CHAPTER 1

INTRODUCTION TO CUTTING STOCK PROBLEM

This chapter reemphasizes the significance and evaluation of the blanking process carried out in lock industry. The percentage of utilization of sheet by using the traditional technique is calculated and the implementation of a non-traditional technique like Genetic Algorithm that reduces the scrap is also taken up in a detailed manner. A brief discussion of the blanking process pertaining to the present work is also presented.

1.1 INTRODUCTION

In sheet metal fabrication, glass making, shoe making, textile industries, aerospace, etc., need to have a plan for efficient use of raw material economically. Technically, the stock cutting process has a major impact on the overall processing requirement and cost. The efficient blanking process not only minimizes the material waste, but also significantly save cost and time. This is possible only through choice of making economical stock size and optimized blanking plan. The cutting stock problem is essentially an optimization problem. i.e., an integer linear programming problems such as general resource allocation, where the objective is subdivided in the predetermined allocation to minimize the scrap or trim losses.
The optimum solution for Cutting Stock Problem is more efficient and it depends on following objectives:

- Maximum utilization of material resource.
- Efficient cutting layout.
- Minimizing trim losses or scrap of the material.
- Improving profit by reducing the wastage, while preparing the cutting layout.

2-D cutting stock problem incorporated with maximum production efficiency and minimum scrap, it is also enhanced with inventory cost, setup cost and bill of material. Maximum utilization of resource cannot be guaranteed, because new pattern leads to waste or scrap. This type of problem can be fixed with more constraints such as sequencing of pattern, pattern count, type of cut like Guillotine cut/Non guillotine cut, cutting line, blade length minimum changes etc (Israni et al(1982)). Mostly, manufacturing setup have to purchase the raw material in standard size, which are subsequently cut into pieces based on the market demand or shape of the part manufactured.

There is an evident that needs the formulation of analysis and evaluation mechanism of different available stock sizes and anticipating optimal quantities of order sizes. It is also necessary to meet the constraint of certain fixed quantity of order size and strips specification before starting the process. This could help in choosing the best stock size for optimum utilization with minimum wastage.
1.2 INDUSTRIAL APPLICATIONS

In today’s competitive world, production cost is the major problem in manufacturing industries as products are available almost instantly from any part of the world. High material utilization is must for industries with mass production; small changes of the layout can result in huge savings of material which ensures decrease in production cost. Cutting and packing problems are also the issues faced by several industries. The difficulty of the problem and finding a solution depend on the geometry of the strips to be placed. While wood, glass and paper industry mainly concentrate on the cutting of regular figures, ship building, textile and leather industry are concerned about irregular figures.

The Layout generation is an important step in industrial applications. Generating layouts manually seems to be a time consuming process which is to be minimal as the layout, time place the constraint on packing time. These in turn, make the industries to move on to automatic packing process. The relationship between rectangular cutting stock problem and linear programming theory was highlighted in the year 1950. The earliest approach belongs to the standard methods of operation. The majority of Industrial problems focused on irregular stock material issues depend on the difficulty of the shapes, the computation at time of irregular nesting layout increases. But for some applications nesting problems are needed to solve in real time. As a consequence, the computation time plays a vital role in solving this problem. An online algorithm is planned for this dynamic version of the nesting problem. The Geometric algorithm in irregular nesting problem is intricate and usually applies a certain degree of rough calculation to reduce the calculation time. When the nesting task is solved offline, the degree of accuracy is high.
It is a regular practice in layout generation to utilize the computational power efficiently by the night runs.

1.3 MANUFACTURING PROCESSES CARRIED OUT IN LOCK INDUSTRIES

The following processes are carried out while manufacturing the padlocks.

- Raw material selection
- Design the inner and outer components
- Design of internal operating mechanism
- Assembly
- Inspection
- Quality control
- Dispatch

1.3.1 Raw Material Selection

Raw material selection is based on the application. Brass or Die cast materials are generally used for internal mechanism of locks. The cams are made of steels. Outer casing made of steel nickel chrome, brass etc.

