Process Analysis and Reduction of Aluminium (Al) and 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 a bus body building company having three bus models (low-end, medium end & High-end buses). The company was having problems with material consumption of two materials namely Al and GI in there process i.e. the cutting section was generating scrap in large volumes of the two materials. Hence the main aim of this project was to perform scrap analysis of Aluminium (Al) and Galvanised Iron (GI), the two main materials consumed during panelling process of bus body building and come up with an alternative to reduce the scarp levels. Low end model bus was considered for this project and it accounted for 30 buses a year.**

The scrap generated from the existing system of two materials consumed for the low end model put together amounted to nearly 30% of the overall scrap due to factors like poor cutting allocations (materials procured come in standard sizes i.e. for Al comes in Sheets of standard size and for GI comes in rolls of standard length) or due to improper cutting methods/techniques employed by the workers working at this unit. After going through the existing system thoroughly we decided to apply one dimensional cutting stock problem a branch of Linear Programming Problem (LPP) for optimizing the current process. This approach helped us to reduce the scrap levels to 7.542% from the existing level.

Keywords- Cutting Stock problem, LPP, Scrap levels, Bus body building, low end.

1.INTRODUCTION

Aluminium (Al) and Galvanized Iron (GI) are used for the panelling of bus body. 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 hence in the process the materials are not completely utilized. Only a certain portion in the standard size of the material is utilized leaving the rest as scrap as dimensions after a particular cut do not either match with the next operation or process or workers just resist to apply their mind for better usage of the left over materials. The data given by the company said that 30% of Al and GI are 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.

2.METHODOLOGY

The methodology adopted was using one dimensional cutting stock problem a branch of Linear Programming Problem (LPP) for optimizing the current process.

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.

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 software is used to carry out the computational work. It helps in solving the problems and finding the optimum results.

3. APPROACH

LPP was adopted in order to optimize the material consumption and to achieve scrap level reduction

Mathematical Representation

The problem is solved using the below mentioned mathematical model to minimize scrap of the materials used. The model was used manually and also 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.

The materials that are used for paneling purpose and their dimensions are given in the following table. There are 5 categories of materials that are being used for the purpose of paneling.

Table 1 - The five categories of materials

Sl. No.	Material	Gauge	Dimensions in mm
1	GI	18	25000*1219
2	GI	20	25000*1219
3	Al	10	2438*1219
4	Al	14	2743*914
5	Al	18	2438*1219

For example, 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 = $x_1+2x_4+x_5+3x_6+$

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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

Minimize $z = x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8$

Subject to

x_1 ≥ 20 (610mm) $x_3 +$

$x_5 + x_6$ $+ 2x_8$ ≥ 20 (470mm) $x_3 +$

$+ x_7$ ≥ 60 (736mm) $x_2 +$ x_4

≥ 80 (762mm) $x_1 +$ $2x_4 + x_5 + 3x_6$ $+ x_8$ ≥ 60

(220mm) $x_1 +$ x_2 $+ x_5$ $+ x_7$ ≥ 10 (350mm)

$x_j \geq 0$, j=1, 2…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

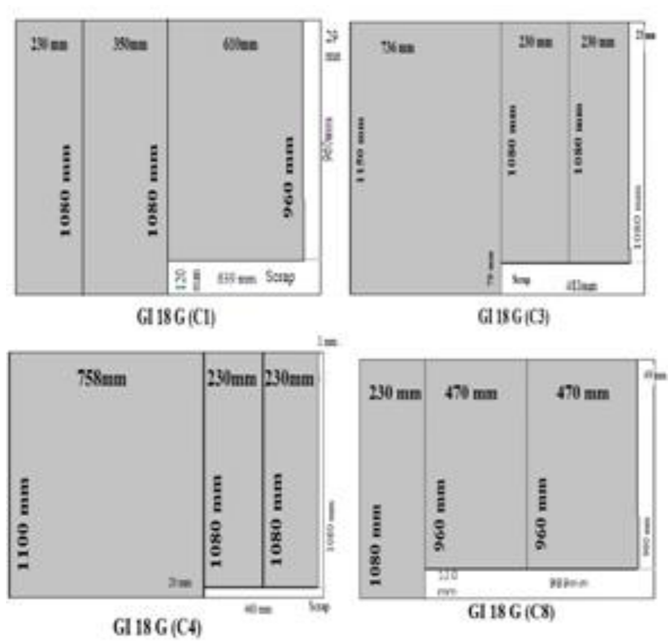

Fig 3- GI allocated for the respective cutting patterns.

