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DAR ALMANDUMAH
الرواد في قواعد المعلومات العربية

العنوان:	Computer- Aided Nesting for Two Dimensional Shapes
المؤلف الرئيسي:	Mostafa, Mohamed Abd Algawad
مؤلفين آخرين:	Tawfeek, Mervat، El Ewa, Ibrahim Mohamed، El Keran, Ahmed A.(Super، Super.)
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ABSTRACT

This work 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 sheet stock or coil stock. The objective is to maximize material utilization and thus reduce material wastage. The problem emerges in various forms in a number of industries such as ship-building, sheet metal, aerospace, glass, clothes and footwear. In some of these industries, small savings in material costs can considerably affect the profitability of the operation. Therefore, considerable care and expertise is devoted to obtaining a reasonable layout with good material utilization. The system extracts the required shape geometrical information directly from the program 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 steps in Y-direction and repeated the motion in X-direction. Trials after, rotating the movable shape with mirroring the shape in horizontal and vertical direction 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 optimum 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.

Workpiece shapes may vary from being simply rectangular to being highly intricate. The optimal solution for rectangular workpieces is simpler because it involves fewer options to workpiece orientation. This is due to the fact that in most cases, stocks are rectangular in shape and, therefore, an optimal solution

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will be based on one where all the rectangular workpiece shapes are aligned parallel to the stock edges. On the other hand, irregular complex shapes require testing a large number of orientations and shape arrangements.

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ملخص البحث

نظرا للتقدم السريع فى مجال الكمبيوتر وأســاليب المفاضلــة والرســم بإستخدام الكمبيوتر وقواعد البيانات كل ذلك أدى إلى التطــور الســريع للإستخدام الأمثل للكمبيوتر فى مجــال الصناعــات الهندســية بــهدف الحصول على أعلى معدل إنتاج بأقل تكلفة ممكنة ومن ثم الحصول على أعلى ربح ممكن من العملية الإنتاجية.

الهدف من هذا البحث هو الحصول على أفضل وضع لتعشيش الأشكال للحصول على الإستغلال الأمثل للمعدن بهدف تقليل الفاقد ومن ثم تقليل التكلفة . وهذه المشكلة متناولة من قبل الباحثين في صور شتــي مــن الصناعة مثال ذلك بناء السفن والألواح المعدنيــة للصــاج وصواريــخ الفضاء والطائرات والزجاج والملابس والصناعات الجلدية . في بعض هذه الصناعات يعتبر أقل توفير في تكلفة المواد الخام يعتبر ربحية عالية جدا للعملية الإنتاجية ومن أجل ذلك كانت العنايــة والخــبرة والعمــل للحصول علي أحسن الأوضاع للشكل لتحسين إستغلال المعدن. تتوقف عمليات الحصول علي أشكال من الألواح المعدنية لإنتاج الشعلات علي الأبعاد القياسية للألواح المتاحة .

وبناءا على ذلك فقد تناول هذا البحث الحصول علي أفضــل إســتغلال للمواد فى حالة قطع منتج متشابه الشكل. في حالة لو شكل متشابــه أي إذا كان شكل واحد الذي نأخذه من اللوح يتم تعريــف هندســة الشكــل للبرنامج ويتم تحويله إلي مصفوفة ثنائية البعد وعمل نسخة منه ووضع المصفوفتين علي بعضهما وبدء عمل تحريك المصفوفة الثانية بالنســبة

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للأولى حتي لا يحدث تداخل في إتجاه محور السينات والصادات وفـــي نفس الوقت عمل دوران للشكل من 0° إلي 180° درجة وذلــك للحصـــول علي الترتيبات الممكنة وحساب الخطوة ونسبة الإستغلال للمعدن في كل مرة والمقارنة بالسابقة مع الإحتفاظ بأكبر قيمة إستغلال حتـــي النهايـــة ويكون ذلك هو الوضع الأمثل للحصول علي أفضـــل إســـتغلال. ويتـــم حساب نسبة الإستغلال على جميع ألواح الصاج القياسية الموجودة فـــى قاعدة البيانات وإختيار أنسب لوح لكل شغلة. وبالتـــالي نقلـــل الجـــهد والزمن اللازم للحصول علي أعلي كفاءة وأفضـــل نوعيـــة إســـتغلال للمعدن .

