Process Analysis and Reduction of Galvanized Iron (GI) scrap levels by optimizing its consumption in Bus Body Building process using Linear Programming Model

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***Abstract*- The project was carried out at the bus building facility at NEKRTC, Yadgir and concentrated on Moffusil type of buses. Galvanized Iron (GI) is prominently used material for panelling of the bus. During panelling stage considerable amount of material scrap was generated. From the existing data, it is seen that 30% of the materials are scrapped as they could not be used for building new buses for various reasons. The materials that are procured are of standard size but materials of various dimensions are needed to panel a bus. This prompted the use of cutting stock problem. Fulfilling the requirement keeping the wastage minimum for specified number of lengths of materials to be cut from given stock lengths is the aim of the project. For which the linear programming model was incorporated to minimize the scrap by optimizing the material consumption. By doing so the scrap level was reduced to 6.335% which was 30% earlier. Thus 78.865% of the total scrap generated earlier was reduced during panelling process of the bus.**

***Index Terms*- Linear programming, Cutting Stock problem, optimization, scrap reduction, GI rolls.**

I. INTRODUCTION

Two variants of GI are used for the panelling of bus. They are part of the major materials that are procured as they share the major portion of the cost that has incurred for material procurement. In the process these materials are subjected to bending and cutting to be used in bus panelling. As they are procured in standard sizes they cannot be directly used in panelling for which they need to be cut or bent before going as the final piece to panel the bus.

In the process the materials are not completely utilized. Some portion of it is only being used and others are scrapped. The data given by the company said that 30% of GI material is scrapped during the panelling process. These scrap levels are of considerable amount and needs to be reduced. The reduction in scrap levels can be made by optimizing the consumption of materials by using suitable techniques.

II. METHODOLOGY

The reduction of scrap can be made by optimizing the consumption of materials by using suitable techniques.

A. Optimizing Using Linear Programming

Mathematical modelling technique useful for guiding quantitative decisions in business and industrial engineering

Solving a linear programming problem can be reduced to finding the optimum value of a linear equation called an objective function, subject to a set of constraints expressed as inequalities. The number of inequalities and variables depends on the complexity of the problem, whose solution is found by solving the system of inequalities like equations.

B. Cutting Stock Problem

It is one of the major issues in the industries these days. The demand for various different sizes of materials leads to trim wastages. For which cutting stock problem method can be used to reduce the trim losses and optimize the resource consumption.

The cutting-stock problem is the problem of filling an order at minimum cost for specified numbers of lengths of material to be cut from given stock lengths. The cutting stock problem methodology will be followed in order to reduce the wastages.

The algorithm to solve the problem was developed in the course of time from one dimensional to multi dimensional cutting of the sheets. It was developed by Gilmore & Gomory. The algorithm helps in cutting the materials of interest such a way to make the scrap minimum and optimize the consumption.

In the present problem the one dimensional cutting method is followed which is later extended to two dimensional methods by cutting the sheets into rectangular pieces. Since the requirement of the width is constant first the sheet is cut length wise and then along its width to utilize the materials efficiently.

The cutting stock problem of linear programming is used to solve the current problem where the quantity is allocated such a way that the scrap level is minimized. Solver of excel software will be used to carry out the computation. It helps in giving solving the problems and finding the results.

III. Literature Review

Gilmore and Gomory (1961) discussed the linear programming approach to the cutting stock problem. Gilmore and Gomory discussed the cutting stock problems involving that dealt with a wide range of industrial problems, especially those related to multistage cutting. The cutting-stock problem is the problem of filling an order at minimum cost for specified numbers of lengths of material to be cut from given stock lengths of given cost. In this paper, a technique is described for overcoming the difficulty in the linear programming formulation of the problem. The technique enables one to compute always with a matrix which has no more columns than it has rows

Dikili et al. (2007) proposed a novel approach for solving a one dimensional cutting stock problem in ship building. They used cutting patterns obtained by the analytical methods and mathematical modelling stage. By minimizing both the number of different cutting patterns and material waste, the proposed method was able to get the ideal solution of the analytical methods.

IV. Approach

Linear programming model will be adopted in order to optimize the material consumption in and to achieve scrap level reduction

A. *Mathematical Representation*

The problem is solved using the below mentioned mathematical model to minimize scrap of the materials used. The model will be used and worked in the solver software to get the allocations of the material in order to reduce the scrap.

