CHAPTER 2

LITERATURE REVIEW

2.1 CUTTING STOCK PROBLEM (CSP)

The cutting stock problem determines the best way of cutting a set of large objects into smaller items. This ensures the large potential economic savings resulting from optimization. This kind of problems are applied in a wide variety of industrial applications such as steel, wood, leather, glass, paper industries, etc.

2.2 INTRODUCTION

In stamping, sheet metal strips of different levels of difficulties are produced quickly, often in huge volumes by using rigid tooling. The production process operates competently and material costs can be represented as 75% or more of total costs in stamping facilities. Due to the large volume of strips produced, even minute inefficiency in material utilization per strips can lead to incredibly large amounts of waste material over a die life. Hence, the alternative of an efficient strip layout is an essential step during die design, because the best layout can reduce wastage of sheet material and decrease the overall production cost.

Initially, strip layouts were prepared manually and cardboard blanks were cut to manipulate and get a good layout. Now, the trend has changed to two-dimensional layout solutions based on computer-aided design.


practical CAD system for blanking or piercing of irregularly shaped metal products for producing stator and rotor parts. Singh et al. (1996) used digraph and matrix methods for estimation of metal stamping layouts. In another work, Singh et al. (1998) presented a low cost modeled for 2D metal stamping layouts. Nye (2000) used computer aided design methods for stamping strip layouts for the best possible raw material utilization. Nye (2001) and Kenmochi et al. (2009) described a new algorithm for optimizing the layout of an irregular convex polygonal blank in a strip. This algorithm could arrange a single blank such that the utilization of the strip material was maximized.

Rao (2004) applied the Analytic Hierarchy Process (AHP) method for estimation of metal stamping layouts. A strip layout selection index was planned that could be used for estimating and ranking of strip layouts. Ciurana et al. (2006) offered an activity model for defining sheet metal process planning. Gomes et al. (2006) used simulated annealing and linear programming methods jointly for solving irregular strip packing problems. Kamalapurkar et al. (2006) viewed total scrap and attempted to minimize the total scrap arising from layout as well as rejections. Highly strained regions in a sheet metal blank were identified. Based on the permissible window of difference in the material properties, a ‘defect map’ was generated on the sheet. The blanks were laid out and the possible number of rejections was predicted logically, leading to the calculation of actual utilization of the material. Bortfeldt (2006) and Thomas et al(2014) recommended a genetic algorithm for 2D strip packing problems that functions without any encoding of solutions. Entirely defined layouts were manipulated as such by means of definite genetic operators.
The above approaches were aimed to achieve better material utilization. However, the strip layout with the highest material saving may not be the best strip layout. Indeed, die manufacturing may become more complex which could balance the savings due to material economy unless a number of parts are to be produced. Whatever be the chosen procedure for obtaining alternative strip layouts, it is desirable to make an optimum choice among the available layouts. Fogg et al. (1975) and Donaldson et al. (1976) opined that the decision of selecting a particular strip layout depends on attributes such as material utilization, die cost, stamping operational cost, required production rate, job accuracy, nature of stock (strip or coil), slitting allowance, balance of blanking pressure, space available in the die set, press specifications, bridge width, shearing strength and thickness of the blank material, facilities available on the shop floor, etc. Ideally, it is essential to decide the attributes that are relevant to the specific problem at hand. The actual identification of evaluating attributes are involved discussion with experts working in the fields of production, die making, tool design and product design.

The objective of a strip layout selection procedure is to identify strip layout attributes and obtain the most suitable combination of the attributes in conjunction with the real obligation of the stamping operation. Thus, the effort should be extended to determine attributes that influence strip layout selection for a given stamping operation using a reasonable approach. This effort eliminated unfit strip layouts and ensured selection of a proper one to strengthen the existing strip layout selection procedures.

