DEVELOPMENT OF AN ENHANCED FEATURE RECOGNITION SYSTEM AND ITS APPLICATION FOR OPTIMIZIED PROCESS PLANNING OF SHEET METAL BENDING

By

Amr Abdelaleem Abdelrahman Metwally Salem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Mechanical Design and Production Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Development of an enhanced feature recognition system and its application for optimized process planning of sheet metal bending

Key Words:
Process planning for V-bending; automatic feature recognition; STEP AP-203 format; collision detection; rule-based system ; genetic algorithm

Summary:

The efficient process planning of the V-bending processes involves the determination of a feasible sequence and tool stages of the bending tasks to achieve the final desired product shape. The feasibility of such a sequence is materialized by the absence of collision during V-bending processes. According to the interference nature of the tasks of the V-bending process planning, it is considered as a constrained combinatorial optimization problem. In this thesis, the proposed Computer Aided Process Planning (CAPP) system uses the genetic algorithm as an optimization search algorithm to produce near optimal process plans. The proposed CAPP system includes three modules which are feature recognition module, collision detection module, and genetic algorithm optimization module. In the proposed system, the optimization algorithm is linked with the recognized features of the bent workpieces and the relations between the bend lines which could guide the search to converge to the near optimal process plan in minimum number of generations.

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Nomenclature

CAPP: Computer Aided Process Planning
CAM: Computer Aided Manufacturing
CIM: Computer Integrated Manufacturing
SME: Society of Manufacturing Engineering
GA: Genetic Algorithm
B-rep: Boundary representation
CSG: Constructive Solid Geometry
DXF: Drawing Exchange Format
IGES: Initial Graphics Exchange Specification
STEP: Standard for the Exchange of Product Data
CSA: Cross Section Area
ACRD: Adjacent Component Directional Relationship
TSP: Travelling Sales Person
TPP: Travelling Purchasing Problem
2D: Two Dimensional
3D: Three Dimensional
θ: angle between two normal vectors
CW: Clockwise
CCW: Counter Clockwise
f: Planar surface
b: Bend line

Abstract

The high level of competition among industrial organizations in today's global market demands quick product reach to consumers with competitive quality levels while keeping production costs as low as possible. This necessitates highly efficient process planning that minimizes non-value-added activities in production processes and optimally selects subtle production steps with the right process parameters. The efficient process planning of the V-bending processes involves the determination of a feasible sequence and tool stages of the bending tasks to achieve the final desired product shape. The feasibility of such a sequence is materialized by the absence of collision between the sheet metal and the tool set or any workpiece of the press brake. The problem of finding efficient, feasible process plans for the V-bending process is complex as it involves selecting values for the different parameters, tools and the processing sequence from enormous possible choices. This is identified as a constrained combinatorial optimization problem for which no exact method is known to provide optimal solutions in reasonable computational time. This thesis proposes a Computer Aided Process Planning (CAPP) system that utilizes the genetic algorithm (GA) for providing efficient solutions to this problem.

The proposed CAPP system includes three modules. The first module is a feature recognition module which is responsible for recognizing the features of the bent workpieces from STEP AP-203 format. This module also recognizes the relations between bend lines. It contributes to the feature recognition systems in the literature by providing: (1) a new classification of the collinear bend lines and a method to distinguish between separate and non-separate collinear bend lines; (2) an easier method to determine the included and bend angles; (3) an enhanced method for determining the bend direction; and (4) a method for automated reasoning for the required dimensions to determine the length of the tool stage of each bend line. These contributions aim to reduce the computational time in the feature recognition process and provide more information to produce more efficient process plans.

The automatic collision detection algorithm is the second module in this system which judges the feasibility of any proposed process plan. The proposed collision detection module can distinguish between 2D and 3D bent workpieces. Besides, it includes 2D and 3D collision detection subroutines which are responsible for detecting collisions according to the class of the bent workpiece. This helps in reducing the computational time needed for the collision detection process. The first two modules provide a method for automatically updating the reasoning of the required dimensions to determine the length of the tool stage of each bend.