وقد إحتوى البحث على ما يلى:

الفصل الأول:

مقدمة لإستخدام الكمبيوتر فى تعشيش الأشكال والتى تستخدم فـــى التطبيقات الصناعية المختلفة وعمل الدراسة النظرية لجميـــع الأبحـــاث الخاصة بهذا الموضوع.

الفصل الثانى:

تناول هذا الفصل تعريف الأشكال المختلفة للشغلة المراد أخذهـــا من الصاج والعوامل المختلفة التى تتوقف عليها. وكذلك كيفية ترتيـــب هذه الاشكال وطرق حساب نسبة الستغلال الأمثـــل للمعـــدن للوصـــول للهدف المنشود.

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الفصل الثالث:

شرح البرنامج المصمم للحصول على إستخدام أفضـــل للمعـــدن وإمكانية الحصول على أكبر عدد ممكن من الشغلة من نفـــس الخامـــة وشرح جميع الأوضاع التى يمكن الحصول عليها لتعشيش هذه الأشكال. تم كذلك غرض النتائج الخاصة بتطبيق البرنامج والتى توضح الكفـــاءة العلية للنظام القترح والتى تؤدى إلى التوفير فى المواد الخـــام والـــذى يعنى التقليل من التكلفة وزيادة الربح.

الفصل الرابع:

فى هذا الفصل أعطيت خلاصة البحث وإقتراحات لإتجاه الأبحاث فى هذا المجال فى المستقبل.

تم بحمد الله.

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Mansoura University
Faculty of Engineering
Production Engineering and
Mechanical Design Dept.

Computer-aided Nesting for Two Dimensional Shapes

By

Mohamed Abd El-Gawad Mostafa
B.Sc. Industrial Production Engineering
Faculty of Engineering, Mansoura University

A Thesis

Submitted In Partial Fulfillment For The Degree of
Master of Science

In
Production Engineering

Mansoura - 1998

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Researcher Name : Mohamed Abd El-Gawad Mostafa

Thesis Title : Computer-aided Nesting for Two dimensional Shapes

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1998

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ABSTRACT

This work 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 sheet stock or coil stock. The objective is to maximize material utilization and thus reduce material wastage. The problem emerges in various forms in a number of industries such as ship-building, sheet metal, aerospace, glass, clothes and footwear. In some of these industries, small savings in material costs can considerably affect the profitability of the operation. Therefore, considerable care and expertise is devoted to obtaining a reasonable layout with good material utilization. The system extracts the required shape geometrical information directly from the program 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 steps in Y-direction and repeated the motion in X-direction. Trials after, rotating the movable shape with mirroring the shape in horizontal and vertical direction 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 optimum 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.

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List of symbol

CNTR	Center of the screen
Npts	Number of points of the figure
CheckExt	Check extension of the figure
LExt	Number of lines intersect
Pts1	Values of points of the outer contour
NoPts1	Number of points for the outer counter
Pts2	Values of points of the inner contour
NoPts2	Number of points of the inner contour
MirrorV	Mirror vertical
MirrorH	Mirror horizontal
MirrorD	Mirror diagonal
ShiftH	Shift horizontal
ShiftV	Shift vertical
ShiftD	Shift diagonal

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Chapter(1) General Introduction

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Chapter (1)

General Introduction

1.1- Introduction

The cutting stock problem is of interest in many industries like textile, leather, ship building, aircraft, and sheet metal industries where the cutting of shapes from a piece of row material is recurring activity. Considerable attention has been given by many researchers to developing algorithms for nesting in sheet metal blanking since the 1960's, as rapid development in computers, optimization techniques, computer graphics, data storage and data retrieval techniques have taken place. Sheet metal components from an independent family of widely used parts, ranging from consumer durable to engineering products.

