4. 1: The case study model.

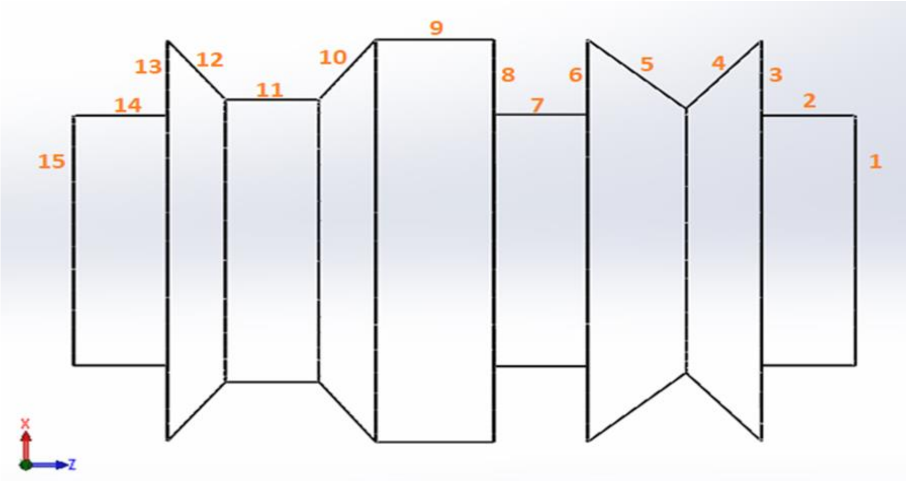


Figure 4.2: Number of faces in the design model.

4.3 The System Steps

After converting the design to a STEP file, it is imported into the system. After that, the developed parser starts reading the file and displays the data to the user on the screen after it is arranged. The system stores data temporarily for the purpose of using it later in the next steps. In this example, the closed-shell has 15 faces, as shown in Figure (). Each face will be displayed, followed by all the information about it, arranged according to the figure (2.2). In the next step, the system processes this data and makes some adjustments in order to facilitate the feature recognition process. finding MaxZ and MinZ, as well as MaxX and MinX for each. Then, merge similar cylindrical faces and similar conical faces. Also, sorting faces based on MaxZ. In the last step, the system recognize the features after comparing them with the predefined features using the methodology described in section (). The system displays each feature and identifies the faces that compose it and the coordinates of each face. Figure ( ) shows the features in the design model. Where the faces that make up one feature were painted in the same color.

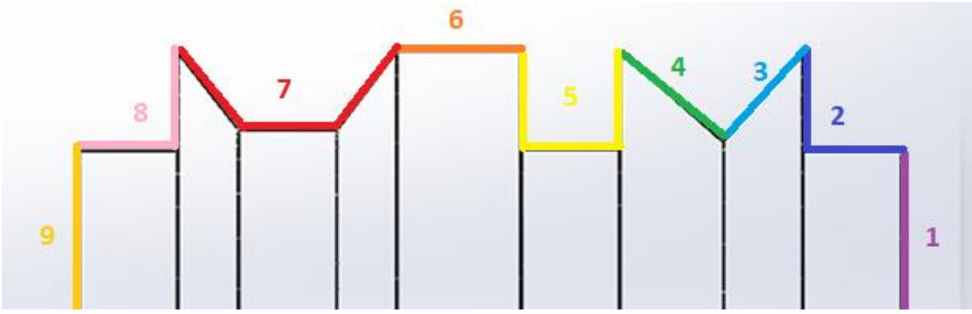


Figure 4.3: The features of the case study.

4.4 Results

Table 4.1: The result of the feature recognition

Feature no.	Feature name	No. of faces	Surface type of each face	Start point	End point
1	facing	1	plane	X= 16.6 Z= 83.25	X= 16.6 Z=83.25
2	Right step	2	Cylindrical	X= 16.6 Z= 83.25	X= 16.6 Z= 73.25
			plane	X= 26.68 Z= 73.25	X= 26.68 Z=73.25
3	Left taper	1	conical	X= 26.68 Z= 73.25	X= 26.68 Z= 65.22
4	Right taper	1	conical	X= 17.5 Z= 65.2	X=17.5 Z= 54.74
5	Square groove	3	Plane	X= 26.79 Z= 54.74	X= 26.79 Z=54.74
			Cylindrical	X= 16.79 Z=54.74	X=16.79 Z=44.74
			plane	X=26.79 Z=44.74	X=16.79 Z=44.74
6	cylindrical	1	cylindrical	X=26.79 Z=44.74	X= 26.79 Z= 44.74
7	Wide groove	3	Conical	X= 26.79 Z= 44.74	X=26.79 Z=26.16
			Cylindrical	X=18.81 Z=26.16	X=18.81 Z=16.16
			conical	X=18.81 Z=16.16	X=18.81 Z=10
8	left step	2	Plane	X=26.69 Z=10	X=26.69 Z=10
			cylindrical	X=16.69 Z=10	X=16.69 Z=0
9	facing	1	plane	X=16.69 Z=0	X=16.69 Z=0

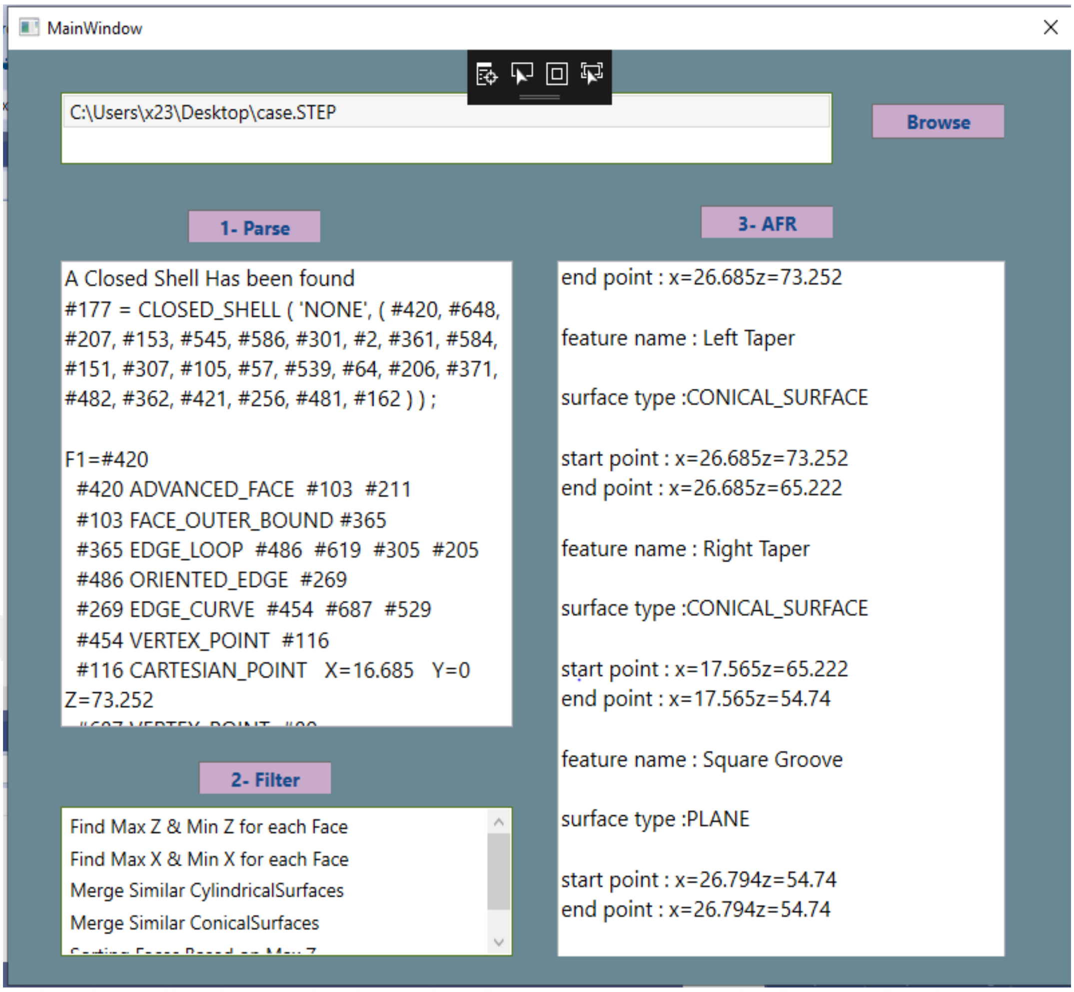


Figure 4.4: The main window of the system with the results.

4.5 Discussion and Summery

All the extracted information mentioned in Table() can be used in the future to create CAPP. The feature information can be relied upon to know the sequence of operations required to create it. Knowing the sequence of operations results in the possibility of choosing the required cutting tools and determining their path. This is the preparation of the process of estimating time which is the objective of this thesis. It also allows the possibility of estimating the cost in the future.

5. RESULTS AND CONCLUSION

5.1 Results

As indicated in the previous chapter, the information extracted from the design model can be used to estimate manufacturing conditions. The information in Table ( ) can be used to estimate the machining time as a result for this work. By estimating the time required to machine one feature. In this chapter, the possibility of using the results of the proposed system in estimating the machining time will be explained

5.2 Estimating Time

Today, the design factors of manufacturing systems are still an active research topic and the predictive models are highly interested by the scholars.The present-day industrial environment demands high- quality products in reduced lead time and cost to meet the ever changing demands of the global market. Computer-aided design (CAD), computer-aided process planning and computer-aided manufacturing (CAM) systems are employed in industry with the aim of reduction of the time and costs of product design and manufacture. Estimating the time required to machining part is one of the results of the CAPP. Time estimation in the early stages of design projects involves a great deal of uncertainty. Therefore, there is a great demand for an effective way to reduce uncertainty in the machining's time estimation.In this chapter, an feature-based method of time estimation is presented.Compared with other methodologies, the feature-based time estimation method has higher accuracy because it takes into account the geometrical information of the part and the required tools and speeds acoording to the need of each feature.

5.2.1 Factors governing machining time

The factors affecting the manufacturing time are shown in Figure (). The figure shows the rotational part and the conditions surrounding it in its simplest form.

