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Computer Aided Process Planning for Freeform Surface Sheet Metal Features in Automotive Industry

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Abstract. This paper describes computer aided process planning for a freeform surface; sheet metal features. Automotive body panels are always manufactured using thin forming sheets; the developed CAPP system consists of two modules which are feature recognition module based on STEP AP203 and a process plan module; two additional modules for automotive panel CAPP system and cost estimation module are also incorporated in the system of punch and bending operation. Stamped or punched features in generative shape design are used to design automotive panels; the generative CAPP system is written in visual basic 2008 language and implemented in several case studies demonstrated in the present work. Feature recognition of punched; stamped internal features in free form surface recognized in base of data exchange files using STEP AP203 ISO-10303-21.

Introduction.

A process plan which is an important tool in the manufacturing field can be defined as a way to determine materials, machines, tools, and process sequence of a part from start to final product in the manufacturing cycle. Computer aided process planning (CAPP) in automotive application is a powerful tool which determines feature recognition, process sequence, and tool types in order to calculate time and estimate cost. Alting and Zhang et al [1-2] identify the following three main reasons for using CAPP: Requirement of consistency, Shortage of process planners and requirement of integration.The application of the CAPP system for sheet metal is classified into three subgroups: CAPP for sheared parts, CAPP for bend parts and CAPP for drawn or formed parts.The application of process planning for shearing operation can be further divided into nesting for blanking operation and strip layout for progressive shearing operation. Some applications also taken into consideration such as, punching, nibbling machines, and for laser cut machines.In case of nesting for blanking, Jagirdar, R [3] made classification system for shearing operations based on the preceding operation relationships criterion.In case of strip layout for progressive shearing, Kumar, S. [4] developed a progressive shearing CAPP system called "ISSLD". It is an integrated system for strip layout design for sheet metal operations on progressive dies. The system uses AutoLISP via AutoCAD.In case of process planning for punching and nibbling machines, Abdelmoneam[5] proposed an intelligent system which worked under Pro-Engineer as a CAD package, and supported with ANN under MATLAB, and the whole system was governed by Visual Basic program. A considerable amount of research has been carried out in this field. Van'tErve [6] developed a CAPP system based on expert system approach, which includes a feature recognition module. Joost R. Duflou [7] described an intelligent computer aided process planning for bending processes. A tool selection methodology to be integrated in the automatic bend sequencing system has been introduced. Barakat [8] discussed a cost estimation system for sheet metal parts in case of shearing, bending, and nibbling operations. B. Verlinden, et al [9] conducted an analysis on developing a less-detailed method, based on a brief analysis of the CAD-file. Cost formulas were composed by applying regression techniques and neural networks.

Feature recognition and CAPP

The feature recognition algorithms involved in this work are based on Boundary Representation (B-Rep) developed by the authors [10]. Generative CAD surface part designed using CATIA V5 generative surface workbench which support STEP AP203 files. AutoCAPP program read generated STEP file and generate automated feature recognition and CAPP reports.

Due to limitation of manual process plans, manufacturer tries to automate the process plan. Variant approach depends on existing process plan and modified are used for same part family. Fig. 1 shows generative CAPP system main modules.

In the process plan, each operation represents a specific feature of the part drawing. In the present work, the process sequence to perform operations based on the feature types such as slot hole, round hole, and square hole, etc**.** Tool setup includes pre-setting and loading of tool into the station. The tool is changed automatically based on the operation to be performed. The tool change implies that the tool is removed from the spindle and another preselected tool from the tool magazine is inserted automatically. The total cost of the operation can be minimized by minimizing the operation time which in turns reduces the manufacturing time. The operations which have the same punch shape are grouped together and use the same tool without delaying the operation. Therefore, the total operation time is reduced significantly.

