International Journal of Engineering Innovation & Research
Volume 4, Issue 6, ISSN: 2277 – 5668

Generation of Cylindrical Features Recognition for CAD/CAM Integration

Dr. Hamza A. Ghulman
Department of Mechanical Engineering, College of Engineering and Islamic Architecture, UQU University, King Saudi Arabia
Email: haghulman@uqu.edu.sa

Dr. Mohamed Abdel Gawad Mostafa
Department of Industrial Engineering, Zagazig University, Egypt
Email: cadcapp@yahoo.com

Eng. Abdulkareem B. Alsayegh
Department of Mechanical Engineering, UQU University, King Saudi Arabia
Email: kareem44444@gmail.com

***Abstract* – This paper discusses the extraction of cylindrical based features from a neutral data format, namely STEP(Standard for the Exchange of Product Model Data) file produced by any Computer Aided Design (CAD)systems. The cylindrical features can be modeled using feature-based design or Constructive Solid Geometry methods. A rule-based algorithm was developed for the extraction of the cylindrical features. The advantages and disadvantages of this method are also highlighted**

***Keywords* – Feature Recognition, STEP, Computer Aided Design.**

I. Introduction

Work on feature-based modeling for CAD/CAM integration has led to the development of two main approaches namely design-by-features and feature recognition. In the design-by-features approach, part models are defined directly by adding, subtracting and manipulating features created as instances of predefined feature types. This approach allows non-geometric information to be stored into the feature model but limits the designer to the use of pre-defined features which thus limits the complexity of the product design that can be represented and making the resulting feature-based model context-dependent. Feature recognition involves computationally recognizing features from conventional geometric models or from neutral data format such as IGES, STEP. This approach avoids the limitation of design-by-features by attempting to identify features from already designed component description but requires a complex analysis of the geometric model. Gao et al (2004)[1] discussed conversion algorithm coaxial hole-series machining feature based on the design feature model for gear box components. The planar-type machining features and non-geometrical attribute features are also studied. The converted machining features model can be transferred to process planning system using STEP file.

Another work by Cicirello and Regli (2001)[2] presented the approach to using machining features as an indexretrieval mechanism for solid models. One of the technical approaches for this research is to perform machining features extraction to map the solid model to a set of STEP machining features. The approach is using automatic feature recognition, based on the FBMach system from Allied Signal to generate feature data to be used in indexing algorithms.Han et al. (2001)[3] proposed the work to integrate feature recognition and process planning in the machining domain. The purpose of the work is to achieve the goal of CAD/CAM integration. The system that was proposed uses STEP as input and output formats. STEP is the interface for portability between CAD and planning systems, feature recognition for manufacturability and setup minimization, feature dependencyconstruction, and generation of an optimal feature-based machining sequence.

Bhandarkar and Ragi (2000)[4] developed feature extraction system takes STEP file as input and to define the geometry and topology of a part. In addition, the system generates STEP file, as output with form featureinformation is AP224 format for form feature process planning. The STEP file can be exchanged betweenvarious companies and can serve as input to further downstream activities such as process planning, scheduling and material requirement planning (MRP).
Henderson and Anderson (1984)[5] used logic rules for cylindrical hole's recognition. An example logic ruleused is as follows:

IF *a hole entrance exists*
AND *the face adjacent to the entrance is cylindrical, and the face is convex,*
AND the next adjacent face is a plane,
AND *this plane is adjacent only to the cylinder,*
THEN *the entrance face, cylindrical face and plane comprise a cylindrical hole.*

Work by Abdalla et al. (1994)[6] used logic rules for the recognition of a hole and it can be defined through thefollowing rules:

If
(There is a circular top edge) and
(There is a circular bottom edge) and
(There is a cylindrical face) and
(There is a top face) and
(There is a bottom face) and
Then(The feature is a hole)

Rule-based and Edge Boundary Classification (EBC) technique for recognition of holes and bosses featureswere presented by Ismail et al. 1997[7]. The main advantage of this method is that it can be applied for holesfeatures having multi curve edge loop (MEL) as a result of interacting with other features that would not beidentified by other techniques found in literature. As an example, the rule for simple and complex (multi curveedge loop) through holes is as follows:

If
a cylindrical face exists
AND *tp_1 for edge loop SEL_1 is off object*
AND *tp_2 for edge loop SEL_2 is off object*
AND *t_{pm} for mid-point of virtual line* is *off object*
Then *he feature is through hole*

This paper discusses the extraction of cylindrical features for CAD/CAM integration from STEP files. Rulebased algorithm is used for the extraction of feature and its geometrical data. The features considered in the casestudy are holes that commonly found in tool and die industry and machined components.