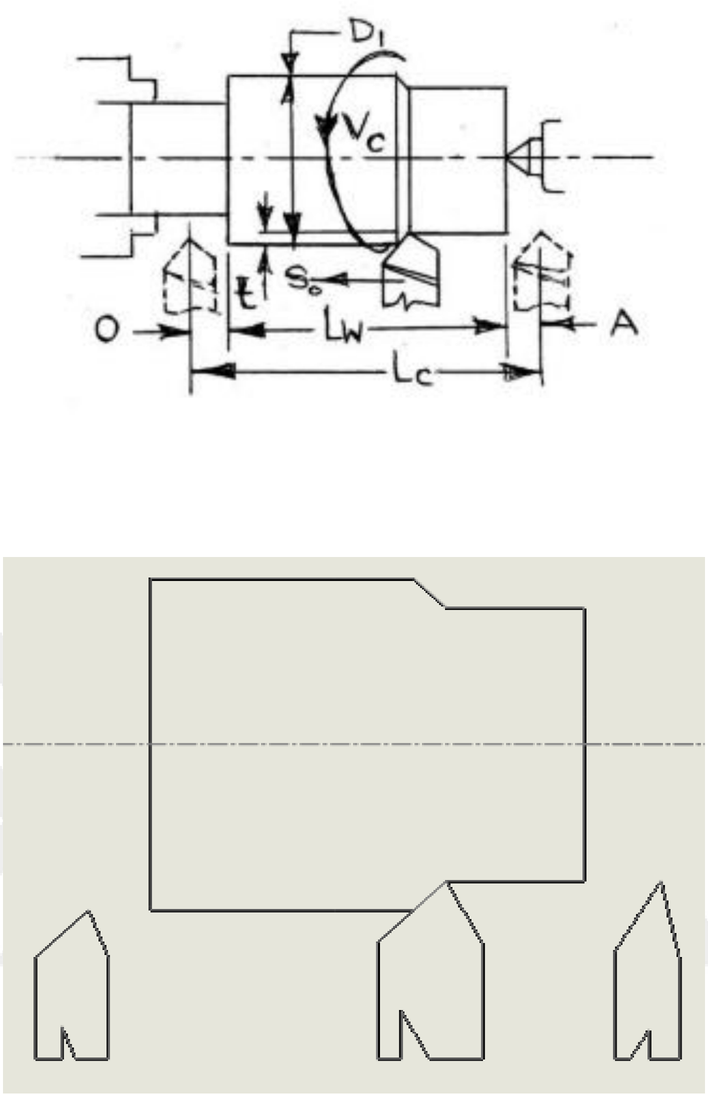


Figure 5.1: The factors that govern time in rotational parts machining.

1. The diameter of the workpiece.

The diameter of the workpiece (D□) affects the number of pasess (n□) to reach the required diameter (D_2).

2. The length of cut.

It represents the path of workpiece from its start point to the end point after complete cutting process.

$L_C = L_w + O + A$ (1)

Where :

LC = actual length of cut.

LW = the length of the workpiece.

3. Number of passing

$$n_{\square} = \frac{D_{\square} - D_2}{2t} \qquad (2)$$

Where :

$D_{\square}$ = diameter befor cutting so the diameter after cutting is D_2 .

t = the cutting depth in each pass.

4. Cutting velocity

$$V_C = \frac{\pi D_{\square} N}{1000} \qquad (3)$$

Where :

VC = cutting velocity.

N = spindle speed.

5. Feed

Where :

S_o = feed

Table 5.1: The ranges of the feed and speed for some metals

Metal of the workpiece	Cutting vielocity		Feed	
	Rough cutting	Smoth cutting	Rough cutting	Smoth cutting
Solid steel	25	40	0.3 – 0.6	0.1 – 0.3
Medium carbon steel	20	30	0.3 – 0.4	0.1 – 0.3
High carbon steel	15	25	0.2 – 0.3	0.1 – 0.2
Soft cast iron	25	35	0.4 – 0.6	0.1 – 0.3
Medium cast iron	20	25	0.4 – 0.6	0.1 – 0.3
Solid cast iron	15	20	0.4 – 0.6	0.1 – 0.3

Bronze	30	60	0.4 – 0.6	0.1 – 0.3
Copper	60	80	0.4 – 0.6	0.1 – 0.3
Aluminum	75	120	0.4 – 0.8	0.1 – 0.3

Finally, the machining time can be calculated mathematically from the equation:

$$T_c = \frac{lc}{V\square S_o} = \frac{\pi D(Lw+A+O)}{1000\ V\square\ S_o} \qquad (4)$$

5.3 Case Study 1

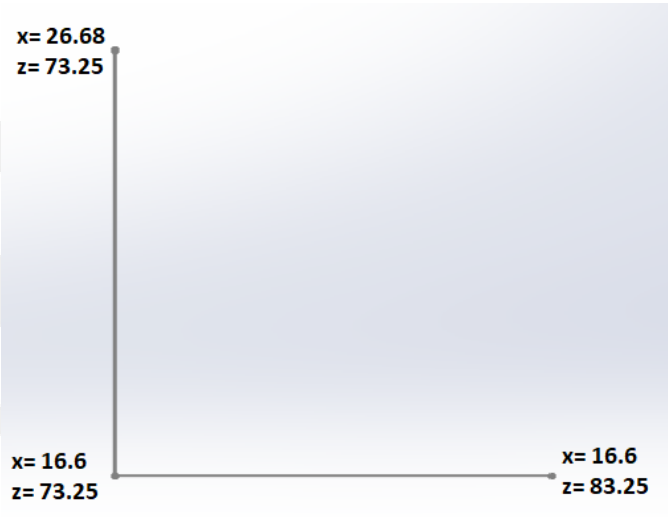


Figure 5.2: the points of the feature from the system results.

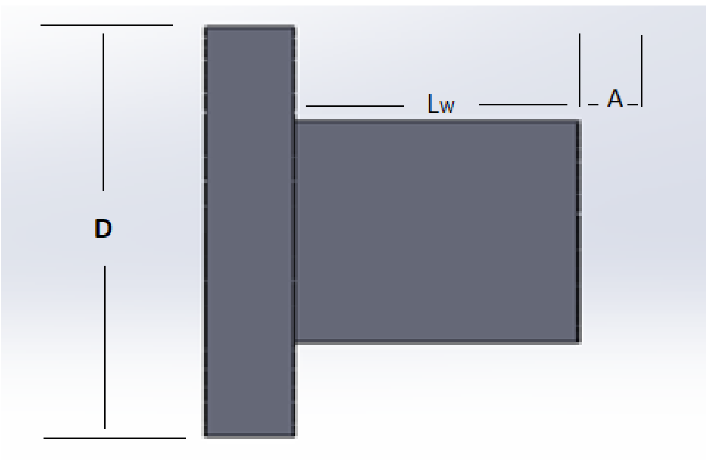


Figure 5.3: the factors of the feature.

From the figure ()

$Lw = Z_{start} – Z_{end}$ = 83.25 – 73.25 = 10 mm

Depth of cut ($d_{\square}$) = $X_{end} – X_{start}$ = 26.6 – 16.6 = 10 mm

suppose that:

D = 53.5 , A = 5 , t = 0.5

$$n_{\square} = \frac{D_{\square} - D_2}{2t} = \frac{53.5 - 33.5}{2*0.5} = 20 \text{ mm}$$

from the table ():

for aluminum $V_{\square}$ = 75 m/min , S_o = 0.4-0.8 mm/rev

suppose that : S_o = 0.6

$$T_c = \frac{3.14*53.5*(10+5)}{1000*75*0.6} * 20 = 1.12 \text{ min}$$

5.4 Case Study 2

In this case study, the time for Square Groove will be calculated based on the information obtained from the system. This feature differs from others in calculating time due to the difference in cutting tools and methods. The cutting tool must have square corners in order to obtain the square shape in the inner corners of the Square Groove. As for the direction of cutting, it must first be perpendicular to the axis of the turning (z-axiz) to ensure that the desired shape is obtained. The lathe that is perpendicular to the axis is called the transverse lathe.

Figure 5.4: The square groove in the system case study.

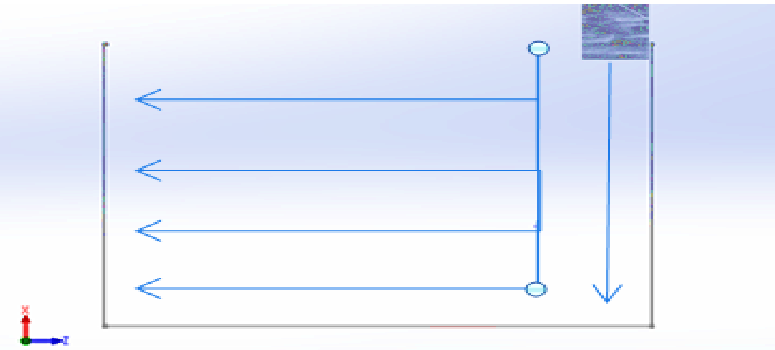


Figure 5.5: The cutting direction.

5.4.1 Transverse lathing (Side turning)

It contains two methods:

a. Based on a fixed number of turns.

Where the cutting speed decreases and continues to diminish by moving the turning tool towards the axis regularly until it reaches zero when the turning tool reaches the working axis.

b. Using a constant cutting speed and then a fixed number of turns.

Where the turning process is divided into two stages. The first of them is done using a constant cutting speed, and the second is done using a constant number of turns (passes).

(Liu et al., 2013) considers that the second method is better than the first method in terms of wasted time. As about 50% of the cutting time is lost in the first method, while 46.8% of it is saved in the second method.

The manufacturing time will be estimated according to the second method, depending on the results of the system.

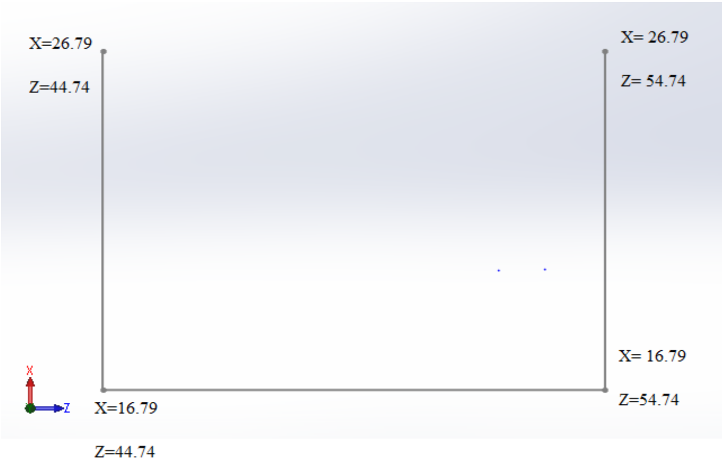


Figure 5.6: The start point and end point of each face depend on the system results.

From the figure () we can find the dimaentions of the square groove:

Lw = $Z_{(2)}$ start – $Z_{(2)}$ end = 54.74 – 44.74 = 10

Depth of cut ($d_{\square}$) = $X_{\square} - X_2$ = 26.79 – 16.79 = 10

A square-shaped tool, 2 mm wide, is used. The reason for using a tool like this is to get a square shape at the inner edges of the groove. The turning process takes place in two stages. The first is in which the tool descends to the required depth by way of lateral (transverse) turning. In the second stage, the longitudinal turning method is used, as in the previous example, where the tool descends a little depth and the machining process is carried out through a number of passes.

