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COMPUTER-AIDED NESTING OF TWO DIMENSIONAL SHAPED FOR PRESS TOOL DESIGN

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ABSTRACT

This paper reports on the design of a Computer-aided Sheet Nesting System (CASNS) for the nesting of two different or two similar shaped sheet-metal blanks on a given or coil stock. The proposed system extracts the required shape geometrical information directly from CAD data base. Initially, the two shapes are overlapped and the different positions can be obtained by fixing the first shape and moving the second in steps in X-direction until no overlapping occurs . After that, the movable shape is moved by a step in Y-direction and repeated the motion in X-direction. Trials after, rotating the movable shape taking grain orientation constrains into a consideration. In each case the system determines the material utilization by calculating the minimum circumscribing rectangular area which contains the two shapes. The developed system has been written in 'Visual C' on an IBM-Compatible Personal Computer. The optimal nesting is calculated from overall trials. The system is applied on different shapes and proved to give a reduced computation time for arriving to the optimal position with higher utilization ratio and minimization of scrap.

Keywords: Nesting, Edge detection, sheet metal stamping, CASNS, Data Exchange Format

1.Introduction

The nesting of two-dimensional shapes for press tool design is subset of general optimization problem known as the two-dimensional cutting stock problem. The objective in every case, is to minimize material wastage. Considerable attention has been given by many researchers to developing algorithms for nesting in sheet metal blanking, as rapid developments in computers, optimization techniques, computers' graphics, data storage and data retrieval techniques have taken place. Raw materials used in the sheet metal industry are available in certain standard sizes. It is often necessary to cut these sheets into strips of required dimensions before they can be used for further operations. The cutting stock problem can be classified according to three attributes such as dimensionally of the problem, type of shapes and the number of shapes to be nested . Gilmore,Gomory and Hoppe [1] ,[2] had initiated the research work by considering the layout problem as one-dimensional. Late, the formulated (XIE LIU, 2007,[3]) the two-dimensional trim-loss problem also like the one dimensional problem, with the constraint that the stock is a rectangular sheet of finite dimensions and the cutting patterns are rectangular .

Haims and Freeman [4] studied a related problem called the template layout problem, in which no constraint is placed on the numbered of pieces of each type to be cut from a single sheet of material. Their method involves enclosing irregular shapes, singly or incombination, in minimum area rectangles called "modules", which are subsequently packed in a given stock sheet using a dynamic programming algorithm. However, in each stage the algorithm always places the rectangular module at one corner of the sheet. Moghaddam andAnoushe[5] also proposed a two- stage algorithm employed special shape clustering techniques and multi-stage dynamic programming and was found to be effective when compared with the results obtained by the manual method. While the work reviewed earlier dealt with the optimal layout of pieces having regular shapes, Albano and Sapuppo [8] used heuristic search method for the two-dimensional layout of irregular shapes on rectangular stock-sheets. Ramesh.and Ramesh [9] also reborted application of heuristic techniques to a cutting stock problem in the manufacture of furniture. Single sheet layout algorithms that are suitable for flame cutting operations have been developed by Shimozono [6], Chow [7]. Tay and Lee[10] developed an algorithm for two-dimensional parts nesting based on heuristic search approach, apparently the first to develop a method for objective testing of irregular parts nesting algorithms with a fractional factorial design and a random generator for irregular parts, they tested the sensitivity of the algorithm to Several variables such as part shapes, part sizes and number of parts even though several software packages are available for nesting most of them have similar limitations. Qu, Sanders andShang [11],[12] introduced an automatic algorithm for nesting of irregular shaped parts whose geometries were approximate by composites of non-overlapping rectangles, and their test, using randomly generated bill-of materials, showed that the algorithm has been efficient in terms of computation time and material Usage. But major limitations of their algorithm are the approximation of part shape by non-overlapping rectangles and the assumption that a good-layout pattern will not be non-orthogonal. Koroupi and Martin [13] considered how many shapes, including concavities and circular sections, can be approximated to a polygon and determine the hexagonal paver that circumscribes this convex polygon for minimum area addition. Ismail and Hon [14] Contained two approaches to the automatic pairwise clustering of two-dimensional shapes for press tool design . The first approach is based on extracting the edge information as edge arrays, which are manipulated to obtain the optimum pairing; while the second applies the non-deterministic concepts of genetic algorithms. Pasad and Somasundaram [15] developed the design and implementation of a computer -aided sheet nesting system for irregular-shaped sheet-metal blanks on a given sheet stock or coil stock. The system is designed by considering several constraints of sheet-metal stamping operations , such as bridge width and grain orientation, and design requirements such as maximizing the strength of the part when subsequent bending is involved and economical justification for a single or multiple station operation. Prasad and Somasundaram [16] developed an intelligent algorithm for nesting of irregular shaped sheet metal blanks with varying blank geometries. A nesting algorithm has been developed by incorporating a new sliding technique in order to find all the feasible arrangements in such a manner that arbitrary blanks do not overlap or intersect. But , the algorithm calculates the utilization ratio by considering neglecting the wastage at the ends of the sheet. The nesting problem addressed by most of the researchers can be classified in two groups. The first one is for blanks having rectangular shapes, in which different mathematical programming techniques have been used to generate optimal layouts. The second one is approaches have been developed for generating optimal layouts by approximating blank profile to either rectangular enclosures or polygons .