2.3 NESTING OF REGULAR PARTS IN REGULAR SHEETS

The two-dimensional shapes have to be arranged on a sheet, prior to cutting, as closely as possible and this is known as nesting process. Optimal nesting layout is generated with the aim of minimizing the wastage of sheet
material and there by arranging the geometrical shapes accordingly. Nesting is a very important task in sheet metal industry, as even a small amount of savings on each sheet material has a significant impact on total material cost. Since the geometry of parts to be cut may vary from simple rectangular shapes to highly complex profile and the quantity of the parts to be cut falls under a wide range, considerable effort is required to obtain the optimal nested pattern. Yeung et al. (2004) proposed the nesting layout of regular shaped parts in sheet as shown in Figure 2.1

![Figure 2.1 Nesting layout of regular shaped parts in regular sheet](Source: Yeung et al. 2004)

Figure 2.1 Nesting layout of regular shaped parts in regular sheet

Further, the two-dimensional nesting process is known to be the NP hard in nature, that means, the possible ways to arrange the parts (search space) increases exponentially with the quantity of parts and their geometrical complexity (Cheng et al. (2000)). To address such two-dimensional nesting problems, several attempts have been made by researchers for the past three decades and several algorithms have been proposed with the consideration of geometrical complexity of parts. However, much attention has not been given to arrange them in a manufacturing perspective. Without considering the manufacturing parameters, generating the nested pattern merely based on geometry is not effective.
Hence the present work focuses on addressing the nesting algorithm to generate the optimal nested pattern, suitable for profile blanking and cutting processes, by considering part geometry as well as cutting process requirements as shown in Figures 2.2 (a), (b) and (c).

Wolf et al. (2013) and Akunuru, R are addressed the nesting of rectangular parts in rectangular sheets. Several researchers have been proposed different methods of employing heuristic algorithms in combination with Artificial Intelligence (AI) methods such as Genetic Algorithm, Simulated Annealing algorithm, Hill Climbing and Tabu Search. Heuristic methods are fixed deterministic approaches which follow certain strategy while arranging parts in the sheet. Many rectangular geometry methods consider the rectangular parts in sequential manner with possible orientations of either 00 or 900 and arrange them on the sheet as close as possible. Whereas, the role of AI methods is to explore the best sequence and orientation of parts with the help of a heuristic method that produces the optimal nested pattern to utilize the sheet metal effectively. The different heuristic strategies proposed by Akunuru et al. (2013) explained with a simple example as given in Figures 2.3(a)-2.3(h).

Jakobs (1996) proposed a bottom left heuristic algorithm as shown in Figure 2.3(a), by considering the parts in a sequential order to arrange them on a single rectangular sheet. Each part in the sequence is moved from the top right corner of the sheet towards bottom until it touches the boundary of the previously placed part(s) or sheet. Then the part is moved towards left until it touches the boundary of the previously placed part(s) or sheet again. In this manner movement of parts continues till the part cannot move further bottom or left. The final position is known as the bottom left position. The Bottom left directional movement of the 8th part is shown in Figure 2.3(a) with dotted lines. In a slightly different heuristic approach shown in Figure 2.3(b) proposed by Liu et al. (1999), the part slides along the boundary of previously
placed parts in bottom–left manner. As shown in Figure 2.3(b), part 8 moves down first and slides along the edge of part 6, then moves down till it touches top edge of part 3. Further it slides left until it touches part 5, which can be seen as the final possible bottom in left position.

Figure 2.2(a) Different geometrical shaped by blanking

Figure 2.2(b) Different geometrical shaped by profile blanking

Figure 2.2(c) Different geometrical shapes by laser cutting process
In contrast to moving the parts in bottom left direction while nesting them on a sheet, Babu et al. (1999, 2012) proposed a method in which parts are translated directly to the predefined positions known as nodes in Figure 2.3(c). The nodes are calculated after placing each part, by projecting imaginary lines from top right corner of the part towards bottom left direction on previously placed part(s)/sheet boundary. From the available nodes, the next part in the sequence, for example, 8\textsuperscript{th} part, occupies bottom left most node where the part does not overlap other parts. Similarly, the bottom left strategy proposed by Hopper et al. (1999, 2001), identified several empty rectangular spaces among the previously placed parts as shown in Figure 2.3 (d). The subsequent parts are placed on possible bottom left most empty rectangular space. Yet another method by Leung et al. (2011), Wu et al. (2013), quantified the empty rectangular spaces as pockets and represented them with parameters such as position (x1, y1), width (w), height of the left wall (h1) and height of the right wall (h2) as shown in Figure 2.3 (e). Each pocket is evaluated to position the next part with a set of rules Leung et al. (2011).