Din = Dout – (dp * 2) = 53.58 – (10 * 2) = 33.58 mm

$$T_{\square} = \frac{[Dout^2 - Din^2]*\pi}{S*V*4000} = \frac{[(53.58)^2-(33.58)^2]*3.14}{0.6*75*4000} = 0.03 \text{ min}$$

$$T_2 = \frac{[Din^2]*\pi}{S*V*2000} = \frac{[(33.58)^2]*3.14}{0.6*75*2000} = 0.04 \text{ min}$$

T for lateral = $T_{\square} + T_2$ = 0.07 min

$$T_3 = \frac{\pi * Dout * (L_{\square}+1)}{S*V*1000} = \frac{3.14*53.58*20}{0.6*75*1000} = 0.59 = 0.6 \text{ min}$$

Ttotal = T_3 + T for lateral = 0.6 + 0.07 = 0.67 min

6. COCLUSION

Part management is a term intended to regulate the manufacture of the part. The part management process is carried out in the early stages, specifically in the planning stage. Part management in the early stages needs accurate information such as dimensions and features obtained from the design. Because of the different nature between the design and planning stages, where the first contains engineering and topological information, while the second contains manufacturing information, it is necessary to have a link between them to bridge the gap. Automatic feature recognition systems are the link between the two stages based on one of the PDE standards to bridge the gap.

In this thesis a system was proposed to identify the features of rotating parts. This system uses step files as input because of its high ability to transfer design information to the planning stage. Because of the random arrangement of the information in the step file, the parser was developed for the purpose of arranging the information before sending it to the next steps. Then the system processes this information for the purpose of facilitating the process of identifying features through filtering and merging processes for the faces that make up the design.

The effectiveness of this system appears in facilitating dealing with designs in different environments and reducing the time spent in the planning process. Where by pressing a single button, the important information in the design will be obtained, on which the advanced stages of the manufacturing process will be built.

In order to verify the effectiveness of the system, a case study was conducted for two different features and the time taken to machine each of them in two different ways based on the information obtained from the proposed system and according to the shape of each feature. The first feature is called right step and machined by longitudinal turning using a triangular cutting tool. The second feature is called square groove and machined firstly by side turning (Transverse turning) and secondly by longitudinal turning Using a square cutting tool. Estimated results were obtained for the machining time of each feature.

6.1 Recommendation For Future Work

- Develop the system so that it can read all forms of file exchange formats.
- Define a larger number of features in the system to identify them.
- Develop the ability to identify automatic features.
- Develop the program to include recognizing the features of non-rotating shapes.
- Make the time calculation process automatic instead of paper and add it to the system.
- System results and time calculation results can be relied upon and used in calculating the manufacturing cost of the part.
- The system can be made to choose a tool for manufacturing automatically, depending on the results of the system that determines the feature, and accordingly, the tool can be selected.
- After identifying the features, you can choose the appropriate processes to machine and include this process in the system And make the process selection process automatically In addition to the sequence of operations
- In other words, the results of the system can be relied upon in estimating all cutting conditions at the design stage. This estimation process can be made automatic in the future.

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APPENDIX

Appendix A:

The step file of the cylindrical shape:

ISO-10303-21;

HEADER;

FILE_DESCRIPTION (('STEP AP214'),

'1');

FILE_NAME ('Part1.STEP',

'2021-05-19T09:55:37',

(''),

(''),

'SwSTEP 2.0',

'SolidWorks 2016',

'');

FILE_SCHEMA (('AUTOMOTIVE_DESIGN'));

ENDSEC;

DATA;

#1 = VECTOR ('NONE', #50, 1000.000000000000000) ;

#2 = FACE_OUTER_BOUND ('NONE', #140, .T.) ;

#3 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 41.53661799456895000)) ;

#4 = ADVANCED_BREP_SHAPE_REPRESENTATION ('Part1', (#79, #14), #76) ;

#5 = PLANE ('NONE', #75) ;

#6 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#7 = PRODUCT_DEFINITION ('UNKNOWN', '', #114, #137) ;

#8 = SURFACE_SIDE_STYLE ('',(#77)) ;

#9 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#10 =(NAMED_UNIT (*) SI_UNIT ($, .STERADIAN.) SOLID_ANGLE_UNIT ( ));

#11 = EDGE_LOOP ('NONE', (#108, #15, #51, #101)) ;

#12 = UNCERTAINTY_MEASURE_WITH_UNIT (LENGTH_MEASURE(1.000000000000000100E-005), #85, 'distance_accuracy_value', 'NONE');

#13 =(NAMED_UNIT (*) SI_UNIT ($, .STERADIAN.) SOLID_ANGLE_UNIT ( ));

#14 = AXIS2_PLACEMENT_3D ('NONE', #98, #99, #73) ;

#15 = ORIENTED_EDGE ('NONE', *, *, #44, .T.) ;

#16 = CYLINDRICAL_SURFACE ('NONE', #96, 36.01204318740952500) ;

#17 = MECHANICAL_DESIGN_GEOMETRIC_PRESENTATION_REPRESENTATION ('', (#127), #55) ;

#18 = ORIENTED_EDGE ('NONE', *, *, #49, .T.) ;

#19 = AXIS2_PLACEMENT_3D ('NONE', #124, #64, #112) ;

#20 = CIRCLE ('NONE', #103, 36.01204318740952500) ;

#21 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#22 = CARTESIAN_POINT ('NONE', (72.02408637481904900, 0.0000000000000000000, 0.0000000000000000000)) ;

#23 = APPLICATION_PROTOCOL_DEFINITION ('draft international standard', 'automotive_design', 1998, #125) ;

#24 = ADVANCED_FACE ('NONE', (#131), #16, .T.) ;

#25 = VERTEX_POINT ('NONE', #120) ;

#26 = ORIENTED_EDGE ('NONE', *, *, #138, .F.) ;

#27 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#28 =(NAMED_UNIT (*) PLANE_ANGLE_UNIT ( ) SI_UNIT ($, .RADIAN.));

#29 = SURFACE_STYLE_USAGE (.BOTH. , #8) ;

#30 = ADVANCED_FACE ('NONE', (#68), #5, .F.) ;

#31 = ORIENTED_EDGE ('NONE', *, *, #69, .F.) ;

#32 = CIRCLE ('NONE', #19, 36.01204318740952500) ;

#33 = EDGE_CURVE ('NONE', #95, #80, #47, .T.) ;

#34 = UNCERTAINTY_MEASURE_WITH_UNIT (LENGTH_MEASURE(1.000000000000000100E-005), #89, 'distance_accuracy_value', 'NONE');

#35 = LINE ('NONE', #61, #92) ;

#36 = PRESENTATION_STYLE_ASSIGNMENT ((#111)) ;

#37 = AXIS2_PLACEMENT_3D ('NONE', #41, #123, #72) ;

#38 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#39 = FILL_AREA_STYLE_COLOUR ('', #87) ;

#40 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 0.0000000000000000000)) ;

#41 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 41.53661799456895000)) ;

#42 = CLOSED_SHELL ('NONE', (#24, #30, #115, #94)) ;

#43 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#44 = EDGE_CURVE ('NONE', #80, #95, #74, .T.) ;

#45 = UNCERTAINTY_MEASURE_WITH_UNIT (LENGTH_MEASURE(1.000000000000000100E-005), #133, 'distance_accuracy_value', 'NONE');

#46 = VERTEX_POINT ('NONE', #83) ;

#47 = CIRCLE ('NONE', #67, 36.01204318740952500) ;

#48 = PRESENTATION_LAYER_ASSIGNMENT ('', '', (#127)) ;

#49 = EDGE_CURVE ('NONE', #80, #25, #35, .T.) ;

#50 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#51 = ORIENTED_EDGE ('NONE', *, *, #138, .T.) ;

#52 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 4.410203342021732900E-015, 0.0000000000000000000)) ;

#53 = PRODUCT_CONTEXT ('NONE', #125, 'mechanical') ;

#54 = ORIENTED_EDGE ('NONE', *, *, #69, .T.) ;

#55 =(GEOMETRIC_REPRESENTATION_CONTEXT (3) GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT ((#34)) GLOBAL_UNIT_ASSIGNED_CONTEXT ((#89, #113, #10)) REPRESENTATION_CONTEXT ('NONE', 'WORKASPACE'));

#56 = PRESENTATION_STYLE_ASSIGNMENT ((#29)) ;

#57 = SHAPE_DEFINITION_REPRESENTATION (#66, #4) ;

#58 = FACE_OUTER_BOUND ('NONE', #11, .T.) ;

#59 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 0.0000000000000000000)) ;

#60 = APPLICATION_PROTOCOL_DEFINITION ('draft international standard', 'automotive_design', 1998, #122) ;

#61 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 4.410203342021732900E-015, 41.53661799456895000)) ;

#62 =(NAMED_UNIT (*) SI_UNIT ($, .STERADIAN.) SOLID_ANGLE_UNIT ( ));

#63 = EDGE_LOOP ('NONE', (#118, #78)) ;

#64 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#65 = CYLINDRICAL_SURFACE ('NONE', #116, 36.01204318740952500) ;

#66 = PRODUCT_DEFINITION_SHAPE ('NONE', 'NONE', #7) ;

#67 = AXIS2_PLACEMENT_3D ('NONE', #59, #130, #6) ;

#68 = FACE_OUTER_BOUND ('NONE', #63, .T.) ;

#69 = EDGE_CURVE ('NONE', #46, #25, #20, .T.) ;

#70 = DIRECTION ('NONE', (0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#71 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 41.53661799456895000)) ;

#72 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, -0.0000000000000000000)) ;

#73 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#74 = CIRCLE ('NONE', #107, 36.01204318740952500) ;

#75 = AXIS2_PLACEMENT_3D ('NONE', #110, #70, #81) ;

#76 =(GEOMETRIC_REPRESENTATION_CONTEXT (3) GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT ((#45)) GLOBAL_UNIT_ASSIGNED_CONTEXT ((#133, #28, #13)) REPRESENTATION_CONTEXT ('NONE', 'WORKASPACE'));

#77 = SURFACE_STYLE_FILL_AREA (#102) ;

#78 = ORIENTED_EDGE ('NONE', *, *, #44, .F.) ;

#79 = MANIFOLD_SOLID_BREP ('Revolve1', #42) ;

#80 = VERTEX_POINT ('NONE', #52) ;

#81 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#82 = STYLED_ITEM ('NONE', (#56), #79) ;

#83 = CARTESIAN_POINT ('NONE', (72.02408637481904900, 0.0000000000000000000, 41.53661799456895000)) ;

#84 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#85 =(LENGTH_UNIT ( ) NAMED_UNIT (*) SI_UNIT (.MILLI., .METRE.));

#86 = SURFACE_SIDE_STYLE ('',(#126)) ;

#87 = COLOUR_RGB ('',0.7921568627450980000, 0.8196078431372548800, 0.9333333333333333500) ;

#88 = FILL_AREA_STYLE_COLOUR ('', #106) ;

#89 =(LENGTH_UNIT ( ) NAMED_UNIT (*) SI_UNIT (.MILLI., .METRE.));

#90 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#91 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 41.53661799456895000)) ;

#92 = VECTOR ('NONE', #84, 1000.000000000000000) ;

#93 = PRESENTATION_LAYER_ASSIGNMENT ('', '', (#82)) ;

#94 = ADVANCED_FACE ('NONE', (#2), #132, .F.) ;