2. Design factor

The proposed system has been considered the grain orientation, the minimum bridge width and maximum material utilization. This is more so if the quantity of blanks to be produced is large and /or if the material is expensive. The grain orientation of strip is important when the bending is needed. To obtain maximum strength of parts, the bend should be made at an angle of 90 degree to the direction of rolling. If no subsequent bending operation is involved a blank can be rotated in any direction without due reference to the rolling direction . If a blank contains several bends only the most critical bend shall be considered. Blank layout also takes into consideration the press capacity available . Multiple blanking requires a large press bed area as well as blanking pressure .

3.Blank Geometry Representation

The two dimensional shapes can be divided into elements such as line segments, arc segments and circles. The system stores co-ordinates of start and end points for line entities, co-ordinates of the center point, start point and end point of the arcs and center, and radii for circles. Generally, the input data for shape can be one of three formats. The first is a sample continuous point-to-point representation in which the number and co-ordinates of the shape vertices are taken in an anti-clockwise direction. This type of format can only be used to represent shapes bounded by linear edges. The second is line-arc format that is available for shapes bounded by lines and arcs . The third format is the STEP format.

4.The New Developed System

The main problem will take drawing shape from any drawing package and will check the extremes of the figure on the screen. Then calculate the maximum and minimum co-ordinates to obtain the rectangle enclosing the figure. It is accepts this co-ordinates as pointers and also change the background color. The figure will be approximated by a number of equally sized connected squares that are calculated by superimposing a rectangular grid on the optimum oriented shape. The grid size is calculated from the maximum dimensions of the optimum circumscribing rectangle and the user selected number of grid elements. The grid is scanned both horizontally and vertically to determine whether an element lies inside or is outside the shape. The elements inside the shape are defined as solid elements but all other elements are defined as empty. The shape will be converted into two dimensional arrays in which solid elements are numerically represented by “1” and empty elements are represented by “0” as shown in Fig. 1.

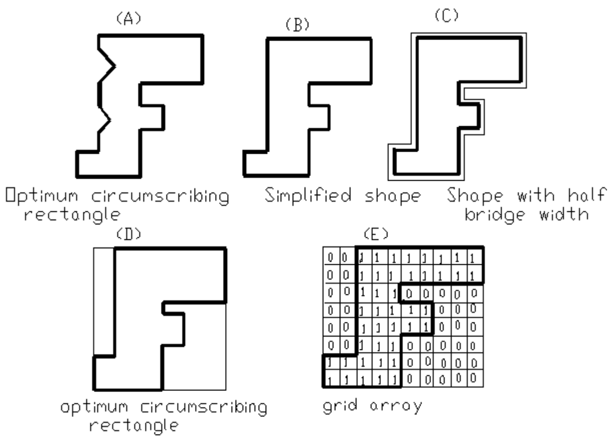

Fig.1 A data conversion shape

4.1-Making possible orientations

Blank can be positioned multi different ways in the strip-choice of the correct method depends upon part shape, production requirements, and any bends that must be applied. These positions or orientations involve fixing one of the two shapes while the other shape can assume one or more of the following :

(a) Rotation from 0oto 180 o

(b) Mirroring relative to the X-axis

(c) Mirroring relative to the Y-axis

And in each previous case, moving the movable shape in horizontal and vertical steps relative to the fixed shape as shown in Fig.2.

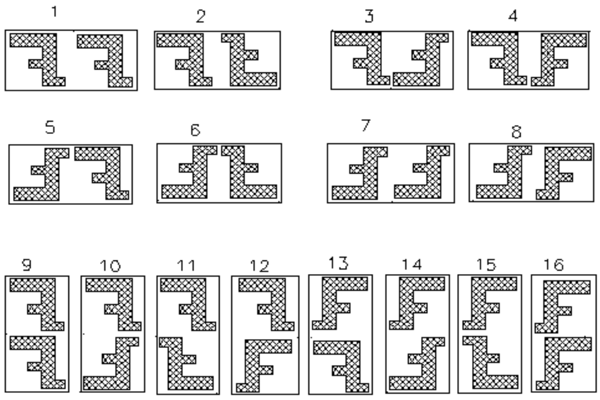

Fig.2 The possible basic orientations.