II. Cylindrical Features Definition

Noort et al. (2002)[8] defined form features as regions of the part that have some functional meaning. The formfeatures contain class-specific design information that is captured by means of feature elements and featureconstraints. Feature elements are shapes and user-defined variables. Features constraints can be, for example, ageometric distance face-face constraint, a dimension constraint, which specifies a dimension to be within agiven range, and on-boundary constraint, which specifies feature face to be on the boundary of the part.

The data structure of cylindrical features consists of circular edges and cylindrical face as shown in figure 1. The *circular edge* is aset of connected edges that may form the closed boundary of a non-self-intersecting face. Non-linear(curve/circular) edges are formed by cylindrical or conical faces.

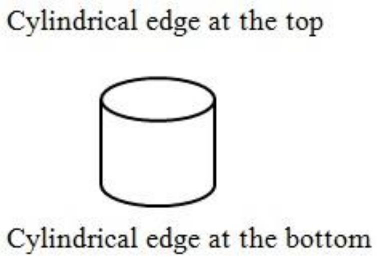


Fig.1. Circular edge of a Cylindrical Face

Hole and bosses features are cylindrical features. Hole can be further divided into simple holes, counter-sunk holes and counter-bored holes. The holes can be created to a specific depth or completely through the body [9].

III. Standard for the Exchange of Product Model Data (STEP)

The purpose of STEP is to build a common standard that ensures the product data can be communicated electronically across different platforms, e.g. CAD, CAM and CAE. The STEP standard differs from IGES by incorporating a formal object-oriented model for data exchange [10].

STEP enables all individuals contributing to the design, manufacturing, marketing and supply of a product and its components to contribute to, to access, and to share information. STEP aims at eliminating the concept of "islands of automation". STEP also attempts to unite manufacturing efforts among corporate partners, distant subsidiaries and suppliers across diverse computer environments. STEP addresses the issues of diversified engineering applications and covers security aspects, which become relevant now that several companies would be sharing the same product information [11].

The STEP neutral file is a text file that contains geometrical data of a component including boundary representation data such as shells, faces, vertices; surface geometric data such as planes, cylinders, cones, curve geometric such as lines, circles, ellipses, b-spline curves. The brief description of some STEP elements is provided as shown in Table 1 [12].

Table 1: The brief description of some STEP elements

CARTESIAN_POINT	Address of a point in Cartesian space.
ADVANCE_FACE	The face that associated with a type of surface.
CYLINDRICAL_SURFACE	A face of cylinder in which the geometry is defined by the associated surface, boundary and vertices.
CIRCLE	A circle in which the geometry is defined by the associated surface, boundary and vertices.
PLANE:	A plane in which the geometry is defined by the associated surface, boundary and vertices.
PLANE:	A line in which the geometry is defined by the associated surface, boundary and vertices.

Geometrical data of CYLINDRICAL_SURFACE shows that the xaxis and the y- axis of the CYLINDRICAL_SURFACE are the same with first circle and second circle. Theradius of CYLINDRICAL_SURFACE, whether the first CIRCLE or second CIRCLE, have the same values. Itproves that first circle and second circle.

IV. Feature Extraction Module

Table 2 shows system developed in this research. The extraction module recognizes cylindrical features from STEP file using Rule-based technique and have the following capabilities:

a) Retrieve the associated entity data name of the current solid model being process from the database

b) Extract all relevant geometric and topological data and pre-processing the information into a format suitable for use by the rule-based technique

c) Process geometric and topological data using interface programming software

d) Perform feature recognition by pattern matching and extraction of feature parameters from geometric database

Table 2: Part of STEP file for blind hole

Item	Descriptions
#23=CARTESIAN_POINT('',(5.,5.,10.)); #27=CIRCLE('',#26,2.5);	1st circle with the radius of 2.5 mmand centre of the circle, X5, Y5, Z10
#182=CARTESIAN_POINT('',(5.,5.,4.,)); #186=CIRCLE('',#185,2.5);	2nd circle with the radius of 2.5 mm andcentre of the circle, X5, Y5, Z4
#205=CARTESIAN_POINT('',(5.,5.,10.,)); #209=CYLINDRICAL_SURFACE('',#208,2.5);	cylindrical surface with the radius of 2 mm