Determine the cutting pattern combinations (variables) that will fill the requirement of varied size pieces (constraints) of the given material type with the least trim-loss area (objective).

The definition of the variables given can change according to the production requirement of the company. Here the variables are defined as the number of standard sheets / rolls to be cut according to a given cutting pattern. This definition requires identifying all the possible cutting patterns-Hamdy Taha[10]

The materials that are used for paneling purpose and their dimensions are given in the following table. There are 2 categories of materials that are being used for the purpose of paneling.

Table 1 - The categories of GI material

Sl. No.	**Material**	**Gauge**	**Dimensions in mm**
1	GI	18	25000*1219
2	GI	20	25000*1219

Now considering GI 18G,

Table 2 - Requirement of GI 18G for paneling**.**

GI 18G	**Length in mm**	**Used in**	**No. Required for 10 buses**
A	610	Battery box	20
B	470	Equipment box	20
C	736	Battery box & Equipment box	60
D	762	Mud guard covers	80
E	220	Footboard	60
F	350	Dash board	10

GI 18	length in mm	C1	C2	C3	C4	C5	C6	C7	C8
A	610	1	0	0	0	0	0	0	0
B	470	0	0	1	0	1	1	0	2
C	736	0	0	1	0	0	0	1	0
D	762	0	1	0	1	0	0	0	0
E	220	1	0	0	2	1	3	0	1
F	350	1	1	0	0	1	0	1	0
	SCRAP	39	107	13	17	179	89	133	59

Fig1 - Cutting patterns generated for GI 18G

To express the model mathematically we define the variables as

x_j= number of standard rolls to be cut

according to setting j, j=1, 2…, 8

The constraints of the model deal directly with satisfying the demand for rolls.

Number of 61 mm piece produced = x_1 ≥ 20

Number of 470mm piece produced = $x_3 + x_5 + x_6 + 2x_8$ ≥ 20

Number of 736mm piece produced $= x_3 + x_7$ ≥ 60

Number of 762mm piece produced $= x_2 + x_4$ ≥ 80

Number of 220mm piece produced = $x_1 + 2x_4 + x_5 + 3x_6 + x_8$ ≥ 60

Number of 350 mm piece produced = $x_1 + x_2 + x_5 + x_7$ ≥ 10

To construct the objective function, we observe that the total trim-loss area is the difference between total area of the standard rolls used and the total area representing all the requirements. Thus

Total area of standard rolls/sheets

$$= 1219L\,(x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8)$$

Total area of requirements

$= L$ (610*20+470*20+736*60+762*80+220*60+350*10)

=14320L

The objective function then becomes

Minimize

$$z = 1219L\,(x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8) - 14320L$$

Because the length L of the standard roll is a constant, the objective function equivalently to minimizing the total number of standard rolls used to fill requirements;

That is

$$\text{Minimize } z = x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8$$

Subject to

$$x_1 \geq 20 \text{ (610mm)}$$

$$x_3 + x_5 + x_6 + 2x_8 \geq 20 \text{ (470mm)}$$

$$x_3 + x_7 \geq 60 \text{ (736mm)}$$

$$x_2 + x_4 \geq 80 \text{ (762mm)}$$

$$x_1 + 2x_4 + x_5 + 3x_6 + x_8 \geq 60 \text{ (220mm)}$$

$$x_1 + x_2 + x_5 + x_7 \geq 10 \text{ (350mm)}$$

$$x_j \geq 0,\ j=1, 2\ldots 8$$

(Source- Hamdy Taha)

GI 18	length in mm	C1	C2	C3	C4	C5	C6	C7	C8
A	610	1	0	0	0	0	0	0	0
B	470	0	0	1	0	1	1	0	2
C	736	0	0	1	0	0	0	1	0
D	762	0	1	0	1	0	0	0	0
E	220	1	0	0	2	1	3	0	1
F	350	1	1	0	0	1	0	1	0
	SCRAP	39	107	13	17	179	89	133	59

Minimize		SCRAP

DECISION VARIABLES		
X1	QTY of material requiredfor cutting method 1	20
X2	QTY of material requiredfor cutting method 2	0
X3	QTY of material requiredfor cutting method 3	60
X4	QTY of material requiredfor cutting method 4	90
X5	QTY of material requiredfor cutting method 5	0
X6	QTY of material requiredfor cutting method 6	0
X7	QTY of material requiredfor cutting method 7	0
X8	QTY of material required for cutting method 8	0