The procedure presented above will be used to obtain the optimum pair orientation that results in maximum material utilization. It is often necessary to determine the number of blanks in each strip to establish the extent of the waste end D. The number of blanks per strip for a single-pass layout is found by the formula :

Single-Pass Layout

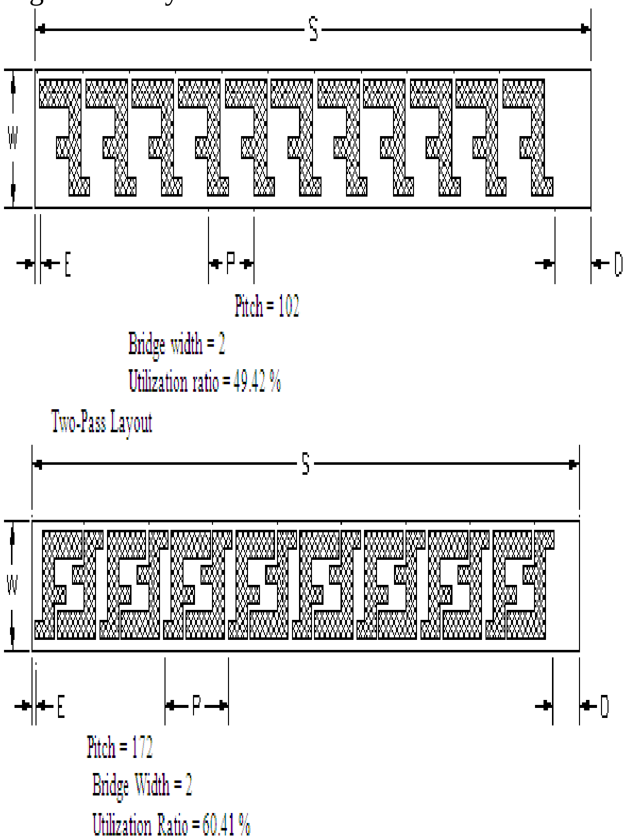

Fig.(3-a) Representative illustration for determining the number of blanks in a strip.

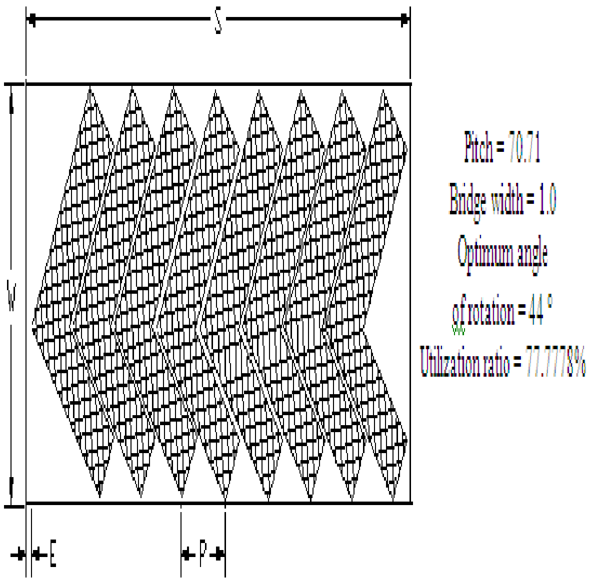

Fig.(3-b)

The area of the blank (A1)=sum($Y_i + Y_{i+1}$)($X_i - X_{i+1}$) /2(1)

The area of a strip(A2)=S*W (2)

Blanks per strip N=S - (P +2E) / P + 1 (3)

For the waste end D=S-[P(N-1)+P+2E] (4)

The utilization ratio=A1*N/A2 (5)

For two rows , the following formulas determine the number of blanks per strip and the extent of the waste end :.