#95 = VERTEX_POINT ('NONE', #22) ;

#96 = AXIS2_PLACEMENT_3D ('NONE', #3, #97, #27) ;

#97 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#98 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#99 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, 1.000000000000000000)) ;

#100 =(NAMED_UNIT (*) PLANE_ANGLE_UNIT ( ) SI_UNIT ($, .RADIAN.));

#101 = ORIENTED_EDGE ('NONE', *, *, #104, .F.) ;

#102 = FILL_AREA_STYLE ('',(#88)) ;

#103 = AXIS2_PLACEMENT_3D ('NONE', #71, #9, #90) ;

#104 = EDGE_CURVE ('NONE', #25, #46, #32, .T.) ;

#105 = ORIENTED_EDGE ('NONE', *, *, #104, .T.) ;

#106 = COLOUR_RGB ('',0.7921568627450980000, 0.8196078431372548800, 0.9333333333333333500) ;

#107 = AXIS2_PLACEMENT_3D ('NONE', #40, #38, #121) ;

#108 = ORIENTED_EDGE ('NONE', *, *, #49, .F.) ;

#109 =(GEOMETRIC_REPRESENTATION_CONTEXT (3) GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT ((#12)) GLOBAL_UNIT_ASSIGNED_CONTEXT ((#85, #100, #62)) REPRESENTATION_CONTEXT ('NONE', 'WORKASPACE'));

#110 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 0.0000000000000000000)) ;

#111 = SURFACE_STYLE_USAGE (.BOTH. , #86) ;

#112 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#113 =(NAMED_UNIT (*) PLANE_ANGLE_UNIT ( ) SI_UNIT ($, .RADIAN.));

#114 = PRODUCT_DEFINITION_FORMATION_WITH_SPECIFIED_SOURCE ('ANY', '', #117, .NOT_KNOWN.) ;

#115 = ADVANCED_FACE ('NONE', (#58), #65, .T.) ;

#116 = AXIS2_PLACEMENT_3D ('NONE', #91, #21, #43) ;

#117 = PRODUCT ('Part1', 'Part1', '', (#53)) ;

#118 = ORIENTED_EDGE ('NONE', *, *, #33, .F.) ;

#119 = LINE ('NONE', #135, #1) ;

#120 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 4.410203342021732900E-015, 41.53661799456895000)) ;

#121 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#122 = APPLICATION_CONTEXT ('automotive_design') ;

#123 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#124 = CARTESIAN_POINT ('NONE', (36.01204318740952500, 0.0000000000000000000, 41.53661799456895000)) ;

#125 = APPLICATION_CONTEXT ('automotive_design') ;

#126 = SURFACE_STYLE_FILL_AREA (#134) ;

#127 = STYLED_ITEM ('NONE', (#36), #4) ;

#128 = PRODUCT_RELATED_PRODUCT_CATEGORY ('part', '', (#117)) ;

#129 = MECHANICAL_DESIGN_GEOMETRIC_PRESENTATION_REPRESENTATION ('', (#82), #109) ;

#130 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#131 = FACE_OUTER_BOUND ('NONE', #136, .T.) ;

#132 = PLANE ('NONE', #37) ;

#133 =(LENGTH_UNIT ( ) NAMED_UNIT (*) SI_UNIT (.MILLI., .METRE.));

#134 = FILL_AREA_STYLE ('',(#39)) ;

#135 = CARTESIAN_POINT ('NONE', (72.02408637481904900, 0.0000000000000000000, 41.53661799456895000)) ;

#136 = EDGE_LOOP ('NONE', (#139, #18, #31, #26)) ;

#137 = PRODUCT_DEFINITION_CONTEXT ('detailed design', #122, 'design') ;

#138 = EDGE_CURVE ('NONE', #95, #46, #119, .T.) ;

#139 = ORIENTED_EDGE ('NONE', *, *, #33, .T.) ;

#140 = EDGE_LOOP ('NONE', (#54, #105)) ;

ENDSEC;

END-ISO-10303-21;

Appendix B:

The step file of the casestudy in chapter three:

ISO-10303-21;

HEADER;

FILE_DESCRIPTION (('STEP AP203'),

'1');

FILE_NAME ('case.STEP',

'2021-06-25T15:03:16',

(''),

(''),

'SwSTEP 2.0',

'SolidWorks 2016',

'');

FILE_SCHEMA (('CONFIG_CONTROL_DESIGN'));

ENDSEC;

DATA;

#1 = AXIS2_PLACEMENT_3D ('NONE', #596, #659, #322) ;

#2 = ADVANCED_FACE ('NONE', (#194), #512, .T.) ;

#3 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 0.0000000000000000000)) ;

#4 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 9.999999999999994700)) ;

#5 = EDGE_CURVE ('NONE', #140, #521, #467, .T.) ;

#6 = AXIS2_PLACEMENT_3D ('NONE', #493, #585, #423) ;

#7 = ORIENTED_EDGE ('NONE', *, *, #17, .T.) ;

#8 = AXIS2_PLACEMENT_3D ('NONE', #175, #266, #341) ;

#9 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, -0.0000000000000000000)) ;

#10 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#11 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#12 = CONICAL_SURFACE ('NONE', #422, 17.56450098615426800, 0.7219157713717205800) ;

#13 = VERTEX_POINT ('NONE', #239) ;

#14 = CARTESIAN_POINT ('NONE', (18.80621231118957200, 2.303096771098385900E-015, 16.15819768043937200)) ;

#15 = ORIENTED_EDGE ('NONE', *, *, #443, .T.) ;

#16 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#17 = EDGE_CURVE ('NONE', #236, #31, #599, .T.) ;

#18 = EDGE_CURVE ('NONE', #475, #538, #160, .T.) ;

#19 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#20 = APPROVAL (#195, 'UNSPECIFIED') ;

#21 = FACE_OUTER_BOUND ('NONE', #25, .T.) ;

#22 = FACE_OUTER_BOUND ('NONE', #169, .T.) ;

#23 = ORIENTED_EDGE ('NONE', *, *, #192, .T.) ;

#24 = FACE_OUTER_BOUND ('NONE', #267, .T.) ;

#25 = EDGE_LOOP ('NONE', (#52, #329, #411, #101)) ;

#26 = DATE_AND_TIME (#351, #143) ;

#27 = DIRECTION ('NONE', (-0.7878870561738601200, 0.0000000000000000000, -0.6158197680439371200)) ;

#28 = CIRCLE ('NONE', #559, 16.68508287292818100) ;

#29 = VECTOR ('NONE', #338, 1000.000000000000000) ;

#30 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#31 = VERTEX_POINT ('NONE', #231) ;

#32 = AXIS2_PLACEMENT_3D ('NONE', #299, #156, #544) ;

#33 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 54.73964107556695100)) ;

#34 = PERSON_AND_ORGANIZATION_ROLE ('creator') ;

#35 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#36 = VECTOR ('NONE', #612, 999.9999999999998900) ;

#37 = EDGE_LOOP ('NONE', (#401, #530, #342, #319)) ;

#38 = CONICAL_SURFACE ('NONE', #6, 17.56450098615426800, 0.7219157713717205800) ;

#39 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#40 = CIRCLE ('NONE', #503, 26.79377624939497300) ;

#41 = EDGE_CURVE ('NONE', #377, #311, #308, .T.) ;

#42 = CARTESIAN_POINT ('NONE', (18.80621231118957600, 0.0000000000000000000, 83.25227341343882900)) ;

#43 = ORIENTED_EDGE ('NONE', *, *, #569, .F.) ;

#44 = EDGE_CURVE ('NONE', #124, #13, #40, .T.) ;

#45 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#46 = AXIS2_PLACEMENT_3D ('NONE', #291, #255, #209) ;

#47 = AXIS2_PLACEMENT_3D ('NONE', #344, #30, #241) ;

#48 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#49 = FACE_OUTER_BOUND ('NONE', #646, .T.) ;

#50 = EDGE_LOOP ('NONE', (#416, #522, #369, #673)) ;

#51 = ORIENTED_EDGE ('NONE', *, *, #154, .T.) ;

#52 = ORIENTED_EDGE ('NONE', *, *, #501, .F.) ;

#53 = CARTESIAN_POINT ('NONE', (16.79377624939497700, 0.0000000000000000000, 54.73964107556695100)) ;

#54 = ORIENTED_EDGE ('NONE', *, *, #443, .F.) ;

#55 = CARTESIAN_POINT ('NONE', (-17.56450098615426800, 0.0000000000000000000, 65.22193776039259200)) ;

#56 = DIRECTION ('NONE', (0.7987563938205390900, 0.0000000000000000000, 0.6016545714368069000)) ;

#57 = ADVANCED_FACE ('NONE', (#24), #298, .T.) ;

#58 = EDGE_CURVE ('NONE', #185, #506, #616, .T.) ;

#59 = CIRCLE ('NONE', #302, 16.79377624939497700) ;

#60 = EDGE_CURVE ('NONE', #238, #377, #455, .T.) ;

#61 = ORIENTED_EDGE ('NONE', *, *, #373, .F.) ;

#62 = CYLINDRICAL_SURFACE ('NONE', #603, 16.68508287292818100) ;

#63 = ORIENTED_EDGE ('NONE', *, *, #141, .T.) ;

#64 = ADVANCED_FACE ('NONE', (#366), #581, .T.) ;

#65 = AXIS2_PLACEMENT_3D ('NONE', #333, #671, #337) ;

#66 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#67 = DATE_AND_TIME (#202, #107) ;

#68 = PLANE ('NONE', #32) ;

#69 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#70 = VECTOR ('NONE', #225, 1000.000000000000000) ;

#71 = ORIENTED_EDGE ('NONE', *, *, #540, .T.) ;

#72 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 65.22193776039259200)) ;

#73 = AXIS2_PLACEMENT_3D ('NONE', #77, #440, #230) ;

#74 = CARTESIAN_POINT ('NONE', (-26.68508287292818100, 0.0000000000000000000, 9.999999999999994700)) ;

#75 = LINE ('NONE', #430, #88) ;

#76 = ORIENTED_EDGE ('NONE', *, *, #287, .T.) ;

#77 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 44.73964107556695100)) ;

#78 = ORIENTED_EDGE ('NONE', *, *, #5, .T.) ;

#79 = EDGE_CURVE ('NONE', #236, #318, #244, .T.) ;

#80 = AXIS2_PLACEMENT_3D ('NONE', #680, #279, #677) ;

#81 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#82 = AXIS2_PLACEMENT_3D ('NONE', #189, #398, #86) ;

#83 = LINE ('NONE', #553, #452) ;

#84 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#85 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#86 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#87 = MECHANICAL_CONTEXT ('NONE', #389, 'mechanical') ;

#88 = VECTOR ('NONE', #119, 1000.000000000000000) ;

#89 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 73.25227341343882900)) ;

#90 = ORIENTED_EDGE ('NONE', *, *, #91, .T.) ;

#91 = EDGE_CURVE ('NONE', #13, #124, #122, .T.) ;