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 sheet stock or coil stock. The system extracts the required shape geometrical information directly from CAD (Autocad R12) database. 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 steps in Y-direction and repeated the motion in X-direction. Trial 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 that contains the two shapes. The developed system has been written in '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.

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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.

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, as shown in Fig. (1.1).

1.2- Literature Review

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 by slitting or cutting before they can be used for further operations.. This raises problems such as waste minimization, reduction in complexity of cutting etc., so that the overall cost of cutting is reduced. All these problems can be classified as cutting stock problems. The methods of solving cutting stock problem may be divided into two groups: algorithmic and heuristic. An algorithmic method often leads to optimal solution for a problem, while a heuristic method may lead to sub-optimal solutions. Heuristic methods are accepted in practice if they yield "good enough" solutions. In general, heuristic methods are highly domain dependent that is they are developed for specific problems. They may have little or no applicability beyond that particular problem. Heuristic methods are usually adopted where algorithmic methods are not feasible or coupled with high computational cost.

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1.2.1. One-dimensional cutting stock problem

The research work has been initiated by Gilmore and Gomory [1,2] in the area of layout by considering one-dimensional problems. In these problems, only one dimension of the stock is significant while the other dimensions of the stock are fixed and not relevant to the solution. This case is encountered, for example, in the cutting of steel bars and cutting paper rolls. Gilmore and Gomory [1,2] formulated the one-dimensional cutting stock problem as an integer-programming problem. Their method involves solving an auxiliary knapsack problem at each stage of the simplex method, to determine the successor solution. In their method the large number of variables involved generally makes computation unfeasible. In their work described a technique, called the Column Generation Technique, for overcoming difficulties in the formulation of the linear programming problem. Problems referred to, as "one-and-a-half-dimensional" are those in which the stock has one fixed and one variable dimension, both of which are significant for the solution. Such a situation occurs, for example, when glass is produced as a ribbon of constant width by a continuous flow process. The cutting stock problem is to cut ribbon into the ordered rectangles so as to minimize the length of the ribbon to be produced.

1.2.2. Two-dimensional cutting stock problem for regular blanks

In the two dimensional cases, the stock is rectangular sheet of finite dimensions and the blanks are two-dimensional having rectangular or irregular shapes. Such problems appear in sheet-metal stamping, cutting cloth for manufacturing of parachutes and garments, cutting leather for footwear, cutting wood for furniture, and cutting plates for shipbuilding. Gilmore and Gomory [3] formulated the two-dimensional trim-loss problem as similar to the one-dimensional problem described earlier, with the constraint that cutting patterns are now rectangular.

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Chambers and Dyson [4] considered a version of the two-dimensional assortment problem in which the possible widths and lengths for stock sizes are integers in a given range. The width is determined by a simpling method of solving a representative trim-loss problem for each possible width under the assumption that all possible lengths are available.

Haims and Freeman [5] studied a related problem, called the Template Layout problem, in which no constraint is placed on the number of pieces of each type to be cut from a single sheet of material. The solution method proposed consists of enclosing irregular shapes, singly or in combination, in minimum- area rectangles called "modules". The modules are then packed in a given stock sheet using a dynamic programming algorithm. Successive iterations of the algorithm are used to determine whether higher- order modules (containing more irregular shapes) can improve the solution. The algorithm requires that at each stage the rectangular module always be placed at one corner of the sheet. To eliminate this constraint Adamowicz and Albano [6,7], who used this approach to solve a version of the cutting stock problem in the shape-building industry suggested an improvement to this algorithm.