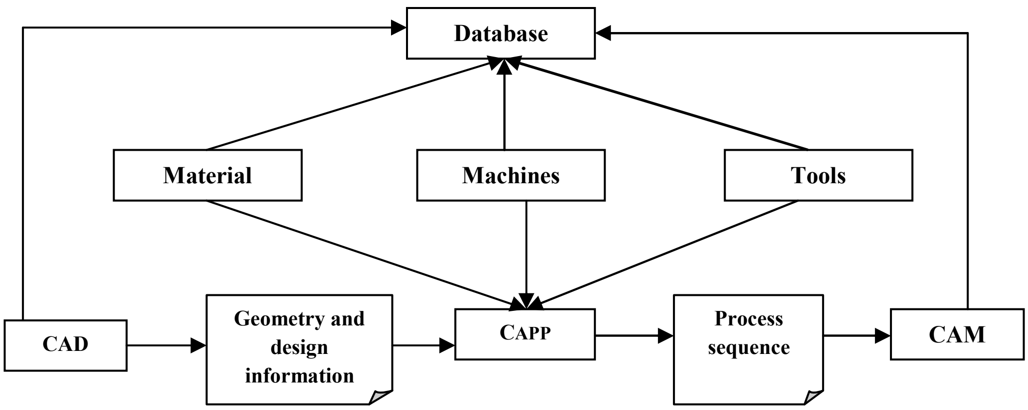


Fig.1. CAPP system modules.

Cost Estimation of Sheet Metal

Cost factors are considered first while taking a design decision since cost plays an important role in the industry especially in sheet metal processes such as stamping and bending, etc.In this section, operation time is an important factor for cost estimation. Punching and bending operations will be considered in this paper.

Table 1. Input parameter for time estimation [8].

Operation	Input parameter	Equation
Punching	Z = No. of holes	T = [(LD x Z) (t / M)](k) / S S for punching M/C = 40 m / min
	S = Rapid traverse (M/C) m/min	
	LD = Land distance (m)	
	M = Material factor	
	k = Labor skill factor	
	t = Sheet Thickness (mm)	
Bending	A = Bend angle (90^{o})	Time = Z x w x k / S Z = no of edges w = bending allowance w = 0.0078 t + 0.0174 R x A S for bending M/C = 16 m/min
	R = Inside Radius ≥ t	
	t = Sheet Thickness (mm)	
	Z= (no. of bends per Workpieace.)	
	k =Labor skill factor	

Table 1 illustrates operation time equation for punching and bending processes**.** Labor skill factor (k) is classified by three brands with (k) values equal to 0.9 , 0.75 and 0.6 .Operation cost in sheet metal working is assumed to be 35 $/hour in the present work **.**

AutoCAPP System and case study

The designed part is created using CATIA V5R19 CAD system that supports STEP AP203 protocol translators. AutoCAPP Program is developed using Windows-based Microsoft **Visual basic 2008** on a PC environment. Main construction of AutoCAPP program has the three modules of the program are as follows: Generative process plan which include (Data extraction; feature recognition and generative CAPP), Semi-generative CAPP module for automotive panels and Cost estimation of sheet metal process shown in Fig.2.

To verify the developed AutoCAPP system, several case studies designed in CATIA V5R19 are carried out. Sixteen case studies were performed using the program. A sophisticated automotive side wall shown in Fig.3 contains two rectangular holes, and two U-Arc-Notches holes in the CAD panel. Fig. 4 shows header of sophistic side wall panel automobile, while Fig.5**,** shows final CAPP report of the case study.