CONSTRAINTS			
	20		20
	60		20
	60		60
	90		80
	200		200
	20		10

SCRAP			3090

Fig 2-Solver solution of GI 18G

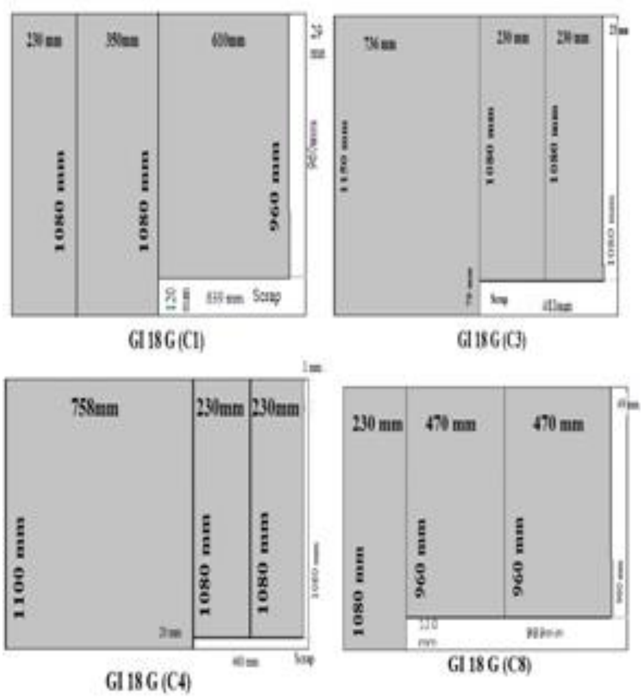

Fig 3 - GI allocated for the respective cutting patterns.

The solver software was used to allocate materials keeping the scrap minimum. The minimum scrap that would be generated for 10 buses after incorporating the cutting patterns which was got using Linear programming model for GI 18G is as follows:

Table 3 - Scrap generated in GI 18gauge after incorporating LP model

Sl. No.	Cutting Pattern	Scrap generated (in sq. mm)
1	C1	2090400
2	C3	3519000
3	C4	822400
4	C8	1657200
Total		8089000

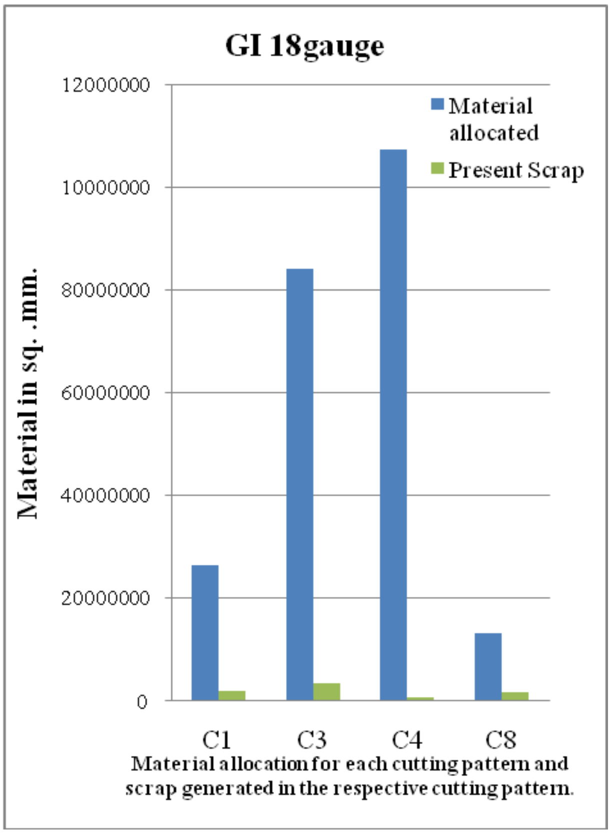

Fig 4 - Scrap generated for the allocated material in respective cutting patterns.

The similar procedure is followed for the other material to achieve reduction in scrap levels.

V. RESULT

The following quantity of scrap was obtained after optimizing the usage of materials by the results got from solver.