Adamowicz and Albano [8,9] also proposed a two-stage algorithm containing a shape clustering stage and a rectangular layout stage. This algorithm employs special shape clustering techniques and multi-stage dynamic programming. Comparing the results with the ones obtained by the manual method proved the effectiveness of this algorithm. However, there are other applications, such as in press working, where the kind of solution produced is not satisfactory, because it is not possible to embed in the algorithm a number of constraints specific to press working.

Christofieds and Whitlock [10,11] presented a tree search algorithm for the rectangular cutting stock problem in which there exist constraints on the maximum number of each type of blank and the use of guillotine-type cuts

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only. This algorithm is, however, inefficient in terms of computer time when solving problems of large size, as often encountered in practice.

1.2.3- Two-dimensional cutting stock problem for irregular blanks

While the research work reviewed earlier dealt with optimal layout of pieces having regular shapes, Albano and Sapuppo [12] used heuristic search methods [13-15] for two-dimensional layout of irregular shapes on rectangular stock-sheets. Roberts's [16] also reported the application of heuristic techniques to a cutting stock problem in the manufacture of furniture. Other examples of single sheet layout algorithms are from Shimo-Zono [17], Chow [18], Solly [19] and Arbel []. All these algorithms have been tested for flame cutting operations.

Instead of considering only one sheet layout at a time, some researchers have considered a whole bill-of-materials at one time and laid out several sheets at the same time. Dagli and Taloglu [21] proposed a two-stage hierarchical approach that deals with the two-dimensional allocation problems of irregular blanks in multi-plates. In the first stage an initial allocation of the patterns to the plates is made through mathematical programming. Then, based on initial allocation, the second stage makes a detailed two-dimensional allocation through heuristic algorithms.

Israni and Sanders [22] developed an algorithm for two-dimensional parts nesting based on the heuristic search approach. They appear to be the first to develop a method for objective testing of irregular parts nesting algorithms. With a fractional factorial design and a specially designed random generator for irregular parts they tested the sensitivity of their algorithm to several variables such as part sizes, part shapes and number of the parts in the bill-of-materials.

Qu and Sanders [23,24] introduced an automatic algorithm for nesting of irregularly shaped parts whose geometries were approximated by composites

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of non-overlapping rectangles. They performed a test using randomly generated bills-of-materials and showed that the algorithm is 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.

1.2.4. Two-dimensional irregular shapes for sheet-metal applications

The two-dimensional layout problems can be treated mathematically as reported above. In a metal stamping operation, however, there are many other constrains which may effect a blank layout solution, and this constrains are usually difficult to incorporate mathematically. Therefore, in the heuristic approach, all the considerations of a tool designer have to be included. The works done by many of the researchers in the area of mathematical programming are applicable to general layout problems without pertaining to any specific application.

Nee [25,26] dealt with a sub-class of the above problem and developed an algorithm for nesting of given parts for application in the sheet-metal industry. Nee-developed two solution approaches based on heuristics. The first, approach is a single-row layout and second one is a pair-wise clustered layout. In the single-row layout, Nee implemented the traditional approach. It is to tilt the blanks at various angles and place them side by side, giving due consideration for the bridge width requirement. In the pair-wise clustered layout, a pair of blanks at 180° Orientation is considered. A polygon is first reoriented such that one of its sides coincides with the x-axes. A second polygon at 180° Orientation to the first is used to match the various sides of the first polygon. If the polygons overlap, a preset incremental shift is performed until such overlapping is completely cleared [27]. This algorithm requires a much longer computation time but generally yields a better utilization ratio. The limitations of this algorithm are the approximation of the

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blank profile by a polygon.

1.2.5. Commercial packages for sheet-metal nesting

With the advent of CAD/CAM technology, several software packages for nesting have become commercially available. The Automatic Nesting System from Auto-Trol, PINS from Intergraph, GNST from McDonnell Douglas and Dynanest from Computer vision are some of the commercially available packages in the area of sheet-metal nesting.