<table>
<thead>
<tr>
<th>Figure 2.3(a)</th>
<th>Figure 2.3(b)</th>
<th>Figure 2.3(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom left movement strategy</td>
<td>Bottom left sliding strategy</td>
<td>Bottom left positioning strategy</td>
</tr>
</tbody>
</table>

(Source Liu et al. 1999)  
(Source Babu et al. 1999)
Burke et al. (2004) proposed the Best-Fit heuristic, to arrange the parts on a sheet based on the skyline concept as shown in Figure 2.3(f). Skyline is a contour of lines drawn from the top most edges of previously placed parts. The height of the skyline for each incremental distance along the width of the sheet, (x-axis), is represented in Figure 2.3 (f). Wei et al. (2011) proposed an improved version of the skyline based method as shown in Figure 2.3 (g). Here, each skyline segment is, evaluated with several parameters such as the exact fit on the selected skyline segment, the local wastage produced after placing the part, etc., before choosing the criteria to place a part. For example, 8th part is placed where the local wastage is minimum as given in Figure 2.3(g).
It is obvious that one of these heuristic methods produces a nested pattern for the given input parameters like the part sequence, orientation and problem specific constraints such as skyline or empty rectangular space parameters, sheet corner direction as given in Figure 2.3 (h). Then the efficiency of the nested pattern is evaluated by means of the fitness function. In many nesting approaches, the fitness value of a nested pattern is usually considered as the percentage of utilization or height of the nested pattern. It is quite a tough task, to find the correct set of input parameters that are required for producing the best possible nested pattern. In this context, meta-heuristic Algorithms are known to be effective methods to find the optimal solution through intelligent search process.

Zhang et al. (2013), Yang (2002), Goldberg (2012) and Burke et al. (2006) projected nesting strategies using Genetic Algorithms in combination with heuristic methods. To find the best sequence and orientation of strips required for producing optimal nested patterns corresponding to heuristic methods explained earlier, genetic strings are formulated with sequence of strips and their orientations. Then through several genetic operations such as initial population, reproduction, crossover and mutation, the best strings that attain the maximum stiffness value are evolved. In contrast to the genetic algorithm method, Burke et al. (2004 & 2009) and Leung et al. (2011) proposed simulated annealing method, which works on processing a single solution at a time, and it is found to be time consuming in converging the solution.

Similarly, Bennell et al. (2001) proposed a tabu search method for nesting rectangular parts in a rectangular sheet. First, the parts are sorted and then ordered according to certain rules such as falling order of part area or width or height or perimeter. With the initial set of sequences of parts, tabu
iterative process continues until it finds the most excellent sequence of parts, which gives the highest fitness value, through exchange of rectangles.

Bennell et al. (2010) exhaustively considered the effectiveness of the nested patterns for various artificial intelligence methods such as genetic algorithm, simulated annealing algorithm, hill climbing (local search algorithm) and also planned random search in combination with selectively chosen heuristic methods. It is observed that, the simulated annealing algorithm generates better solutions for majority of test cases considered. However, it is found to be computationally expensive, i.e., it takes more time to reach the optimal results. But genetic algorithm is found to be efficient in terms of producing the best possible results in less time compared to simulated annealing method.

With the above status of the research, it is clear that several algorithms are projected to address the nesting of 2D rectangular parts in rectangular sheets, by considering the geometry of parts, with the aim of utilizing material efficiently. However more importance is not given to the problem from a manufacturing perspective. It means, the cutting process and its related issues are not addressed while generating the nested pattern. If the manufacturing conditions and constraints are considered, the objectives of the nesting algorithms can be focused further, to enhance the capability of the cutting process in terms of minimizing the process time, apart from utilizing the sheet metal effectively.

2.4 NESTING OF IRREGULAR PARTS IN REGULAR SHEETS

Hong et al. (1997) and Burke et al. (2006, 2007) introduced a system of optimized nesting with an analogical learning mechanism. First, irregular parts are processed in advance and their optimal rectangular enclosures are obtained. The problem is transformed into a solution of the
rectangular allocation problem. Then the relative optimal solution is gained using heuristic search. Anand et al. (1999) presented a Genetic Algorithm to generate part layouts for irregular parts using the

- Polygonal images obtained through a machine vision module that acquires the images of irregular parts and storing them in a database of parts.
- Manufacturing schedules and priorities as manufacturing constraints.