The rule for through hole at XY plane is written as follows:

If
Circle $_{iX}$and *Circle* $_{iy}$for a circle same with *Circle* $_{iX}$and *Circle* $_{iy}$for other circle and also same with *Circle* $_{jX}$and *Circle* $_{jy}$for one of the cylindrical
And
The *CIRADIUS* for same circle same with *CIRADIUS* for other same circle and also samewith *CYRADIUS* for the same cylindrical
And
CIPLANE for one of the circle is *FALSE*
AndCIPLANE for other circle also must be *FALSE*
Then
The result is ***Through Hole***

4-1. Operation selection and sequence

The performance of a CAPP system is mainly based on the determination of sequence of operations. The function of operation sequencing in the CAD/CAM integration is to provide a technological knowledge about the machining which is further used by the down-stream process planning phases like tool selection, etc. Therefore, determination of the sequence of operations is the heart of CAPP, and the efficiency of CAPP systems depends upon the sequence of operations. It should also be noted that optimization of operation sequences is strictly necessary to satisfy the cost requirements. The sequence of operations according to precedence relationships can be classified in the following way:

- ❖ Dimensions with a datum as anteriority;
- ❖ Geometric tolerances with data references as interiorities;
- ❖ Technological constraints in order to execute sequences of operation properly;
- ❖ Economic constraints which reduce production costs and wear or breakage of costly tools.

4.2. Examples of these different types of interiorities are explained blew:

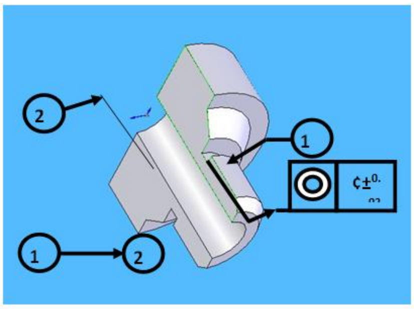


Fig.3. Case of geometric precedence

1. Figure (2) illustrates the case of a dimensional precedence: surface F1 being dimensioned in relation to the rough surface B1, it is logical to execute surface F1 before surface F6 (also because of the tighter tolerances ±0.3).
2. Figure (3) illustrates a geometric anteriority where the tolerance of coaxially of hole (2) is referred to shaft (1), taken as a datum and therefore an anteriority.
3. Figure (4) given an example of a technological constraint. This anteriority says that a hole having the smallest diameter or the longest depth has to be machined before another hole of a larger diameter or lesser depth. This is because the straightness of a thinner hole or of a more precise hole can be impaired by the larger or less precise hole when they intersect (e.g. H7 has to be produced before H11).
4. Figure (5) illustrates economical constraints. In one case, drilling of two coaxial holes could be performed by drilling the long and small hole first. However, by drilling the large hole first, the length and time of processing is reduced and time spent on the large hole is not influenced by the presence of the small hole. Therefore, it is more economical in fact to drill the large hole first. In a second case, it is more economical to finish surface (2) first so that surface (1) would not be damaged and Figure (6) CAD/CAM integration.