#92 = CARTESIAN_POINT ('NONE', (-26.79377624939497000, 3.281291232089191900E-015, 32.17474339480743600)) ;

#93 = ORIENTED_EDGE ('NONE', *, *, #682, .T.) ;

#94 = LOCAL_TIME (18, 3, 16.00000000000000000, #630) ;

#95 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, 1.000000000000000000)) ;

#96 = AXIS2_PLACEMENT_3D ('NONE', #268, #84, #388) ;

#97 = PLANE ('NONE', #46) ;

#98 = APPROVAL_ROLE ('') ;

#99 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#100 = PERSON_AND_ORGANIZATION_ROLE ('design_owner') ;

#101 = ORIENTED_EDGE ('NONE', *, *, #18, .T.) ;

#102 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#103 = FACE_OUTER_BOUND ('NONE', #365, .T.) ;

#104 = EDGE_LOOP ('NONE', (#345, #7, #76, #402)) ;

#105 = ADVANCED_FACE ('NONE', (#679), #278, .T.) ;

#106 = CC_DESIGN_DATE_AND_TIME_ASSIGNMENT (#26, #133, (#224)) ;

#107 = LOCAL_TIME (18, 3, 16.00000000000000000, #657) ;

#108 = CARTESIAN_POINT ('NONE', (-26.79377624939497000, 3.281291232089191900E-015, 83.25227341343882900)) ;

#109 = CARTESIAN_POINT ('NONE', (-18.80621231118957600, 2.303096771098386300E-015, 26.15819768043936500)) ;

#110 = EDGE_CURVE ('NONE', #281, #637, #135, .T.) ;

#111 = EDGE_CURVE ('NONE', #687, #637, #158, .T.) ;

#112 = AXIS2_PLACEMENT_3D ('NONE', #480, #424, #588) ;

#113 = APPLICATION_PROTOCOL_DEFINITION ('international standard', 'config_control_design', 1994, #476) ;

#114 = ORIENTED_EDGE ('NONE', *, *, #282, .F.) ;

#115 = AXIS2_PLACEMENT_3D ('NONE', #548, #118, #505) ;

#116 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 73.25227341343882900)) ;

#117 = DATE_AND_TIME (#429, #378) ;

#118 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#119 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#120 = CIRCLE ('NONE', #47, 16.68508287292818100) ;

#121 = ORIENTED_EDGE ('NONE', *, *, #479, .F.) ;

#122 = CIRCLE ('NONE', #526, 26.79377624939497300) ;

#123 = PLANE ('NONE', #660) ;

#124 = VERTEX_POINT ('NONE', #688) ;

#125 = DATE_AND_TIME (#621, #595) ;

#126 = EDGE_CURVE ('NONE', #665, #580, #417, .T.) ;

#127 = AXIS2_PLACEMENT_3D ('NONE', #570, #138, #567) ;

#128 = AXIS2_PLACEMENT_3D ('NONE', #510, #556, #220) ;

#129 = APPROVAL_STATUS ('not_yet_approved') ;

#130 = ORIENTED_EDGE ('NONE', *, *, #406, .T.) ;

#131 = APPLICATION_PROTOCOL_DEFINITION ('international standard', 'config_control_design', 1994, #389) ;

#132 = CIRCLE ('NONE', #73, 16.79377624939498000) ;

#133 = DATE_TIME_ROLE ('classification_date') ;

#134 = ORIENTED_EDGE ('NONE', *, *, #330, .T.) ;

#135 = CIRCLE ('NONE', #571, 16.68508287292818100) ;

#136 = VERTEX_POINT ('NONE', #468) ;

#137 = CC_DESIGN_APPROVAL (#257, (#224)) ;

#138 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#139 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#140 = VERTEX_POINT ('NONE', #528) ;

#141 = EDGE_CURVE ('NONE', #326, #136, #346, .T.) ;

#142 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 44.73964107556695100)) ;

#143 = LOCAL_TIME (18, 3, 16.00000000000000000, #165) ;

#144 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 16.15819768043937200)) ;

#145 = CYLINDRICAL_SURFACE ('NONE', #431, 16.79377624939498000) ;

#146 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#147 = ORIENTED_EDGE ('NONE', *, *, #460, .F.) ;

#148 = VECTOR ('NONE', #652, 1000.000000000000200) ;

#149 = EDGE_LOOP ('NONE', (#219, #200)) ;

#150 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#151 = ADVANCED_FACE ('NONE', (#643), #62, .T.) ;

#152 = CARTESIAN_POINT ('NONE', (26.68508287292818100, 0.0000000000000000000, 73.25227341343882900)) ;

#153 = ADVANCED_FACE ('NONE', (#22), #551, .T.) ;

#154 = EDGE_CURVE ('NONE', #672, #412, #485, .T.) ;

#155 = AXIS2_PLACEMENT_3D ('NONE', #683, #399, #35) ;

#156 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#157 = FACE_BOUND ('NONE', #212, .T.) ;

#158 = LINE ('NONE', #577, #662) ;

#159 = AXIS2_PLACEMENT_3D ('NONE', #81, #552, #328) ;

#160 = CIRCLE ('NONE', #155, 26.79377624939497700) ;

#161 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#162 = ADVANCED_FACE ('NONE', (#425), #691, .T.) ;

#163 =(NAMED_UNIT (*) SI_UNIT ($, .STERADIAN.) SOLID_ANGLE_UNIT ( ));

#164 = ORIENTED_EDGE ('NONE', *, *, #669, .T.) ;

#165 = COORDINATED_UNIVERSAL_TIME_OFFSET (3, 0, .AHEAD.) ;

#166 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#167 = CARTESIAN_POINT ('NONE', (-26.79377624939497000, 3.281291232089191900E-015, 32.17474339480743600)) ;

#168 = CIRCLE ('NONE', #128, 26.68508287292818100) ;

#169 = EDGE_LOOP ('NONE', (#321, #474, #391, #557)) ;

#170 = ORIENTED_EDGE ('NONE', *, *, #126, .T.) ;

#171 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#172 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, -0.0000000000000000000)) ;

#173 = LINE ('NONE', #273, #36) ;

#174 = FACE_OUTER_BOUND ('NONE', #348, .T.) ;

#175 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 9.999999999999994700)) ;

#176 = ORIENTED_EDGE ('NONE', *, *, #524, .F.) ;

#177 = CLOSED_SHELL ('NONE', (#420, #648, #207, #153, #545, #586, #301, #2, #361, #584, #151, #307, #105, #57, #539, #64, #206, #371, #482, #362, #421, #256, #481, #162)) ;

#178 = ORIENTED_EDGE ('NONE', *, *, #592, .T.) ;

#179 = EDGE_CURVE ('NONE', #326, #580, #606, .T.) ;

#180 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 44.73964107556695100)) ;

#181 = PRODUCT_DEFINITION_FORMATION_WITH_SPECIFIED_SOURCE ('ANY', '', #233, .NOT_KNOWN.) ;

#182 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 32.17474339480743600)) ;

#183 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#184 = CIRCLE ('NONE', #1, 18.80621231118957200) ;

#185 = VERTEX_POINT ('NONE', #53) ;

#186 = VERTEX_POINT ('NONE', #410) ;

#187 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#188 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#189 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#190 = CONICAL_SURFACE ('NONE', #543, 26.79377624939497000, 0.9252253956665805700) ;

#191 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#192 = EDGE_CURVE ('NONE', #558, #318, #626, .T.) ;

#193 = AXIS2_PLACEMENT_3D ('NONE', #404, #397, #463) ;

#194 = FACE_OUTER_BOUND ('NONE', #332, .T.) ;

#195 = APPROVAL_STATUS ('not_yet_approved') ;

#196 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT (#293, #352, (#181)) ;

#197 = DIRECTION ('NONE', (-0.7505411200053598900, 9.191477802430334900E-017, 0.6608237489536069600)) ;

#198 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#199 = CONICAL_SURFACE ('NONE', #507, 26.68508287292818100, 0.8488805554231758600) ;

#200 = ORIENTED_EDGE ('NONE', *, *, #221, .F.) ;

#201 = CARTESIAN_POINT ('NONE', (-26.68508287292818100, 3.267980132531335400E-015, 73.25227341343882900)) ;

#202 = CALENDAR_DATE (2021, 25, 6) ;

#203 = CARTESIAN_POINT ('NONE', (-17.56450098615426800, 0.0000000000000000000, 65.22193776039259200)) ;

#204 = VECTOR ('NONE', #653, 1000.000000000000000) ;

#205 = ORIENTED_EDGE ('NONE', *, *, #602, .F.) ;

#206 = ADVANCED_FACE ('NONE', (#327, #306), #97, .T.) ;

#207 = ADVANCED_FACE ('NONE', (#174), #38, .T.) ;

#208 = ORIENTED_EDGE ('NONE', *, *, #669, .F.) ;

#209 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#210 = DIRECTION ('NONE', (0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#211 = CYLINDRICAL_SURFACE ('NONE', #409, 16.68508287292818100) ;

#212 = EDGE_LOOP ('NONE', (#469, #218)) ;

#213 = APPROVAL_PERSON_ORGANIZATION (#576, #257, #276) ;

#214 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#215 = CIRCLE ('NONE', #651, 16.68508287292818100) ;

#216 = ORIENTED_EDGE ('NONE', *, *, #269, .F.) ;

#217 = VECTOR ('NONE', #533, 1000.000000000000000) ;

#218 = ORIENTED_EDGE ('NONE', *, *, #373, .T.) ;

#219 = ORIENTED_EDGE ('NONE', *, *, #18, .F.) ;

#220 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#221 = EDGE_CURVE ('NONE', #538, #475, #408, .T.) ;

#222 = AXIS2_PLACEMENT_3D ('NONE', #639, #473, #525) ;

#223 = PLANE ('NONE', #472) ;

#224 = SECURITY_CLASSIFICATION ('', '', #684) ;

#225 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#226 = LINE ('NONE', #152, #148) ;

#227 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#228 = EDGE_LOOP ('NONE', (#465, #289)) ;

#229 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#230 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#231 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 0.0000000000000000000)) ;

#232 = CARTESIAN_POINT ('NONE', (26.68508287292818100, 0.0000000000000000000, 73.25227341343882900)) ;

#233 = PRODUCT ('case', 'case', '', (#87)) ;

#234 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#235 = LINE ('NONE', #42, #661) ;

#236 = VERTEX_POINT ('NONE', #3) ;

#237 = ORIENTED_EDGE ('NONE', *, *, #569, .T.) ;

#238 = VERTEX_POINT ('NONE', #109) ;

#239 = CARTESIAN_POINT ('NONE', (-26.79377624939497700, 3.281291232089192700E-015, 44.73964107556695100)) ;

#240 = PERSON_AND_ORGANIZATION (#562, #390) ;

#241 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#242 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#243 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#244 = LINE ('NONE', #295, #217) ;

#245 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#246 = VERTEX_POINT ('NONE', #594) ;

#247 = EDGE_LOOP ('NONE', (#277, #63, #413, #655)) ;