1.3.2 Design of Inner and Outer Components

While design the inner and outer components of lock, the manufacturer has concentrated the customer satisfaction, size, weight, shape etc.
1.3.3 Design of Internal Operating Mechanism of Lock

In this step the mechanisms are made to fit a particular lock order. The machines may be re-tooled or reset during this step. Also, this step has fine tolerances when cutting the metal.

1.3.4 Assembly Process

Assembly of the components is precise with the back plate disc shaft, combination cam, and spacers forming one subassembly. The outer and inner cases are riveted together and then pierced at the point where the shackle is inserted. The combination dial, outer and inner case unit, and combination cam are then fastened together. Finally, these sub-assemblies and the remaining parts are fitted together. The lock case is closed and the edges folded over and sealed. Conventional hardware fasteners that can be released with the proper tool are not used.

1.3.5 Inspection

In this step, the workers check to make sure that the key is matching lock.

1.3.6 Quality Control

This is the next step after inspection; it may pass to a quality control station to make sure everything is right.

1.3.7 Dispatch

Finally, the workers pack the completed locks and box them for shipment.
1.4 NESTING IN THE SHEET METAL INDUSTRY

The sheet metal industry has to focus on both regular, irregular nesting problems with certain constraints based on the properties of material. The cutting process and scheduling are the different packing tasks in this field. Apart from minimizing the scrap, there are various other factors that decides the final layout of the parts.

1.4.1 Material Properties

The raw materials are in the form of sheet material with fixed dimension or as coiled with fixed width. The homogeneous properties of materials like grain orientation, the number of possible orientations strips can be nested and possibly limited. This is mainly based on the application and further development of the strips. If the parts are rotated in any direction, then bending operations are carried out.

1.4.2 Nesting Process

The strips to be nested have void area, some of which may be large enough to be considered for nesting of smaller strips. In the ship building industry hole nesting technique is commonly used. To reduce waste, the nesting algorithm needs to find out the void areas of irregular shapes. Sometimes this current technique does not match a sufficient number of relatively small shapes.

Most of the nesting tasks may involve different materials based on the variation in thickness. In ship building industry the different thickness constraints should be involved in the nesting process. While a number of parts require a certain sheet type, often several thicknesses are suitable for a
subsection of the order list. Depends on the availability, the nesting algorithm needs to work on optimum allocation. In certain applications, the geometry of the strips may allow suitable layout configuration. Normally the order list contains many similar shapes; rotation with its axis can permit two shapes to be nested optimally in a cluster that could be repeated again in the layout. Grouping technique can be used to combine two or more parts together which are used for layout generation. Their frequent use increases the speed of the layout generation.

### 1.4.3 Cutting Process

The cutting practice used to gain the strips has a great impact on the layout preparation. In cutting technology, minimum distance required between the parts is referred to as bridge width. The plasma and laser cutting processes operate with a certain bridge width. In order to avoid damages in parts, considerable distance between neighboring shapes is necessary. In stamping processes, the material tries to slip at the cutting edges if the bridge width is too small. Cutting length is also the most important parameter that determines the cutting process. The optimized layout containing all parts with distance of stock and cutting can be carried out under minimum distance.

### 1.4.4 Scheduling

The sequence of the parts to be cut is important for the succeeding manufacturing process. This process decides the parts needed to be executed in different steps. If the layouts are huge a unique allocation of the parts with respect to the sheets are followed for placing the parts.
1.5 RECTANGULAR NESTING PROBLEMS

The rectangular packing problem arises in the wood, glass and paper industries. The shear cuts impose a characteristic constraint on layout generation. The packing patterns are essential to be guillotined, such that the parts can be perfectly cut throughout the remaining layout.

1.5.1 Strip Packing

The paper industry mainly concentrates on strip packing problem as the raw materials are available in the form of rolls. Hence, the process aims to reduce the height of the layout.