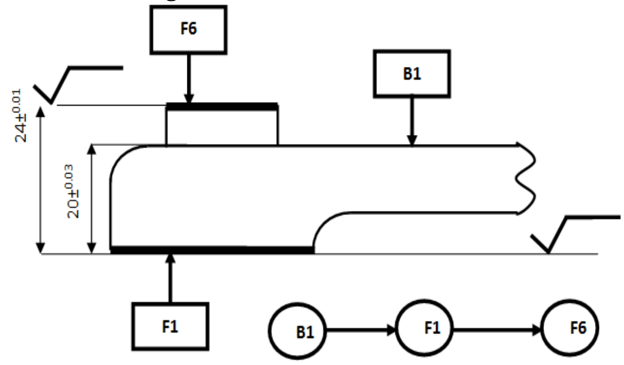


Fig.2. case of dimensional precedence

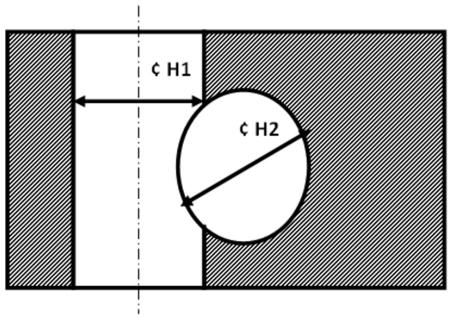


Fig.4. Case of technological constraint

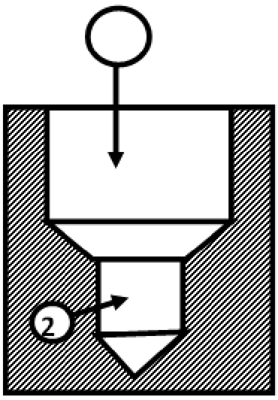


Fig.5. case of economical constraint

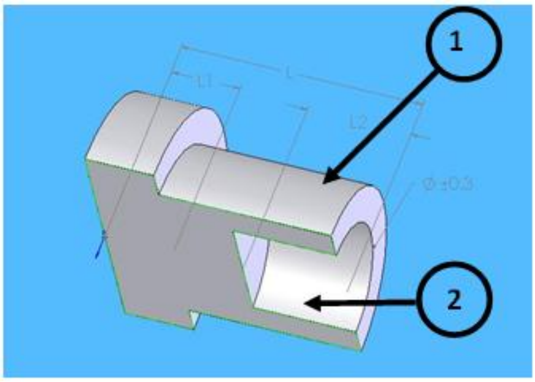
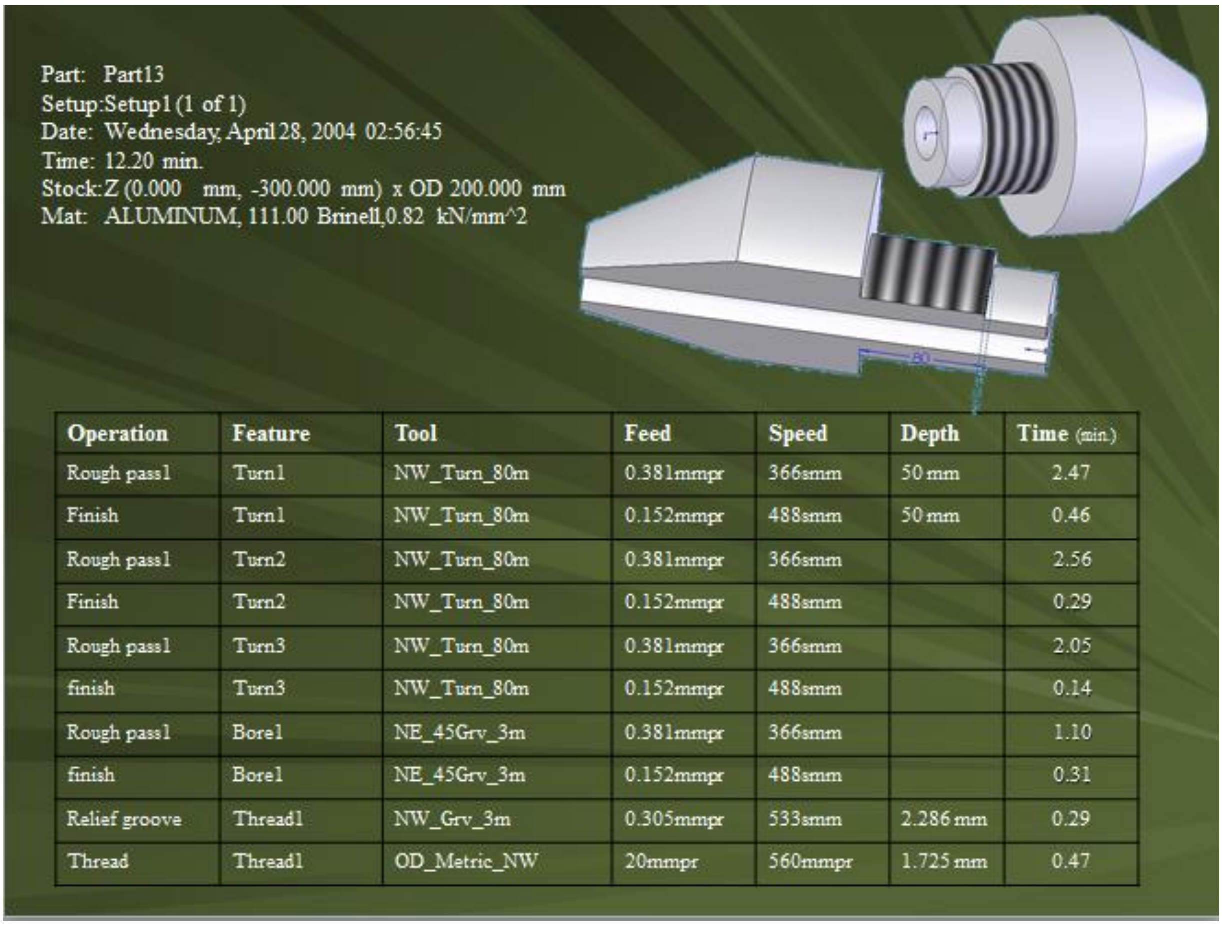