Auto-trol's Automatic Nesting System offers a comprehensive solution for the planning, scheduling, controlling and manufacturing of plate components. The Auto-trol system combines the automatic nesting capability with interactive user modification to optimize material usage. The part geometry definition used by the system is the APT-formatted tool path defining the part profile. The automatic nesting system is specifically used in the production of components whose manufacture begins with numerically controlled plasma or oxy-fuel cutting of plate stock.

McDonnell Douglas Uni-Graphics nesting module (GNST) is a minicomputer-based system developed on Vax platforms. The GNST system operates either on geometry or cutter location source files (CLSFs) created in a unigraphics design module. For nesting purposes, the CLSF point data or geometry is replaced by squared form. When nesting the geometry, the input consists inset details that are reference sets containing geometry. The output is an assembly whose components are the details translated into a proper position on the nest. This system is mainly used in the production of components with plasma or gas cutting.

In summary, almost all the nesting packages address generalized nesting problems, which are applicable to numerically controlled plasma or oxy-fuel cutting of plate stock, rather than addressing directly the problem of sheet-metal nesting, where special constrains are to be considered.

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1.3 Summary of literature review

The foregoing review of the available literature on nesting can be summarized as follows. The nesting problem addressed by most of the researchers can be classified into two groups. The first one is for blanks having rectangular shapes, where different mathematical programming techniques are used to generate optimal layouts. The second one is for blanks having irregular shapes, where different heuristic approaches [28,29] are developed for generating optimal layouts by approximating the blank profile by either rectangular enclosures or polygons. The solutions resulting from the latter approach are widely used in the leather, art and sheet metal industries.

Algorithms developed for nesting of irregularly shaped blanks consider the blank geometry approximated by non-overlapping rectangles or polygons. It has been observed that the approximation of blank geometry by non-overlapping rectangles and polygons does not always lead to the optimum layout and also requires more storage space. Some of the existing algorithms for nesting are incapable of handling blanks having different geometries.

Y.K.D.V. Prasad and S. Somasundaram [30-32] make algorithms developed for nesting of irregularly shaped blanks for press working, by considering the grain orientation, minimum bridge width and maximum material utilization. Representation of the true geometry of the blank without approximating as enclosing rectangles or approximating the curves with polylines in **SPSR** and **SPMR** algorithms pair-wise clustering with reference to the longest side of the blank, nesting different blank geometries by using sliding technique in the **MPSR** algorithm.