(Source: Lee et al. 2008)

**Figure 2.4 Nesting layout of irregularly shaped parts in regular sheet**

Galiev et al. (2016) developed an exact algorithm for orienting the parts on the strip to maximize material utilization. The algorithm optimally nests convex or non-convex blanks on a strip and predicts both orientation and strip width that minimize material usage. Technological constraints such as blank orientation constraints due to planar anisotropy are also incorporated into the algorithm as shown in Figure 2.4. Cheng et al. (2000) proposed an algorithm, which combines the Compact Neighborhood Algorithm (CNA) with GA to optimize large-scale nesting process with the consideration of multiple orientation constraints. This study is aimed at improving the flexibility of CNA by incorporating the available freedom in the orientation of patterns.
GA follows natural rules to optimize the generated layouts. The combination of CAN with GA is the best solution obtained mathematically and the technique is highly suitable for large scale nesting purposes. Yang et al. (2013) and Zhang et al. (2013, 2016) proposed the problem to cut identical blanks from long strips of raw material and showed that the orientation of the blank strongly affects material utilization. Further, the author described a new algorithm for optimizing the layout of an irregular convex polygonal blank in a strip. This algorithm orients the blank such that the utilization of the strip material is maximized. Samarghandi et al. (2010), developed the utility of Particle swarm algorithm that can be incorporated into a Computer Aided Engineering (CAE) system for automated design and optimization of parts made from sheet materials. Djurisic et al. (2003) and Suliman SMA (2006) presented a conceptual solution and a prototypical intelligent nesting system for optimal cutting conditions. The problem of nesting can generally be divided into two intellectual phase recognitions:

- Classification of shapes.
- Arrangement of recognized shapes on a given surface.

Kamalapurkar et al. (2006) attempted to minimize the total wastage arising from layout as well as rejections. Highly strained regions in a sheet metal blank are identified. Based on the permissible window of variation in the material properties, a defect map is generated on the sheet. The blanks are laid out and the possible number of rejections is predicted probabilistically, leading to the prediction of the actual utilization of the material. Mulero et al. (2007) presented a Minkowski sum method for maximizing the number of parts within gaps on a rectangular sheet of material. It also provides results for laying out a more complex part in ganged sections, demonstrating a result that would be difficult for a human to reproduce.
Vamanu et al. (2002) and Lam et al. (2007) presented an automatic nesting system for relatively more complex parts. It is devised and implemented on the computer software tool solid works, and visual C++ is used to create the solid works application programming interface for algorithm demonstration. The nesting process is divided into two stages: the nesting of two blanks and part layout formation of two nested pairs. The algorithm starts with the extraction of the blank process, which may consist of straight or circular edges and even concave features, and then uses the Minkowski sum formation to determine the optimum orientation of the nested blank pair and the width of the metal strip.

Bennell et al. (2008) provided the detailed explanation of the most popular techniques for handling geometry when solving nesting problems and provided guidance on their implementation, strengths and weaknesses. The techniques discussed are raster method, direct trigonometry, number of polygon and phi functions. Teresa Costa et al. (2009) presented a particular case of the nesting problem occurs when congruent copies of one irregular shape have to fill as much space as possible in a limited rectangular sheet and proposed three heuristic approaches: Parallel Angles Heuristic (PAH), Equally Spaced Angles Heuristic (EAH) and Free Angles Heuristic (FAH). These approaches are used to solve this particular case of nesting problem. EAH is shown as computationally efficient and robust.

Buchwald et al. (2016) addressed the major contribution of upper bound heuristics that can handle simultaneously the maximization of density and percentage of stock sheet utilization. Sheen (2012), Weng et al. (2011) presented an irregular stock cutting system (NEST) developed on Auto CAD software platform by Visual Basic (VB) programming language. This development is based on two known techniques: the bitmap representation to transform all shapes drawn by AutoCAD into pixel matrices before nesting,
and the bottom left fill algorithm for nesting. It provides two important parameters and are given below.

- The precision level which decides how the bitmap representation can precisely describe a shape.
- The unit rotation angle which makes a shape self-rotate in steps with small angles and to be manually placed on the sheet material with its best self rotation angle.