#248 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT (#334, #34, (#290)) ;

#249 = ORIENTED_EDGE ('NONE', *, *, #602, .T.) ;

#250 = EDGE_LOOP ('NONE', (#121, #636, #629, #71)) ;

#251 = APPROVAL_PERSON_ORGANIZATION (#650, #519, #98) ;

#252 = CARTESIAN_POINT ('NONE', (26.79377624939497000, 0.0000000000000000000, 32.17474339480743600)) ;

#253 = EDGE_CURVE ('NONE', #377, #13, #258, .T.) ;

#254 = AXIS2_PLACEMENT_3D ('NONE', #144, #628, #99) ;

#255 = DIRECTION ('NONE', (0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#256 = ADVANCED_FACE ('NONE', (#590, #442), #300, .T.) ;

#257 = APPROVAL (#574, 'UNSPECIFIED') ;

#258 = LINE ('NONE', #108, #434) ;

#259 = EDGE_LOOP ('NONE', (#627, #130, #134, #270)) ;

#260 = VERTEX_POINT ('NONE', #582) ;

#261 = ORIENTED_EDGE ('NONE', *, *, #540, .F.) ;

#262 = PERSON_AND_ORGANIZATION (#562, #390) ;

#263 = LINE ('NONE', #14, #483) ;

#264 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#265 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#266 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#267 = EDGE_LOOP ('NONE', (#43, #694, #164, #356)) ;

#268 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 32.17474339480743600)) ;

#269 = EDGE_CURVE ('NONE', #454, #687, #529, .T.) ;

#270 = ORIENTED_EDGE ('NONE', *, *, #41, .F.) ;

#271 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#272 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT (#359, #678, (#181)) ;

#273 = CARTESIAN_POINT ('NONE', (17.56450098615426800, 2.151030991131435600E-015, 65.22193776039259200)) ;

#274 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#275 = FACE_OUTER_BOUND ('NONE', #427, .T.) ;

#276 = APPROVAL_ROLE ('') ;

#277 = ORIENTED_EDGE ('NONE', *, *, #179, .F.) ;

#278 = CONICAL_SURFACE ('NONE', #254, 18.80621231118957200, 0.9073703189274690000) ;

#279 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#280 = UNCERTAINTY_MEASURE_WITH_UNIT (LENGTH_MEASURE(1.000000000000000100E-005), #458, 'distance_accuracy_value', 'NONE');

#281 = VERTEX_POINT ('NONE', #641) ;

#282 = EDGE_CURVE ('NONE', #136, #665, #226, .T.) ;

#283 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 44.73964107556695100)) ;

#284 = EDGE_CURVE ('NONE', #246, #238, #376, .T.) ;

#285 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#286 = FACE_BOUND ('NONE', #504, .T.) ;

#287 = EDGE_CURVE ('NONE', #31, #558, #566, .T.) ;

#288 = FACE_OUTER_BOUND ('NONE', #664, .T.) ;

#289 = ORIENTED_EDGE ('NONE', *, *, #670, .T.) ;

#290 = PRODUCT_DEFINITION ('UNKNOWN', '', #181, #451) ;

#291 = CARTESIAN_POINT ('NONE', (26.79377624939497300, 0.0000000000000000000, 44.73964107556695100)) ;

#292 = ORIENTED_EDGE ('NONE', *, *, #253, .T.) ;

#293 = PERSON_AND_ORGANIZATION (#562, #390) ;

#294 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#295 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 83.25227341343882900)) ;

#296 = LINE ('NONE', #615, #381) ;

#297 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#298 = CYLINDRICAL_SURFACE ('NONE', #193, 18.80621231118957600) ;

#299 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 10.00000000000000000)) ;

#300 = PLANE ('NONE', #583) ;

#301 = ADVANCED_FACE ('NONE', (#288), #355, .T.) ;

#302 = AXIS2_PLACEMENT_3D ('NONE', #313, #383, #214) ;

#303 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 26.15819768043936500)) ;

#304 = CIRCLE ('NONE', #437, 16.79377624939498000) ;

#305 = ORIENTED_EDGE ('NONE', *, *, #110, .F.) ;

#306 = FACE_BOUND ('NONE', #349, .T.) ;

#307 = ADVANCED_FACE ('NONE', (#286, #339), #68, .T.) ;

#308 = CIRCLE ('NONE', #80, 26.79377624939497000) ;

#309 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#310 = ORIENTED_EDGE ('NONE', *, *, #479, .T.) ;

#311 = VERTEX_POINT ('NONE', #252) ;

#312 = COORDINATED_UNIVERSAL_TIME_OFFSET (3, 0, .AHEAD.) ;

#313 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 54.73964107556695100)) ;

#314 = AXIS2_PLACEMENT_3D ('NONE', #499, #380, #10) ;

#315 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#316 = CYLINDRICAL_SURFACE ('NONE', #633, 16.68508287292818100) ;

#317 =(NAMED_UNIT (*) PLANE_ANGLE_UNIT ( ) SI_UNIT ($, .RADIAN.));

#318 = VERTEX_POINT ('NONE', #4) ;

#319 = ORIENTED_EDGE ('NONE', *, *, #91, .F.) ;

#320 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#321 = ORIENTED_EDGE ('NONE', *, *, #489, .T.) ;

#322 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#323 = EDGE_CURVE ('NONE', #326, #475, #325, .T.) ;

#324 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#325 = LINE ('NONE', #203, #520) ;

#326 = VERTEX_POINT ('NONE', #55) ;

#327 = FACE_OUTER_BOUND ('NONE', #438, .T.) ;

#328 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#329 = ORIENTED_EDGE ('NONE', *, *, #141, .F.) ;

#330 = EDGE_CURVE ('NONE', #246, #311, #433, .T.) ;

#331 = AXIS2_PLACEMENT_3D ('NONE', #675, #564, #613) ;

#332 = EDGE_LOOP ('NONE', (#368, #310, #51, #484)) ;

#333 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#334 = PERSON_AND_ORGANIZATION (#562, #390) ;

#335 = PRODUCT_RELATED_PRODUCT_CATEGORY ('detail', '', (#233)) ;

#336 = PRODUCT_DEFINITION_SHAPE ('NONE', 'NONE', #290) ;

#337 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#338 = DIRECTION ('NONE', (-0.7987563938205390900, 9.781944609908058600E-017, 0.6016545714368069000)) ;

#339 = FACE_OUTER_BOUND ('NONE', #488, .T.) ;

#340 = ORIENTED_EDGE ('NONE', *, *, #154, .F.) ;

#341 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#342 = ORIENTED_EDGE ('NONE', *, *, #460, .T.) ;

#343 = CYLINDRICAL_SURFACE ('NONE', #314, 16.68508287292818100) ;

#344 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#345 = ORIENTED_EDGE ('NONE', *, *, #79, .F.) ;

#346 = CIRCLE ('NONE', #444, 17.56450098615426800) ;

#347 = AXIS2_PLACEMENT_3D ('NONE', #518, #563, #191) ;

#348 = EDGE_LOOP ('NONE', (#54, #497, #608, #607)) ;

#349 = EDGE_LOOP ('NONE', (#436, #176)) ;

#350 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#351 = CALENDAR_DATE (2021, 25, 6) ;

#352 = PERSON_AND_ORGANIZATION_ROLE ('creator') ;

#353 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#354 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#355 = CYLINDRICAL_SURFACE ('NONE', #572, 18.80621231118957600) ;

#356 = ORIENTED_EDGE ('NONE', *, *, #406, .F.) ;

#357 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT (#240, #623, (#224)) ;

#358 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#359 = PERSON_AND_ORGANIZATION (#562, #390) ;

#360 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 83.25227341343882900)) ;

#361 = ADVANCED_FACE ('NONE', (#573), #316, .T.) ;

#362 = ADVANCED_FACE ('NONE', (#21), #12, .T.) ;

#363 = CIRCLE ('NONE', #82, 16.68508287292818100) ;

#364 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#365 = EDGE_LOOP ('NONE', (#486, #619, #305, #205)) ;

#366 = FACE_OUTER_BOUND ('NONE', #37, .T.) ;

#367 = EDGE_LOOP ('NONE', (#170, #178)) ;

#368 = ORIENTED_EDGE ('NONE', *, *, #5, .F.) ;

#369 = ORIENTED_EDGE ('NONE', *, *, #644, .F.) ;

#370 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 83.25227341343882900)) ;

#371 = ADVANCED_FACE ('NONE', (#275), #145, .T.) ;

#372 = APPROVAL_DATE_TIME (#117, #257) ;

#373 = EDGE_CURVE ('NONE', #506, #185, #59, .T.) ;

#374 = AXIS2_PLACEMENT_3D ('NONE', #294, #102, #243) ;

#375 = DIRECTION ('NONE', (-0.6608237489536069600, 0.0000000000000000000, -0.7505411200053601100)) ;

#376 = CIRCLE ('NONE', #527, 18.80621231118957600) ;

#377 = VERTEX_POINT ('NONE', #167) ;

#378 = LOCAL_TIME (18, 3, 16.00000000000000000, #667) ;

#379 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#380 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#381 = VECTOR ('NONE', #27, 1000.000000000000100) ;

#382 = ORIENTED_EDGE ('NONE', *, *, #284, .F.) ;

#383 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#384 = APPROVAL_DATE_TIME (#516, #519) ;

#385 = CC_DESIGN_APPROVAL (#519, (#290)) ;

#386 = MANIFOLD_SOLID_BREP ('Revolve1', #177) ;

#387 = CARTESIAN_POINT ('NONE', (-18.80621231118957200, 0.0000000000000000000, 16.15819768043937200)) ;

#388 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#389 = APPLICATION_CONTEXT ('configuration controlled 3d designs of mechanical parts and assemblies') ;

#390 = ORGANIZATION ('UNSPECIFIED', 'UNSPECIFIED', '') ;

#391 = ORIENTED_EDGE ('NONE', *, *, #58, .F.) ;

#392 = ORIENTED_EDGE ('NONE', *, *, #126, .F.) ;

#393 = EDGE_LOOP ('NONE', (#93, #456, #445, #426)) ;

#394 = CARTESIAN_POINT ('NONE', (-26.68508287292818100, 3.267980132531335400E-015, 73.25227341343882900)) ;

#395 = AXIS2_PLACEMENT_3D ('NONE', #494, #69, #498) ;

#396 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#397 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#398 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#399 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#400 = FACE_OUTER_BOUND ('NONE', #666, .T.) ;

#401 = ORIENTED_EDGE ('NONE', *, *, #253, .F.) ;

#402 = ORIENTED_EDGE ('NONE', *, *, #631, .F.) ;

#403 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#404 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#405 = EDGE_CURVE ('NONE', #186, #185, #502, .T.) ;

#406 = EDGE_CURVE ('NONE', #238, #246, #534, .T.) ;

#407 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#408 = CIRCLE ('NONE', #112, 26.79377624939497700) ;

#409 = AXIS2_PLACEMENT_3D ('NONE', #379, #16, #601) ;