WasteD=S-[0.5P(N-1)+P+2E] (6)

Blanks per strip N1=S-(P+2E)/(0.5P)+1 (7)

The utilization ratio = A1 * N1 / A2

where:

A: number of blanks per strip

S : length of sheet

P : pitch

E : bridge width

Material saving is not the only reason that decides the final blank layout for determining the number of blanks in the strip. The other causes such as proper balance of blanking pressure by adding the bridge width, the dimensions available of strip stock or coil stock and rolling directions of material. These reasons have to be considered together with same of the best layout generated. Initial selection will be done based on best utilization ratio. If it is limited by other constraints the next best utilization that satisfies all the required constraints will be considered. The flow chart depicting is shown in Fig.4

5. Case Study

The nesting algorithm has been implemented on a 32-bit personal computer with 4MB of main memory. The algorithm is implemented in Visual C. Finally, a graphic interface has been developed with the standard graphic format (STEP) to accept the shape geometry. Figure (1) shows a sample blank that is tested with the nesting algorithm. The sample blank in Fig.(1-a) is original shape that removes small concave features within the shape to obtain the simplified shape shows in Fig.(1-b). The bridge width is added through offsetting the shape edges by half the bridge width. This results in creating a surrounding exclusion zone as shown in fig. (1-c). The shape is enclosed by finding the minimum circumscribing rectangular area. After that, the shape conversion routine is a two dimensional array in which solid elements are numerically represented by '1' and empty elements are represented by '0', as shown in Fig.(1-d),Fig(1-e). Then, the optimum pair is achieved by estimating the maximum material utilization factor for each possible orientation that are shown in Fig. 2 for example given in Fig. 1 .

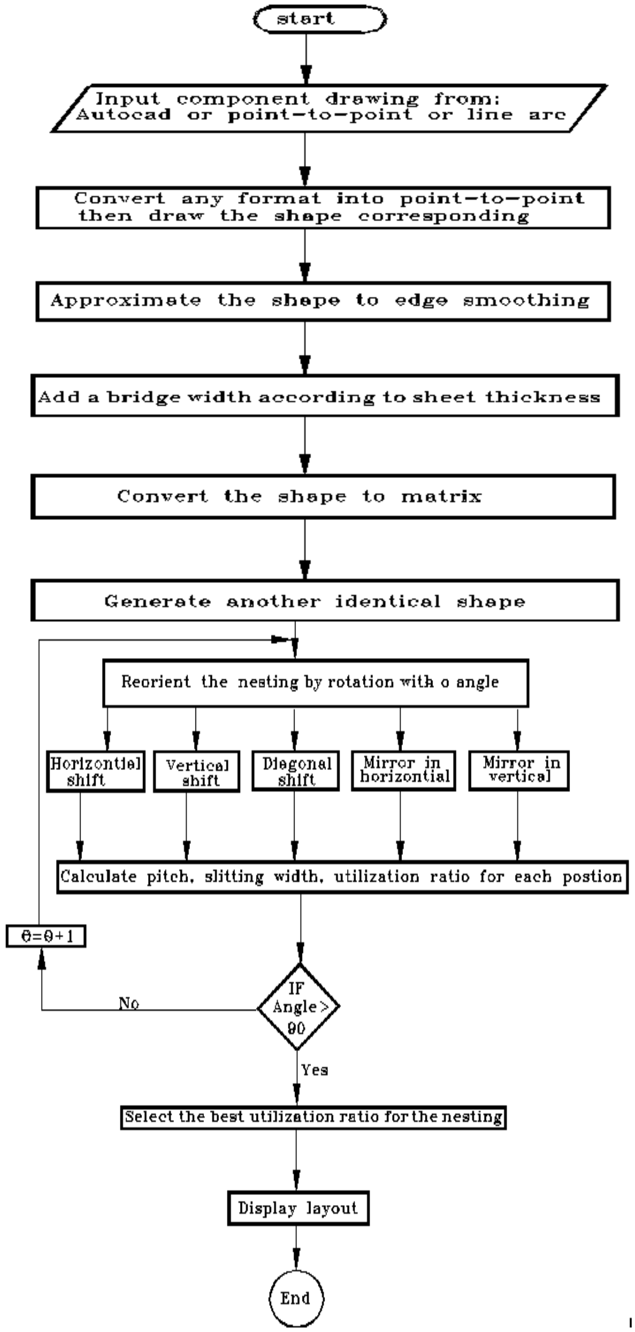

Fig.4 Flow chart showing the main program.

6.Conclusions

In this paper, the nesting of two dimensional shaped sheet metal blanks has been developed. The original shape is converted to an approximate rectangular grid representation where non-essential features are removed and a bridge width added. The two shaped are overlapped and the different positions can be obtained by moving one shape and fixing another. In each position the system determines the material utilization, pitch and slitting width. The system was extensively tested for a large number of components manufactured in various sheet-metal industries. Through many practicable case studies, the utilization depends on the shape geometry, types of material, sheet thickness and the available dimensions of sheet metal. The system proved its efficiency, effectiveness and usefulness.

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