All shapes are tightly positioned on a sheet material through several tests. Holes within positioned shapes and spaces between them are sufficiently utilized by small shapes. Joshi et al. (2012) reviewed the nesting algorithms that were developed to solve various two dimensional regular and irregular nesting problems. Dalalah et al. (2014) addressed a category of two-dimensional NP-hard knapsack problem in which a given convex/non-convex planer items (polygons) have to be cut from a single convex/non-convex master stock.

2.5 NESTING OF IRREGULAR PARTS IN IRREGULAR SHAPED SHEETS

Tay et al. (2002) presented a new nesting approach using GA addressed as evolutionary boundary nesting algorithm. The boundary nesting algorithm basically takes in one shape at a time and uses GA to locate the local optimal position along the boundary of the stock and the shape is nested as shown in Figure 2.5. Then the remaining stock boundary will be extracted and forms a new boundary for the next shape to be nested. Lee et al. (2008) proposed a Quick Location Movement (QLM) to solve the situation of irregular shapes nested on multiple irregular sheets. This approach includes two major parts:
• It approximates irregular shapes to a polygon with the use of a cluster of straight lines.

• It arranges the approximated shapes. This algorithm takes less time to calculate a layout and the material utilization efficiency is higher compared to other methods.

(Source: Tay et al. 2002)

Figure 2.5 Nesting layout of irregularly shaped parts in irregular sheet

2.6 OPTIMAL CUTTING SEQUENCE WITH MINIMUM PATH LENGTH

Manber et al. (1993) addressed the problem of sequencing a torch for the cutting of a stock sheet nested with regular or irregular parts with a minimum member of pierce points. Three algorithms are presented for the problem. The first algorithm is to determine the torch paths. The second algorithm used to trim the margin and to investigate further reduction in number of pierce points. The third algorithm guarantees that the torch path has no vertices of odd degree, no piece will be dropped that needs further interior cuts. Jung et al.(1994) described feature based non cutting tool path selection using Integer Programming (IP) approach that provides an optimum tool dispatching sequence for non cutting path in accordance with the manufacturing rules while avoiding multi dispatch of tools.
Bhadury (1996) investigated a problem of finding a sequence of ‘guillotine cuts’ to cut out two convex polygons P and Q, where P is completely contained in Q, such that the total length of the cutting sequence is minimized. The problem has applications in stock cutting where a particular polygon shape needs to be cut out of a given piece of raw sheet material using only guillotine cuts and where it is desired to minimize the cutting sequence length to improve the cutting time required per piece. Scheme based on dynamic programming an approximation technique is used to solve this problem.

Foerster et al. (1998) solved the Order Spread Minimization Problem (OSMP) that arises in the process of planning industrial cutting operations. It has been looked upon as a generalization of Traveling Salesman Problem (TSP). It is shown that significant improvement in solution quality can be achieved by applying Simulated Annealing Algorithm (SAA) to the OSMP and the solution quality might be improved even further by selecting the parameters of SAA more carefully. Sheng et al. (1998) developed an optimization scheme for laser cutting based on the analytical cutting models for laser cutting on straight beam path and curved beam trajectory. It can predict the laser power, and cutting velocity that can satisfy constraints for material removal rate, entrance taper, exit taper and kerf width. Owing to the cutting of complex features, the laser beam path must shift away from the rotational centre to compensate the curvature effect. Khan et al (1999) illustrated that the studies on machining economics consider feed rate, spindle speed and depth of cut as the principle parameters and no consideration is given to non-productive machining time.

A machining sequencing problem with the objective of minimizing non-productive machining time is formulated as a large scale Traveling Salesman Problem (TSP) and proposed an SAA addressed as stochastic
search procedure to solve these instances of TSP. The solution allows the optimization of non-productive movement thus reducing the machine tool resident time and power consumption. Han et al. (1999) presented an efficient laser cutting sequence based on SAA. One of the main features of the algorithm is that heat effect is incorporated into the cost function. The requirement of any sequence of the path is that all the edges of nested parts should be traversed exactly once by the laser torch as shown in Figure2.6. Hence the algorithm finds the shortest path sequence that avoids the occurrence of critical temperature.

Castelino et al. (2002) described an algorithm for minimizing the airtime for milling by optimally connecting different tool path segments. This problem is formulated as a generalized Traveling Salesman Problem (TSP) with precedence constraints and is solved using a heuristic method. This algorithm has been implemented in an automated process planning system and can be applied easily to other area of path planning optimization like laser cutting.