#410 = CARTESIAN_POINT ('NONE', (16.79377624939498000, 0.0000000000000000000, 44.73964107556695100)) ;

#411 = ORIENTED_EDGE ('NONE', *, *, #323, .T.) ;

#412 = VERTEX_POINT ('NONE', #74) ;

#413 = ORIENTED_EDGE ('NONE', *, *, #282, .T.) ;

#414 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#415 = FACE_OUTER_BOUND ('NONE', #514, .T.) ;

#416 = ORIENTED_EDGE ('NONE', *, *, #284, .T.) ;

#417 = CIRCLE ('NONE', #374, 26.68508287292818100) ;

#418 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#419 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#420 = ADVANCED_FACE ('NONE', (#103), #211, .T.) ;

#421 = ADVANCED_FACE ('NONE', (#634), #199, .T.) ;

#422 = AXIS2_PLACEMENT_3D ('NONE', #72, #11, #324) ;

#423 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#424 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#425 = FACE_OUTER_BOUND ('NONE', #228, .T.) ;

#426 = ORIENTED_EDGE ('NONE', *, *, #287, .F.) ;

#427 = EDGE_LOOP ('NONE', (#457, #542, #536, #61)) ;

#428 = EDGE_CURVE ('NONE', #260, #506, #75, .T.) ;

#429 = CALENDAR_DATE (2021, 25, 6) ;

#430 = CARTESIAN_POINT ('NONE', (-16.79377624939498000, 2.056644432941840400E-015, 83.25227341343882900)) ;

#431 = AXIS2_PLACEMENT_3D ('NONE', #315, #656, #171) ;

#432 = CARTESIAN_POINT ('NONE', (-16.79377624939497700, 2.056644432941840000E-015, 54.73964107556695100)) ;

#433 = LINE ('NONE', #693, #605) ;

#434 = VECTOR ('NONE', #161, 1000.000000000000000) ;

#435 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#436 = ORIENTED_EDGE ('NONE', *, *, #489, .F.) ;

#437 = AXIS2_PLACEMENT_3D ('NONE', #180, #604, #561) ;

#438 = EDGE_LOOP ('NONE', (#589, #90)) ;

#439 = DIRECTION ('NONE', (0.7878870561738601200, 9.648833614329486000E-017, -0.6158197680439371200)) ;

#440 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#441 = FACE_OUTER_BOUND ('NONE', #446, .T.) ;

#442 = FACE_BOUND ('NONE', #681, .T.) ;

#443 = EDGE_CURVE ('NONE', #136, #326, #625, .T.) ;

#444 = AXIS2_PLACEMENT_3D ('NONE', #685, #354, #414) ;

#445 = ORIENTED_EDGE ('NONE', *, *, #192, .F.) ;

#446 = EDGE_LOOP ('NONE', (#547, #618)) ;

#447 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 83.25227341343882900)) ;

#448 = ORIENTED_EDGE ('NONE', *, *, #668, .F.) ;

#449 = APPROVAL_DATE_TIME (#125, #20) ;

#450 = CC_DESIGN_APPROVAL (#20, (#181)) ;

#451 = DESIGN_CONTEXT ('detailed design', #476, 'design') ;

#452 = VECTOR ('NONE', #19, 1000.000000000000000) ;

#453 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 9.999999999999994700)) ;

#454 = VERTEX_POINT ('NONE', #116) ;

#455 = LINE ('NONE', #92, #29) ;

#456 = ORIENTED_EDGE ('NONE', *, *, #79, .T.) ;

#457 = ORIENTED_EDGE ('NONE', *, *, #428, .F.) ;

#458 =(LENGTH_UNIT ( ) NAMED_UNIT (*) SI_UNIT (.MILLI., .METRE.));

#459 = CARTESIAN_POINT ('NONE', (26.68508287292818100, 3.267980132531335000E-015, 9.999999999999994700)) ;

#460 = EDGE_CURVE ('NONE', #311, #124, #464, .T.) ;

#461 = EDGE_CURVE ('NONE', #521, #140, #184, .T.) ;

#462 = AXIS2_PLACEMENT_3D ('NONE', #418, #478, #647) ;

#463 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#464 = LINE ('NONE', #597, #598) ;

#465 = ORIENTED_EDGE ('NONE', *, *, #110, .T.) ;

#466 = VECTOR ('NONE', #197, 1000.000000000000200) ;

#467 = CIRCLE ('NONE', #331, 18.80621231118957200) ;

#468 = CARTESIAN_POINT ('NONE', (17.56450098615426800, 2.716161111610314100E-015, 65.22193776039259200)) ;

#469 = ORIENTED_EDGE ('NONE', *, *, #58, .T.) ;

#470 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#471 = FACE_OUTER_BOUND ('NONE', #149, .T.) ;

#472 = AXIS2_PLACEMENT_3D ('NONE', #396, #609, #172) ;

#473 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#474 = ORIENTED_EDGE ('NONE', *, *, #428, .T.) ;

#475 = VERTEX_POINT ('NONE', #663) ;

#476 = APPLICATION_CONTEXT ('configuration controlled 3d designs of mechanical parts and assemblies') ;

#477 = CC_DESIGN_PERSON_AND_ORGANIZATION_ASSIGNMENT (#610, #100, (#233)) ;

#478 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#479 = EDGE_CURVE ('NONE', #140, #672, #263, .T.) ;

#480 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 54.73964107556695100)) ;

#481 = ADVANCED_FACE ('NONE', (#415), #343, .T.) ;

#482 = ADVANCED_FACE ('NONE', (#157, #471), #123, .T.) ;

#483 = VECTOR ('NONE', #439, 1000.000000000000100) ;

#484 = ORIENTED_EDGE ('NONE', *, *, #554, .F.) ;

#485 = CIRCLE ('NONE', #222, 26.68508287292818100) ;

#486 = ORIENTED_EDGE ('NONE', *, *, #269, .T.) ;

#487 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#488 = EDGE_LOOP ('NONE', (#261, #340)) ;

#489 = EDGE_CURVE ('NONE', #186, #260, #132, .T.) ;

#490 = AXIS2_PLACEMENT_3D ('NONE', #360, #635, #690) ;

#491 = DIRECTION ('NONE', (1.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#492 = CC_DESIGN_SECURITY_CLASSIFICATION (#224, (#181)) ;

#493 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 65.22193776039259200)) ;

#494 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 26.15819768043936500)) ;

#495 = VECTOR ('NONE', #320, 1000.000000000000000) ;

#496 = ORIENTED_EDGE ('NONE', *, *, #111, .F.) ;

#497 = ORIENTED_EDGE ('NONE', *, *, #501, .T.) ;

#498 = DIRECTION ('NONE', (1.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#499 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#500 = CARTESIAN_POINT ('NONE', (16.79377624939497700, 0.0000000000000000000, 54.73964107556695100)) ;

#501 = EDGE_CURVE ('NONE', #136, #538, #173, .T.) ;

#502 = LINE ('NONE', #600, #495) ;

#503 = AXIS2_PLACEMENT_3D ('NONE', #283, #624, #403) ;

#504 = EDGE_LOOP ('NONE', (#23, #531)) ;

#505 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#506 = VERTEX_POINT ('NONE', #432) ;

#507 = AXIS2_PLACEMENT_3D ('NONE', #658, #265, #435) ;

#508 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 9.999999999999994700)) ;

#509 = APPROVAL_PERSON_ORGANIZATION (#262, #20, #620) ;

#510 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#511 = LINE ('NONE', #447, #70) ;

#512 = CONICAL_SURFACE ('NONE', #127, 18.80621231118957200, 0.9073703189274690000) ;

#513 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 83.25227341343882900)) ;

#514 = EDGE_LOOP ('NONE', (#496, #649, #249, #523)) ;

#515 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#516 = DATE_AND_TIME (#638, #94) ;

#517 =(GEOMETRIC_REPRESENTATION_CONTEXT (3) GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT ((#280)) GLOBAL_UNIT_ASSIGNED_CONTEXT ((#458, #317, #163)) REPRESENTATION_CONTEXT ('NONE', 'WORKASPACE'));

#518 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 32.17474339480743600)) ;

#519 = APPROVAL (#129, 'UNSPECIFIED') ;

#520 = VECTOR ('NONE', #375, 999.9999999999998900) ;

#521 = VERTEX_POINT ('NONE', #387) ;

#522 = ORIENTED_EDGE ('NONE', *, *, #60, .T.) ;

#523 = ORIENTED_EDGE ('NONE', *, *, #670, .F.) ;

#524 = EDGE_CURVE ('NONE', #260, #186, #304, .T.) ;

#525 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#526 = AXIS2_PLACEMENT_3D ('NONE', #142, #146, #245) ;

#527 = AXIS2_PLACEMENT_3D ('NONE', #303, #166, #309) ;

#528 = CARTESIAN_POINT ('NONE', (18.80621231118957200, 2.785538451814860700E-015, 16.15819768043937200)) ;

#529 = CIRCLE ('NONE', #462, 16.68508287292818100) ;

#530 = ORIENTED_EDGE ('NONE', *, *, #41, .T.) ;

#531 = ORIENTED_EDGE ('NONE', *, *, #631, .T.) ;

#532 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#533 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#534 = CIRCLE ('NONE', #395, 18.80621231118957600) ;

#535 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#536 = ORIENTED_EDGE ('NONE', *, *, #405, .T.) ;

#537 = SHAPE_DEFINITION_REPRESENTATION (#336, #591) ;

#538 = VERTEX_POINT ('NONE', #674) ;

#539 = ADVANCED_FACE ('NONE', (#579), #190, .T.) ;

#540 = EDGE_CURVE ('NONE', #412, #672, #692, .T.) ;

#541 = AXIS2_PLACEMENT_3D ('NONE', #33, #515, #183) ;

#542 = ORIENTED_EDGE ('NONE', *, *, #524, .T.) ;

#543 = AXIS2_PLACEMENT_3D ('NONE', #182, #611, #271) ;

#544 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, -0.0000000000000000000)) ;

#545 = ADVANCED_FACE ('NONE', (#49), #587, .T.) ;

#546 = CARTESIAN_POINT ('NONE', (26.68508287292818100, 0.0000000000000000000, 73.25227341343882900)) ;

#547 = ORIENTED_EDGE ('NONE', *, *, #682, .F.) ;

#548 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 65.22193776039259200)) ;

#549 = CC_DESIGN_DATE_AND_TIME_ASSIGNMENT (#67, #568, (#290)) ;

#550 = FACE_OUTER_BOUND ('NONE', #50, .T.) ;

#551 = CYLINDRICAL_SURFACE ('NONE', #555, 16.79377624939498000) ;

#552 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#553 = CARTESIAN_POINT ('NONE', (-18.80621231118957600, 2.303096771098386300E-015, 83.25227341343882900)) ;

#554 = EDGE_CURVE ('NONE', #521, #412, #296, .T.) ;

#555 = AXIS2_PLACEMENT_3D ('NONE', #358, #45, #48) ;