Table 4 - Percentage reduction in scrap levels

Material	Scrap (Before) in sq.mm.	Scrap (Present) In sq. mm.	Scrap Percentage (Present) in %	Reduction in Scrap level in %
GI 18G	69263580	8089000	3.5	88.3
GI 20G	45028641	13772970	9.17	69.43

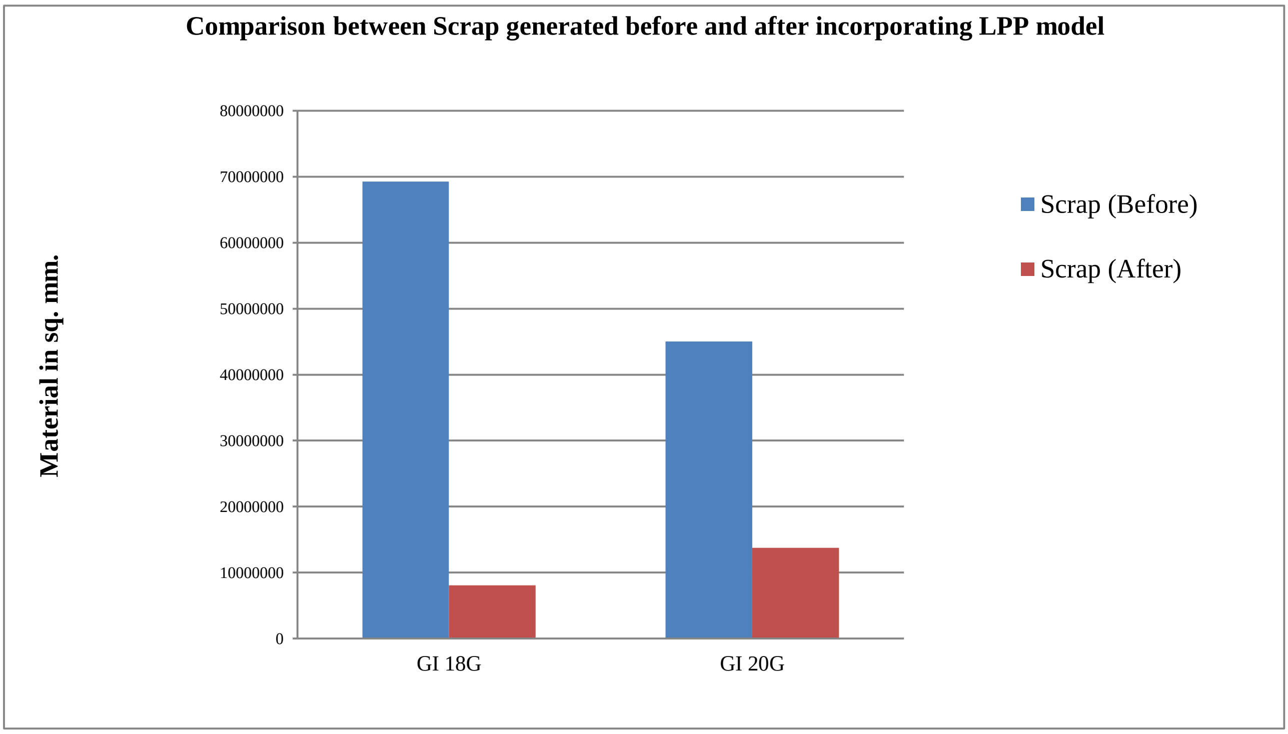

Fig 5 - Scrap level comparison before and after incorporating LP model.

VI. CONCLUSIONS

Thus it can be seen that following optimization techniques helps in scrap minimization and in efficient utilization of the resources. The reduction of scrap levels saved cost incurred due to the materials being scrapped.

The scrap that had occurred between June2013–Dec 2013 was 30% was reduced to 6.335% after using LP model. The aim of the project is thus met. The scrap levels are reduced by 78.86%.

Cutting stock problem algorithm can be applied to problems where there is demand for various different sizes of materials. It helps in allocating the materials keeping the scrap minimum thus saving on the cost incurred due to materials wastages.

This can also be extended to other types sheet metals that are used to panel buses and also to other type of buses that are built in the company. The project can also be extended and applied in the structure process. One dimensional cutting method can be used for the purpose as the materials need to be cut only on length wise.

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