Rajan et al. (2001) and Dwivedi et al. (2004), proposed a method for torch path planning applicable to Solid Freeform Fabrication (SFF) based on welding. It describes a method based on the subdivision of a two-dimensional polygonal section into a set of monotone polygons to generate a continuous path for material deposition. The path for each individual sub polygon is generated. The final torch path is obtained by connecting individual paths for all the sub polygons and trimming along the points of intersection of the paths for individual sub polygons. The final path is a closed loop. Therefore, any point can be selected as the starting point for material deposition. Wang et al. (2005) and Vukota et al. (2005) addressed the process planning problem of a combined punch-laser machine blanking. Wang et al. (2005) proposed an Ant Colony Optimization (ACO) algorithm for optimal
tool path to laser blanking processes and showed that their proposed method can significantly improve the operation efficiency for the combined punch-laser machine.

Tiwari et al. (2006) used the GA based multi-objective optimization procedure for optimizing the layout of rectangular parts by minimizing the required sheet length (or the trim loss) as well as the number of cuts (or the total length of the cut required) to achieve the cutting process. This algorithm is used to study both guillotine and non-guillotine cutting cases. The near optimal solution set is obtained by the evolution of pareto-front. Elamvazuthi et al. (2009) solved the problem in leather industry, for placing a set of irregularly shaped pieces on a plane irregularly shaped surface. The manual cum automated processes of nesting and cutting for the leather furniture production also discussed. This work reported the productivity improvement through automation of the leather cutting process. Xie et al. (2009) investigated the nesting issue and the machining path planning issue for improving the sheet metal machining efficiency. GAs are proposed and developed for the above two issues. The proposed GAs are tested in a sheet metal industrial case against the Ant Colony Optimization (ACO). The experimental results are compared with the results from the ant colony algorithm. The GA shows better performance than ant colony algorithm. Jin et al. (2011) developed a mixed and adaptive tool path generation algorithm, which is aimed to optimize both surface quality and fabrication efficiency in Rapid Prototyping (RP). The algorithm can generate contour tool paths for the boundary of each RP sliced layer to reduce the surface errors of the model and zigzag tool paths for the internal area of the layer to speed up fabrication.

Yanxin Xu (2016) developed a novel grouping particle swarm optimization approach for 2D irregular cutting stock problem. The new position of strips and its velocity updating are grouped together to find the
optimum cutting layout. Lu et al. (2013) adopted technique for optimization of irregular graph stock layout problem using mixed coding methodology. This approach helped to reduce the time complexity of genetic algorithm. Baldacci (2014) developed an algorithm used to solve the problem in leather garment and furniture industry. The irregular strips are nesting in the irregular sheet for getting optimum utilization of stock and defects are avoided.

Martinez Sykora et al. (2016) and Verstichel et al. (2013) formulated an algorithm for 2D bin packing problem for a set of irregular pieces which may have concave stock sheet with fixed dimensions. The problem arises in ceramic industry. The authors proposed integer programming model for placing the strips on the sheet for getting maximum utilization. Rymm Halleh et al. (2016), Silva et al. (2014) suggested the Cut Order Planning (COP) in the apparel industry. The algorithm consists of dividing each garment order into sections in such a way that the total fabric length is minimized. Wauters et al. (2013) and Zhang et al. (2006) presented an algorithm with approximate solution of packing regular convex polygons in a closed domain for achieving the maximum fitness value. Hongtao Tang et al. (2015) and Wei et al. (2009) proposed an optimizing model for rectangular pieces which are frequently used in cement industry. Lowest horizontal screening algorithm had been implemented to optimize the rectangle channel by using Genetic Algorithm. Annamalai vasantha et al. (2016) developed human in the loop approach for nesting the shapes that use the online workers to produce packing efficiencies using CAM packages. This approach increases the efficiency 4% higher than the commercial packages which would be applicable to textile, automotive industry applications.
Christofides et al. (1995) and Bennell et al. (2001, 2008) developed an algorithm for frequently used L shaped strips for nesting and evaluating a cut consideration technique to accelerate the solution process. The dynamic sequencing reduces average solution time and then significantly increases the computation time by 12%. Tuzkaya et al. (2013), Huang et al. (2007) and Lai et al. (1996) generated facility layout problem, which is solved by the combination of heuristic approaches such as genetic algorithm, simulated annealing algorithm. The results were compared based on their fitness function and time requirement using various tests. Hongho Tang et al established the new approach from manual nesting. The lower horizontal line searching with mathematical modeling was described. This approach mainly used to optimize the layout in the cement industry.