1.5.2 Bin Packing

Bin packing refers to packing of multiple bins and can be found where the stock material is available in the form of sheets rather than rolls. Bin packing is not restricted to the rectangular case. In industrial applications this problem is referred to as stock cutting. The objective is to find out the set of sheets to accommodate all parts of the order to ensure minimization of the total material used.

1.5.3 Non-Guillotine Layouts

Industrial applications are less periodic. The 2D stock cutting problem occurs as a partial problem in pallet and container loading. The usually adopted approach is to shrink the 3D problem into 2D problem Bortfeldt (1994). Processor allocation can also be regarded as a 2D packing problem (Hwang (1997)) certain metal industries the rectangular packing problem can occur in the non Guillotine from where different cutting methods such as laser and plasma cutting are used to obtain parts.
1.6 SOLUTION APPROACHES

The solutions to small packing problems are solved by the method of linear programming. Since these methods are accurate, they find the optimal solution. For higher complexity problems, the solution space is big due to more number of possible combinations. In this case the optimal solution with computing time is not possible to achieve.

More flexibility is obtained by general heuristic methods called as meta heuristics which explain general search opinion rather than special rules. Some of the nontraditional techniques are encouraged by optimization processes in nature such as Simulated Annealing, Genetic Algorithm etc.

The solution quality depends on the implementation of this information and the parameters applied to control the search process, the achievement of the meta heuristics is derived from their flexibility in taking into account the problem specific constraints and their good swapping between solution quality and computational attempt.

The profitable heuristic search methods are based on the solution approach in packing problems and their performances are evaluated against the cost of generated layouts either manually or specific heuristics methods. The computing power of meta-heuristic search techniques has become very competitive in complex packing problems with huge solution spaces. Genetic algorithm has exploration, manipulator within a great search space, it has been repeatedly applied by researchers in new work.
1.7 NEED FOR FURTHER RESEARCH

Even though various nontraditional algorithms are used to solve the basic nesting algorithm with combined heuristic algorithm, this methodology has given optimum percentage utilization with some limitations. They are

- Manually produced layouts are not yielding an optimized result.
- Wastage of time to prepare the profile layouts.
- Over Stocking and cut quotation time have been increased.
- Large Material wastage is directly affecting the holding cost.
- Nesting software is readily available with limited constraints.
- Basically software is not suitable for all kinds of regular and irregular parts which are frequently used.
- Software handling is not easy because it needs knowledge.

Based on the limitations, the industry will not be able to meet customer satisfaction. By considering these constraints industry is looking for good software modules like nontraditional optimization techniques.

1.8 RESEARCH SCHEME

Nesting is a classical problem of finding the most efficient layout for cutting parts with minimum material wastage. Nesting is characterized by the intrinsic difficulty of dealing with geometry, satisfaction of non overlapping containment of constraint and complex computation. The proposed methodology deals with the contribution of traditional and nontraditional algorithms that are applied in the sheet metal nesting of the parts.
Figure 1.1 Scheme of Research work
Figure 1.1 explains the scheme of research work. It starts with identifying basic raw material and ends with finished shapes which crossed several intermediate processes. The simple Genetic algorithm explains how the problem can be easily converted into chromosomes while applying the basic genetic rules with limited constrains.

- Sheet size is fixed.
- Sheet without holes are considered for selection.
- Bridge width is given as 1mm, because the process can be further machined by unconventional machining.
- No bending processes are involved.

1.9 SHEET METAL TERMINOLOGY

The common features used in sheet material are given below.

**Blanking** - The operation of punching, cutting or shearing a piece out of stock to predetermined shapes.

**Compound Die** - Any die designed to perform more than one operation apart from one stroke of the process, such as blanking, and piercing, in which all functions are performed simultaneously within the confines of the blank size being worked.

**Die** – Tool with avoid or cavity which precisely fits to“punch”used to shear or form sheet metal parts.

**Die Clearance** - Amount of space between the punch and die opening.

**Die Marks** - Scratches, scrubbers, denotations, Galling or burnishing of sheet metal work piece by tooling.
Die stamping – The general term for a sheet metal part that is formed, shaped or cut by a die in one or more operations.