The third module is the genetic algorithm optimization module which is responsible for generating efficient process plans. This module utilizes a solution representation (chromosome) and a fitness function that are modifications to previous studies. The GA utilizes the recognized features of the bent workpieces and the relations between the bend lines which are provided by the first module. This helps in reducing the number of iterations to reach an efficient solution.

Chapter 1 : Introduction

The high level of competition among industrial organizations in today's global market demands quick product reach to consumers with competitive quality levels while keeping production costs as low as possible. This necessitates highly efficient process planning that minimizes non-value-added activities in production processes and optimally selects subtle production steps with the right process parameters. Computers have played a major role in achieving such targets via computer aided process planning (CAPP) systems, which are the interface between computer-aided design (CAD) and computer aided manufacturing (CAM). The scheme of Computer Integrated Manufacturing (CIM) is shown in Figure 1.1.

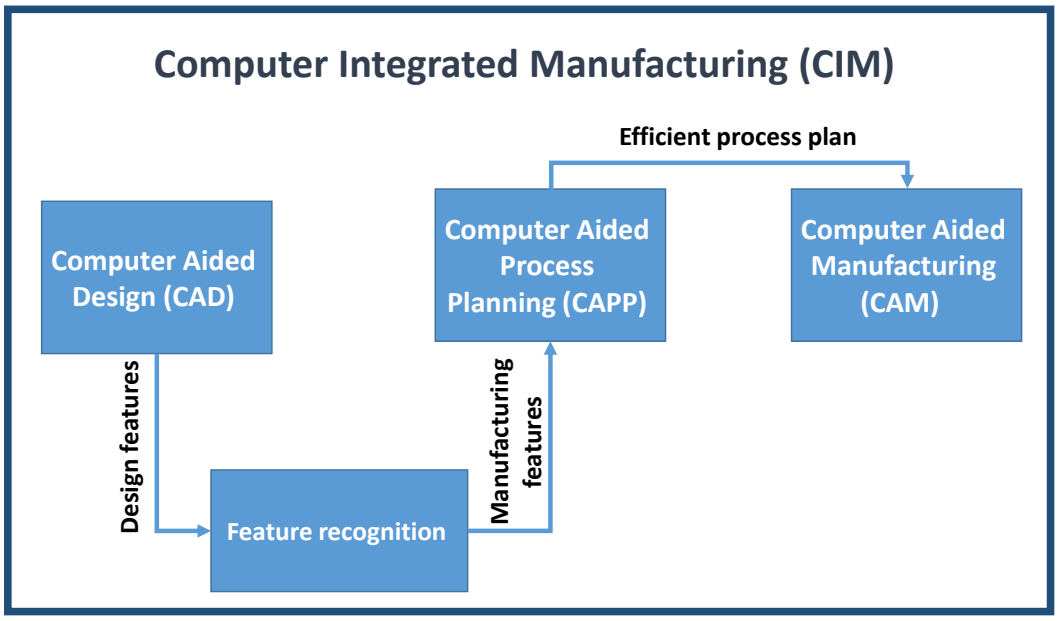

Figure 1.1 : Scheme of the Computer Integrated Manufacturing (CIM)

1.1. Computer Aided Process planning (CAPP)

Process planning is the bridge between the design and manufacturing stages of any product. It selects the manufacturing details according to the design. The Society of Manufacturing Engineering (SME) define the process planning as "process planning is the systematic determination of the methods by which a product is to be manufactured economically and competitively". Consequently, the full process planning includes: (1) the characterization of the raw material of the workpiece; (2) the manufacturing operations and its sequence; (3) the manufacturing machine; (4) the selected tools and holding devices; and (5) the manufacturing conditions. There are two approaches to produce the process plan of any product which are the experience-based method and the computer aided process planning methods.

The experience-based method is a manual method which depends on the experience of the process planner. Many manual process plans may face the same manufacturing