Fig.6. CAD/CAM integration

V. Results and Discussion

The case study's test part is as shown in Figure (7). The part consists of step cylinder shape as shown. The partial result of features recognized is shown in Table 2. All features labeled in Figure (8) are recognized. The cylindrical features are in xy, xz and yz plane with correct length and radius of each hole.



Part: Part13
Setup:Setup1 (1 of 1)
Date: Wednesday, April 28, 2004 02:56:45
Time: 12.20 min.
Stock:Z (0.000 mm, -300.000 mm) x OD 200.000 mm
Mat: ALUMINUM, 111.00 Brinell,0.82 kN/mm^2

Operation	Feature	Tool	Feed	Speed	Depth	Time (min.)
Rough pass1	Turn1	NW_Turn_80m	0.381mmpr	366smm	50 mm	2.47
Finish	Turn1	NW_Turn_80m	0.152mmpr	488smm	50 mm	0.46
Rough pass1	Turn2	NW_Turn_80m	0.381mmpr	366smm		2.56
Finish	Turn2	NW_Turn_80m	0.152mmpr	488smm		0.29
Rough pass1	Turn3	NW_Turn_80m	0.381mmpr	366smm		2.05
finish	Turn3	NW_Turn_80m	0.152mmpr	488smm		0.14
Rough pass1	Bore1	NE_45Grv_3m	0.381mmpr	366smm		1.10
finish	Bore1	NE_45Grv_3m	0.152mmpr	488smm		0.31
Relief groove	Thread1	NW_Grv_3m	0.305mmpr	533smm	2.286 mm	0.29
Thread	Thread1	OD_Metric_NW	20mmpr	560mmpr	1.725 mm	0.47

Fig.7. The input part form

International Journal of Engineering Innovation & Research
Volume 4, Issue 6, ISSN: 2277 – 5668

Part: part12
Setup: Setup1 (1 of 1)
Date: Monday, April 26, 2004 03:24:19
Stock: Z (0.000 mm, -200.000 mm) x OD 100.000 mm
Mat: ALUMINUM, 111.00Brinell,0.82 kN/mm^2

Operation	Feature	Tool	Feed	Speed	Depth	Time (min.)
Rough pass1	Turn1	NW_Turn_80m	0.381mmpr	366smm		0.36
Finish	Turn1	NW_Turn_80m	0.152mmpr	488smm		0.03
Rough pass1	Groove1	WN_B_Grv225_1m	0.381mmpr	366smm	2.91mm	0.17
Finish	Groove1	WN_B_Grv225_1m	0.152mmpr	488smm	3mm	0.04
Rough pass1	Turn2	NW_Turn_80m	0.381mmpr	366smm		0.22
finish	Turn2	NW_Turn_80m	0.152mmpr	488smm	5mm	0.04
Rough pass1	Turn3	NW_Turn_80m	0.381mmpr	366smm	5mm	0.22
finish	Turn3	NW_Turn_80m	0.152mmpr	488smm		0.04
Rough pass1	Turn4	NW_Turn_80m	0.381mmpr	366smm		0.16
finish	Turn4	NW_Turn_80m	0.152mmpr	488smm		0.03
Rough pass1	Turn5	NW_Turn_80m	0.381mmpr	162smm		0.32
finish	Turn5	NW_Turn_80m	0.152mmpr	213smm		0.06
Rough pass1	Turn6	NW_Turn_80m	0.381mmpr	366smm	10mm	0.16
finish	Turn6	NW_Turn_80m	1.5mmpr	488smm	10mm	0.04
Rough pass1	Turn7	NW_Turn_80m	0.381mmpr	366smm	10mm	0.11
finish	Turn7	NW_Turn_80m	0.152mmpr	488smm	10mm	0.05
Rough pass1	Turn8	WS_B_Small_80m	0.381mmpr	366smm		0.12
finish	Turn8	WS_B_Small_80m	0.152mmpr	488smm		0.09
Rough pass1	Groove2	User defined	0.381mmpr	366smm	2.286mm	0.04