#556 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#557 = ORIENTED_EDGE ('NONE', *, *, #405, .F.) ;

#558 = VERTEX_POINT ('NONE', #508) ;

#559 = AXIS2_PLACEMENT_3D ('NONE', #453, #560, #227) ;

#560 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#561 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#562 = PERSON ('UNSPECIFIED', 'UNSPECIFIED', 'UNSPECIFIED', ('UNSPECIFIED'), ('UNSPECIFIED'), ('UNSPECIFIED')) ;

#563 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#564 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#565 = CIRCLE ('NONE', #347, 26.79377624939497000) ;

#566 = LINE ('NONE', #370, #204) ;

#567 = DIRECTION ('NONE', (-1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#568 = DATE_TIME_ROLE ('creation_date') ;

#569 = EDGE_CURVE ('NONE', #521, #238, #83, .T.) ;

#570 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 16.15819768043937200)) ;

#571 = AXIS2_PLACEMENT_3D ('NONE', #532, #578, #297) ;

#572 = AXIS2_PLACEMENT_3D ('NONE', #487, #640, #419) ;

#573 = FACE_OUTER_BOUND ('NONE', #393, .T.) ;

#574 = APPROVAL_STATUS ('not_yet_approved') ;

#575 = ORIENTED_EDGE ('NONE', *, *, #644, .T.) ;

#576 = PERSON_AND_ORGANIZATION (#562, #390) ;

#577 = CARTESIAN_POINT ('NONE', (-16.68508287292818100, 2.043333333383982000E-015, 83.25227341343882900)) ;

#578 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#579 = FACE_OUTER_BOUND ('NONE', #259, .T.) ;

#580 = VERTEX_POINT ('NONE', #394) ;

#581 = CYLINDRICAL_SURFACE ('NONE', #632, 26.79377624939497000) ;

#582 = CARTESIAN_POINT ('NONE', (-16.79377624939498000, 2.056644432941840400E-015, 44.73964107556695100)) ;

#583 = AXIS2_PLACEMENT_3D ('NONE', #546, #210, #66) ;

#584 = ADVANCED_FACE ('NONE', (#441), #223, .T.) ;

#585 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#586 = ADVANCED_FACE ('NONE', (#550), #614, .T.) ;

#587 = CYLINDRICAL_SURFACE ('NONE', #65, 26.79377624939497000) ;

#588 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#589 = ORIENTED_EDGE ('NONE', *, *, #44, .T.) ;

#590 = FACE_OUTER_BOUND ('NONE', #367, .T.) ;

#591 = ADVANCED_BREP_SHAPE_REPRESENTATION ('case', (#386, #622), #517) ;

#592 = EDGE_CURVE ('NONE', #580, #665, #168, .T.) ;

#593 = AXIS2_PLACEMENT_3D ('NONE', #686, #353, #491) ;

#594 = CARTESIAN_POINT ('NONE', (18.80621231118957600, 0.0000000000000000000, 26.15819768043936500)) ;

#595 = LOCAL_TIME (18, 3, 16.00000000000000000, #312) ;

#596 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 16.15819768043937200)) ;

#597 = CARTESIAN_POINT ('NONE', (26.79377624939497000, 0.0000000000000000000, 83.25227341343882900)) ;

#598 = VECTOR ('NONE', #264, 1000.000000000000000) ;

#599 = CIRCLE ('NONE', #645, 16.68508287292818100) ;

#600 = CARTESIAN_POINT ('NONE', (16.79377624939498000, 0.0000000000000000000, 83.25227341343882900)) ;

#601 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#602 = EDGE_CURVE ('NONE', #454, #281, #511, .T.) ;

#603 = AXIS2_PLACEMENT_3D ('NONE', #198, #285, #39) ;

#604 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#605 = VECTOR ('NONE', #56, 1000.000000000000000) ;

#606 = LINE ('NONE', #201, #466) ;

#607 = ORIENTED_EDGE ('NONE', *, *, #323, .F.) ;

#608 = ORIENTED_EDGE ('NONE', *, *, #221, .T.) ;

#609 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#610 = PERSON_AND_ORGANIZATION (#562, #390) ;

#611 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#612 = DIRECTION ('NONE', (0.6608237489536069600, 8.092756889565889800E-017, -0.7505411200053601100)) ;

#613 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#614 = CONICAL_SURFACE ('NONE', #96, 26.79377624939497000, 0.9252253956665805700) ;

#615 = CARTESIAN_POINT ('NONE', (-18.80621231118957200, 0.0000000000000000000, 16.15819768043937200)) ;

#616 = CIRCLE ('NONE', #541, 16.79377624939497700) ;

#617 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 83.25227341343882900)) ;

#618 = ORIENTED_EDGE ('NONE', *, *, #17, .F.) ;

#619 = ORIENTED_EDGE ('NONE', *, *, #111, .T.) ;

#620 = APPROVAL_ROLE ('') ;

#621 = CALENDAR_DATE (2021, 25, 6) ;

#622 = AXIS2_PLACEMENT_3D ('NONE', #139, #95, #350) ;

#623 = PERSON_AND_ORGANIZATION_ROLE ('classification_officer') ;

#624 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#625 = CIRCLE ('NONE', #115, 17.56450098615426800) ;

#626 = CIRCLE ('NONE', #593, 16.68508287292818100) ;

#627 = ORIENTED_EDGE ('NONE', *, *, #60, .F.) ;

#628 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#629 = ORIENTED_EDGE ('NONE', *, *, #554, .T.) ;

#630 = COORDINATED_UNIVERSAL_TIME_OFFSET (3, 0, .AHEAD.) ;

#631 = EDGE_CURVE ('NONE', #318, #558, #28, .T.) ;

#632 = AXIS2_PLACEMENT_3D ('NONE', #617, #229, #274) ;

#633 = AXIS2_PLACEMENT_3D ('NONE', #364, #150, #535) ;

#634 = FACE_OUTER_BOUND ('NONE', #247, .T.) ;

#635 = DIRECTION ('NONE', (0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#636 = ORIENTED_EDGE ('NONE', *, *, #461, .F.) ;

#637 = VERTEX_POINT ('NONE', #513) ;

#638 = CALENDAR_DATE (2021, 25, 6) ;

#639 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 9.999999999999994700)) ;

#640 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#641 = CARTESIAN_POINT ('NONE', (16.68508287292818100, 0.0000000000000000000, 83.25227341343882900)) ;

#642 = CONICAL_SURFACE ('NONE', #159, 26.68508287292818100, 0.8488805554231758600) ;

#643 = FACE_OUTER_BOUND ('NONE', #104, .T.) ;

#644 = EDGE_CURVE ('NONE', #311, #377, #565, .T.) ;

#645 = AXIS2_PLACEMENT_3D ('NONE', #85, #234, #188) ;

#646 = EDGE_LOOP ('NONE', (#575, #292, #695, #147)) ;

#647 = DIRECTION ('NONE', (1.0000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#648 = ADVANCED_FACE ('NONE', (#400), #642, .T.) ;

#649 = ORIENTED_EDGE ('NONE', *, *, #668, .T.) ;

#650 = PERSON_AND_ORGANIZATION (#562, #390) ;

#651 = AXIS2_PLACEMENT_3D ('NONE', #407, #242, #187) ;

#652 = DIRECTION ('NONE', (0.7505411200053598900, 0.0000000000000000000, 0.6608237489536069600)) ;

#653 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#654 = DIRECTION ('NONE', (0.0000000000000000000, 0.0000000000000000000, -1.000000000000000000)) ;

#655 = ORIENTED_EDGE ('NONE', *, *, #592, .F.) ;

#656 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#657 = COORDINATED_UNIVERSAL_TIME_OFFSET (3, 0, .AHEAD.) ;

#658 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 73.25227341343882900)) ;

#659 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#660 = AXIS2_PLACEMENT_3D ('NONE', #500, #654, #9) ;

#661 = VECTOR ('NONE', #676, 1000.000000000000000) ;

#662 = VECTOR ('NONE', #470, 1000.000000000000000) ;

#663 = CARTESIAN_POINT ('NONE', (-26.79377624939497700, 0.0000000000000000000, 54.73964107556695100)) ;

#664 = EDGE_LOOP ('NONE', (#78, #237, #382, #208)) ;

#665 = VERTEX_POINT ('NONE', #232) ;

#666 = EDGE_LOOP ('NONE', (#15, #689, #392, #114)) ;

#667 = COORDINATED_UNIVERSAL_TIME_OFFSET (3, 0, .AHEAD.) ;

#668 = EDGE_CURVE ('NONE', #687, #454, #120, .T.) ;

#669 = EDGE_CURVE ('NONE', #140, #246, #235, .T.) ;

#670 = EDGE_CURVE ('NONE', #637, #281, #363, .T.) ;

#671 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#672 = VERTEX_POINT ('NONE', #459) ;

#673 = ORIENTED_EDGE ('NONE', *, *, #330, .F.) ;

#674 = CARTESIAN_POINT ('NONE', (26.79377624939497700, 3.281291232089193100E-015, 54.73964107556695100)) ;

#675 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 16.15819768043937200)) ;

#676 = DIRECTION ('NONE', (-0.0000000000000000000, -0.0000000000000000000, 1.000000000000000000)) ;

#677 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#678 = PERSON_AND_ORGANIZATION_ROLE ('design_supplier') ;

#679 = FACE_OUTER_BOUND ('NONE', #250, .T.) ;

#680 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 32.17474339480743600)) ;

#681 = EDGE_LOOP ('NONE', (#216, #448)) ;

#682 = EDGE_CURVE ('NONE', #31, #236, #215, .T.) ;

#683 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 54.73964107556695100)) ;

#684 = SECURITY_CLASSIFICATION_LEVEL ('unclassified') ;

#685 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 65.22193776039259200)) ;

#686 = CARTESIAN_POINT ('NONE', (0.0000000000000000000, 0.0000000000000000000, 9.999999999999994700)) ;

#687 = VERTEX_POINT ('NONE', #89) ;

#688 = CARTESIAN_POINT ('NONE', (26.79377624939497300, 0.0000000000000000000, 44.73964107556695100)) ;

#689 = ORIENTED_EDGE ('NONE', *, *, #179, .T.) ;

#690 = DIRECTION ('NONE', (1.000000000000000000, 0.0000000000000000000, 0.0000000000000000000)) ;

#691 = PLANE ('NONE', #490) ;

#692 = CIRCLE ('NONE', #8, 26.68508287292818100) ;

#693 = CARTESIAN_POINT ('NONE', (26.79377624939497000, 0.0000000000000000000, 32.17474339480743600)) ;

#694 = ORIENTED_EDGE ('NONE', *, *, #461, .T.) ;

#695 = ORIENTED_EDGE ('NONE', *, *, #44, .F.) ;

ENDSEC;

END-ISO-10303-21;

RESUME

EDUCATION

High School : 2013 graduated from Fadak High School.

Bachelor : 2017 graduated from the University Of Technology in Baghdad, Production And Metrology Department, branch of CAD/CAM engineering.