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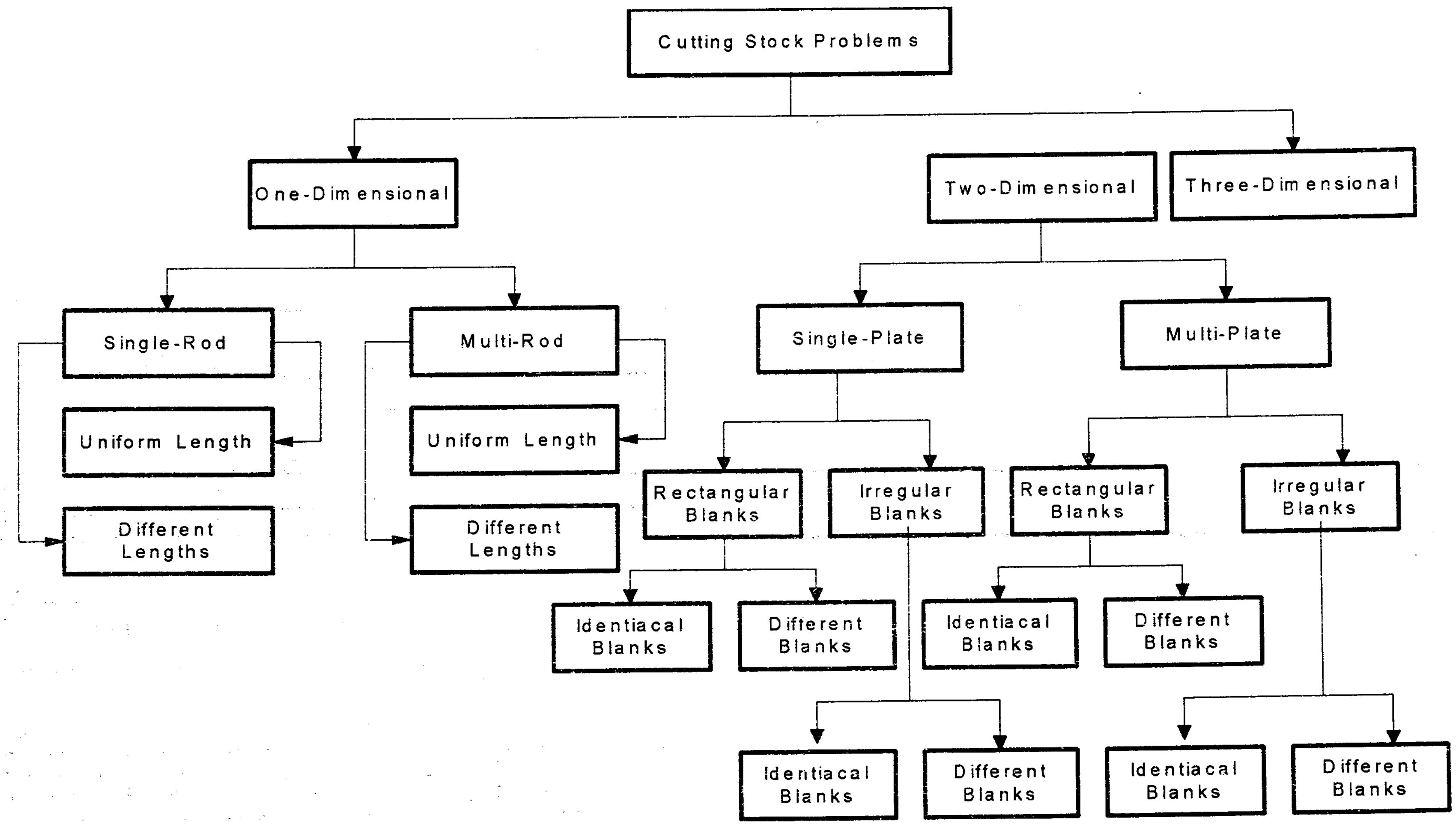

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Chapter(2)

The Blank Parameters

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Chapter (2)

The Blank Parameters

2.1. Introduction

A Blank is a piece of flat metal cut to any outside contour. The thickness of a blank may range among 0.0254 to 12.7 mm or more depending on its function. However, most stampings are among 0.18 to 4.5 mm in thickness. Some blanks have simple round, or rectangular contours. Others may be very irregular in shape. Many blanks are subsequently bent, formed, or we refer to a blank, what is meant is the flat part before deformation has been applied.

2.2. Methods of blanking in presses.

Cutting operations that are done by dies in press [37] to produce blanks include cutoff, parting, blanking, notching and lancing. The first three of these operations can produce a complete blank in a single press stroke. In progressive die, two or more of these five operations are done in sequence to develop the complete outline of the blank and to separate it from the sheet, strip or coil stock.

Trimming, or cutting off excess material from the periphery of a workpiece, usually is done in dies, and is a similar to blanking. Often it is the final operation on a formed or drawn part.

Cutoff is cutting along a line to produce blanks, without generating any scrap in the cutting operation, most of the part outline having been developed by notching or lancing in preceding stations. The cutoff line may have almost any shape-straight, broken or curved. After being cut off, the blanks fall onto a conveyer or into a chute or container. A cutoff die may be used to cut the entire outline of blanks whose shape permits nesting in a layout that uses all of the material, as shown in Fig (2.1) Alternating positions can sometimes be

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الرواد في قواعد المعلومات العربية

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