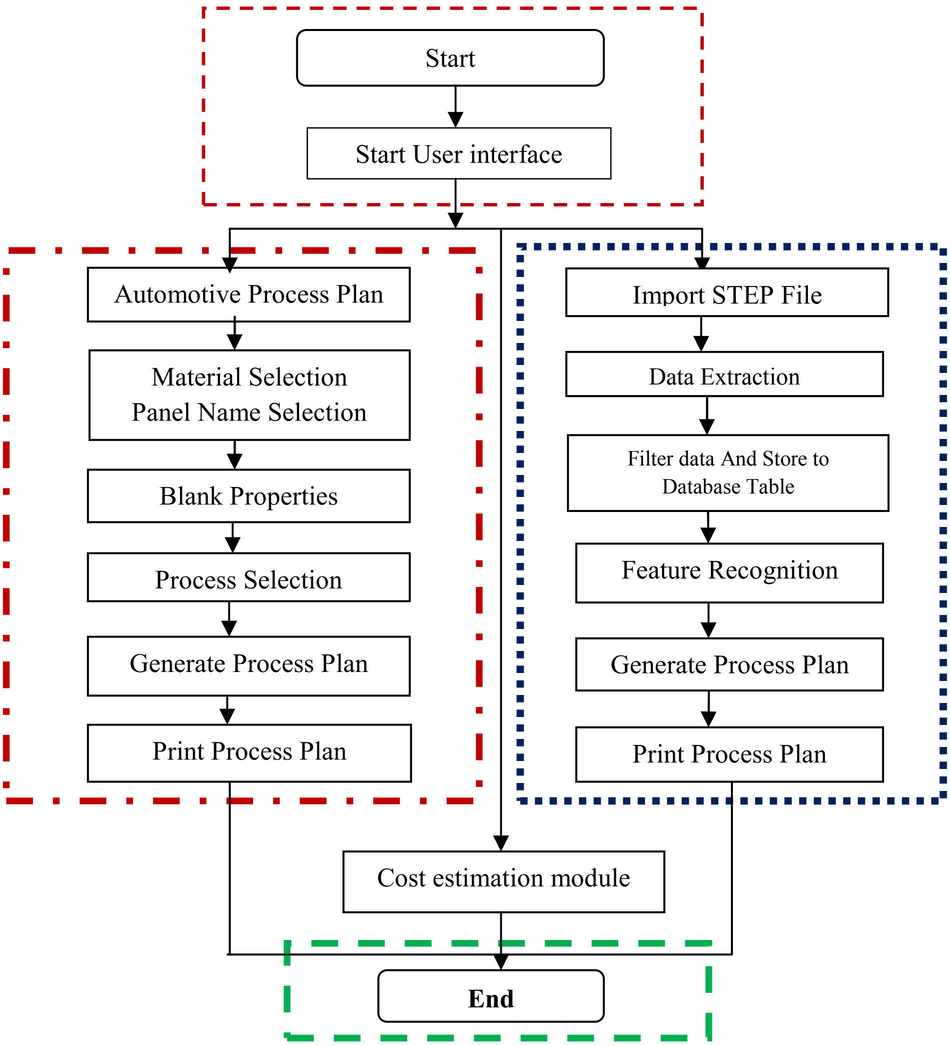


Fig.2. Main construction of AutoCAPP program.

Fig.3. Side wall panel of an automobile.

Fig.4. Header of an automobile side wall panel.

Generative CAPP Report.							
Planer Name	Hamouda Mousa	Company		Part Name	Automotive Side Wall	Sheet Thickness (t)	0.7
Material Type	Aluminum 3003-H14 =0.30	Part Code	AF02	Date			

Detailed Process Plan Sheet

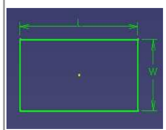
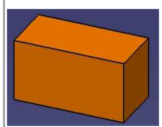
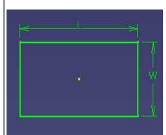
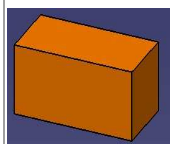
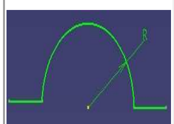
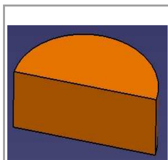
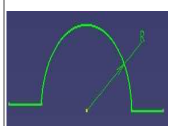
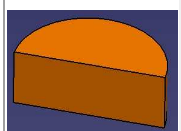
Operation Sequence	Feature Name	Feature Geometry (mm)	Feature Shape	Feature ID	Operation Type	Die Concavity	Punch Shape	Machines	Time (min)	Cost ($)
1	Rectangle Hole	L = 70 W = 20		1	Punching Rectangle Hole	Rectangle Punching Die		Punch Press	13.5	7.88
2	Rectangle Hole	L = 70 W = 20		2	Punching Rectangle Hole	Rectangle Punching Die		Punch Press	13.5	7.88
3	Arc-Notch	R = 25		3	Notching Arc-Shape	Arced Punching Die		Punch Press	4.12	2.4
4	Arc-Notch	R = 25		4	Notching Arc-Shape	Arced Punching Die		Punch Press	4.12	2.4

Fig.5. Generated CAPP of an automotive side wall panel.

Conclusions

In the present work; a new approach has been adopted and implemented for automatic recognition of features from freeform surface CAD models represented in STEP format. Notch features has been proposed and implemented with the help of ACCESS database. The reported algorithm is capable of recognizing both internal stamped, punched features and external notching features.A generative CAPP system based on feature recognition module from STEP AP203 file is developed. The proposed system generates and reports a process plan outlining the operation sequence, feature name, operation type, feature ID, tools, machines, feature geometry, operation time, and operation cost.The algorithms and procedures were implemented in Visual Basic 2008 software. AutoCAPP application with a user-friendly interface is built and used for STEP data extraction, free form surface recognition, CAPP of free form sheet applications, and sheet metal cost estimation of bending and punching operation.

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