Bi et al. (2012) proposed an analytical energy model to optimize the machine setup for energy saving based on the kinematic and dynamic behaviors of the chosen machine tool. Rodrigues et al (2012) proposed a memetic algorithm to solve the rural postman problem and stated that it can be used for path optimization of component cutting operations. Hamzeei et al. (2013) presented the problem of finding the minimum total loaded travel distance in which a bidirectional path, location of Pickup and Delivery (P/D) stations of each location have been determined simultaneously. In order to solve the problem, two different algorithms are developed. A cutting plane algorithm to solve mixed integer linear programming model. A Simulated Annealing (SA) approach was used to solve this problem to obtain a near best solution.
2.7 RESEARCH GAP

Based on the literature review, the following research gap has been identified in the area of nesting of sheet metal parts with cutting sequences:

- The complexity in placing irregular parts in regular sheets is high and a lot of avenues are still open for research in this area.
- Optimal cutting tool path planning or minimum path length is not concentrated.
- Integrated planning of nesting and cutting sequence is not given as much attention.
- Minimum cutting time of the parts is a major issue in laser cutting industries.
- The non-traditional techniques have been considered for solving the nesting of sheet metal strip with limited constraints.
- On the above concerns, the problem of placement of irregular shaped parts in standard sheets in combination with cutting sequence of nesting and cutting sequence is not given much importance.
- On the above concerns, this research considers the problem of placement of irregular shaped parts in standard sheets in combination with Profile cutting.

2.8 PROBLEM IDENTIFICATION

Based on the literature review, the two dimensional nesting problem has been identified. A series of hybrid approaches and metal
heuristic approaches are developed to solve the two dimensional rectangular, irregular strip packing and two dimensional bin packing problems. Most of the literature reviews encourage the use of heuristic based nontraditional algorithm with the practical and industrial aspects of the cutting stock problem. There are a number of other factors that decide the final layout of the parts. The raw material is in the form of sheets with fixed dimension or a coil with fixed width. This has an impact on the objective of nesting.

As the material has in homogeneous properties such as grain orientation and the number of possible orientations of the parts to be nested may be limited. This is depends on the application and further processing of the shapes. The objective is to rotate the parts in any direction otherwise, a specified angle with respect to the grain orientations needs to be applied and also limited. The main focus of this investigation is on the application of simple Genetic Algorithm in a sheet metal blanking operation is to be carried out. This research work is carried out in the SIDCO lock industry.

2.9 OBJECTIVES OF RESEARCH WORK

Normally the lock industries need a scope for the efficient use of raw materials from industrial point of view. The stock cutting process has a major impact on the overall processing requirements and cost savings. The improved cutting plan not only minimizes the material waste but also save the cost and time. The optimum solution of cutting layout is the most efficient and it satisfies the following objectives.

- To prepare the cutting layout and selection of a number of strips based on the previous research work.
• To investigate the effect of input process parameters such as sheet size, bridge width and number of strips on the output responses such as Material Utilization Ratio and Scrap Ratio.

• To develop the optimum cutting layout by using the traditional and nontraditional approach.

• To maximize the utilization of strips in the cutting layout by using the traditional approach.

• To optimize the cutting layout for the lock industry by using nontraditional technique such as Genetic Algorithm, Coordinate Optimization Technique

• To validate the experimental results.

2.10 SUMMARY

Based on the literature review, it is observed that the researchers are concentrated on the rectangular, irregular nesting algorithm applied in various fields like leather, textile industry, paper cup manufacturing industry, glass making industry using the various nontraditional algorithms. These algorithms are very difficult to understand for process planner to implement on the manufacturing environment. But lock industry they are in a position to maximize the productivity, minimize scrap and optimum layout are needed while utilizing the stock sheets. The various nontraditional algorithms are used to solve the basic nesting algorithm to find out the optimum Material Utilization Ratio (MUR). The succeeding chapter explains the evaluation of sheet metal blank layout using traditional methods.