Fig.8. The final result Generating Complete Process Planning for another product

The case study shows that the cylindrical features, namely through holes in xy, xz, and yz plane can be recognized easily. The database of this system can be upgrade to accommodate other featuressuch as protrusion type features. The extraction of features data is tackled by developing a rule-based techniquefor each feature.

VI. Conclusion

The main advantage of this method is any CAD system can be used to model the part. The shortcoming ofusing neutral data format method is that, a hole that is drilled at an angle to the entrance face (elliptical edges) would not be recognized as the rule for a hole specifies a circular edge at the entrance face and bottom. The work reported that only negative (depression) features are recognized. Extended work is currently being undertaken to include recognition of prismatic part that have slot, pocket, step features.

Future Work

We suggest use STEP format for other feature in rotational parts. Also make this study in prismatic pats to make sure can capable to generate the optimum cutting conditions and generate the computer aided process planning. These remain a critical issue for future study.

References

[1] Gao, J, Zheng, D.T and Gindy, N. (2004). Extraction of machining features for CAD/CAM integration, International Journal of Advanced Manufacturing Technology.

[2] Cicirello, V. and Regli, W. C. (2001). Machining feature-based comparisons of mechanical parts, SMI-2001: International Conference on Shape Modeling and Applications, Genova, Italy, May 2001.

[3] Han, J. H. Kang M. and Choi, H. (2001). STEP-based feature recognition for manufacturing cost optimization", Computer-Aided Design, 33, pp. 671-686.

[4] Bhandarkar, M. P. and Nagi, R. (2000). STEP-based feature extraction from STEP geometry for agilemanufacturing" Computers in Industry, 41, pp. 3-24.

[5] Henderson, M. R. and Anderson, D. (1984). Computer Recognition and Extraction of Form Features.Computers in Industry, 5; 329-339.

[6] Abdalla, H. S. and Knight, J. (1994). An expert system for concurrent product and process design ofmechanical parts, Proceedings Institution of Mechanical Engineers, Part B: Journal of EngineeringManufacture, 208:167-172.

[7] Ismail, N. and Abu Bakar, N. (1997). Recognition of features from B-rep Solid Models" ASEAN Journalof Science and Technology Development, 14(2) pp 35-49.

[8] Noort, A., Hoek, G.F.M. and Bronsvoort, W.F. (2002), Integrating part and assembly modeling,Computer-Aided Design, 34:899-912.

[9] Electronic Data System Corporation, (1997). Solidworks software, MO, USA, Solidworks User Manual Version 2013.

[10] Trappey, A. J. C. and Chang, C. R., (2000). ISO 10303-compliant computer-aided wheel rim design system- the framework and data model, International Journal of Production Research, 28(6):1325-1338.

[11] Lau, H. and Jiang, B. (1998). A generic integrated system from CAD to CAPP: a neutral file-cum-GT approach, Computer Integrated Manufacturing System, 11(1/2):67-75.

[12] Liang, M., Ahamad, S. and van den Berg, B. (1996). A STEP based tool path generation system for rough machining of planar surfaces, Computers in Industry, 32:219-231.

AUTHOR'S PROFILE

Dr. Hamza A. Ghulman

Dean of College of Engineering and Islamic Architecture, Umm El Qura University, Makkah, King Saudi Arabia

Dr. Mohamed Abdel Gawad Mostafa

has permanent work in zagazig university in Egypt and now working an in Mechanical Engineering, College of Engineering and Islamic Architecture in Umm El Qura University, Makkah , King Saudia Arabia. He had PhD degree in Industrial engineering. His areas of interest include Computer aided production planning; Computer integrated manufacturing systems, manufacturing modeling, case based reasoning, feature recognition, *Maintenance* , Robotics.

Eng. Abdulkareem B. Alsayegh

admistrator in the Department of Mechanical Engineering, College of Engineering and Islamic Architecture in Umm El Qura University, Makkah, King Saudia Arabia.