Forming - Operation converts a flat sheet metal work piece into a three dimensional part.

Notching – Operation in which the punching removes material from the edge or corner of a strip or blank.

Master die – Universal tool is acceptable for holding changeable tool systems.

Perforating – Punching of many holes, usually identical and arranged in a regular pattern in a sheet, work place blank or a previously formed part. The holes are usually round or in any shape that the operation is also called multiple punching.

Piercing- The general term of cutting openings are holes and slots in sheet metal, plate or parts. This operation is similar to blanking. The difference is that the piece produced by piercing is scrap while blank produced by blanking is the useful part.

Progressive Die – A die with two or more stations arranged in line for performing two or more operations apart from one operation usually being performed at each station.

Punch - Male part of a die is distinguished from the female part which is called as die. The punch is usually the upper member of the complete die assembly and it is mounted on the slide or in a die set for alignment.

**Punch size** - Side on which the punch enters the material.

**Scrap** - Unused material relegated to recycling.

**Shearing** - Cutting force applied parallel to plane of failure causing the material to yield and break.

**Shut Height** – Clearance in a press between ram and bed with ram down and adjustment up.

**Stamp** - To design by pressure into the surface of a material.

### 1.10 SCOPE OF RESEARCH WORK

The scopes of this investigation are listed below.

- Significantly reduce sheet metal waste and cost.
- Produce efficient cutting layout.
- Efficient reuse of scraps.
- Calculate accurate raw panels cost.
- Reduce mistakes while preparing strip layout.
- Algorithm helps to reduce material wastage, cycle time, labor and processes.

### 1.11 ORGANISATION OF THE THESIS

The thesis is a research effort on the development of an optimum cutting layout by employing traditional and nontraditional techniques which can be used in various industrial sectors. The overview of the thesis is represented below.
Chapter 1 entitled “Introduction to Cutting Stock Problem” represents the introduction of 2Dimensional cutting stock process, material selection and scope research work are given.

Chapter 2 entitled “Literature Review” in the area of one dimensional, two dimensional Cutting Stock Problems (CSP) and related techniques are presented. Literature topics related to sheet metal based on non-traditional algorithm are presented.

Chapter 3 discussed the “Evaluation of Sheet Metal Blank Layout using Traditional Methods”. Sheet metal blank manufacturing process consists of three essential areas. They are design, programming, and production. The design process involves drawing of strips or finals which is followed by the generation of NC program with special packages for the final production phases. Manual nesting of sheet metal strips is also proposed in which the process of interaction with each strip is dragged and dropped on the raw material. The user has to work with the individual strips like moving, replacing and rotating to achieve the optimal nest based on his knowledge. All choices of using strips to place raw material are left to the programmer.

Chapter 4 entitled “Sheet Metal Blank Cutting Layout using Response Surface Methodology” for profile cutting operation has presented the behavior of different responses on the work piece material and different constraints. The steps involved in RSM technique are explained and also analyzed.

Chapter 5 discussed the “Genetic Algorithm (GA) Optimization for Sheet Metal Nesting”. The algorithm is implemented to arrange the parts in such a way that minimizes scrap, maximizes the material utilization and optimal layout. The problem is implemented and executed in computer with
latest configuration. The Visual basic programming is the front end software and back end is MS-ACCESS.

**Chapter 6** entitled “Prediction of Cutting Layout in Sheet Metal using Coordinate Optimization Technique” is explained and it works based on the natural selection and survival of the fittest value. This technique is implemented to solve the coordinates of sheet metal blank or strips using the MATLAB software.

**Chapter 7** entitled “Results and Discussion” represents the comparison and analysis of the results obtained from all the optimization techniques.

**Chapter 8** entitled “Conclusions and Future scope” are discussed. This chapter also presents the limitations of this research work and scope of the future works. In addition, the reference used for literature survey is also discussed.