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**

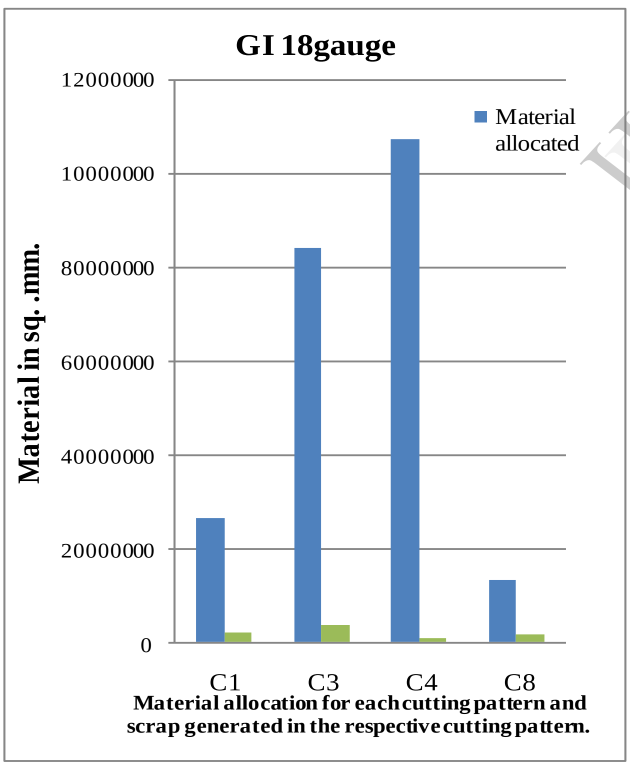

Fig 4- Scrap generated for the allocated material in respective cutting patterns.

The similar procedure is followed for the other 4 materials to achieve reduction in scrap levels.

4. RESULT

The incorporation of LPP model in the cutting process helped in optimizing the material consumption and in turn we were able to reduce scrap levels of the materials. The present scrap levels are much lower than the previous scrap that was generated. 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
Al 10G	10535204	2590432	6.2	79.33
Al 14G	18812865	6359550	10.14	66.2
Al 18G	90064010	26221510	8.7	79

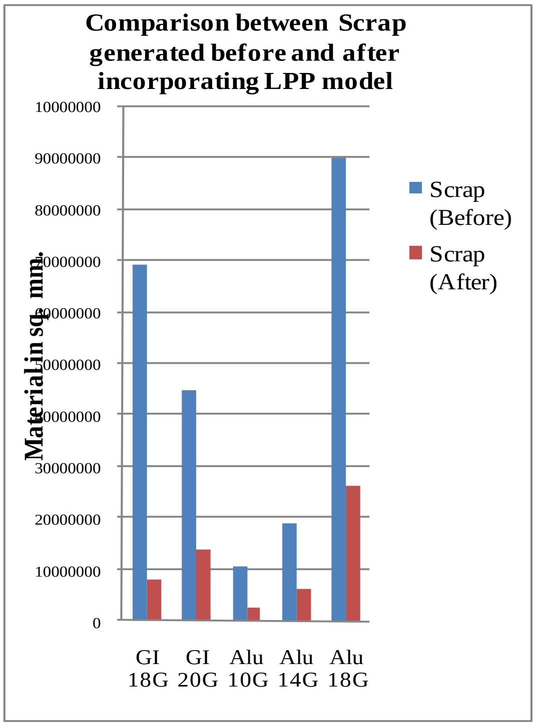

Fig 5 - Scrap level comparison before and after incorporating LP model

5. 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 a specific period of six months before commencement of our work was at around 30%, which was reduced to 7.542% after using LPP model gaining almost use of around 22% of materials which was being scrapped. The problem identified was well implemented which has saved the company a lot of material which is represented in fig.5. This has also further improved on the profits of the company.

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 material wastages. One dimensional cutting method can be used for the purpose as the materials need to be cut only on length wise

The same methodology can be implemented to the other two models as well. The project can also be extended and applied in the structure process and also there is scope for looking into two and three dimensions as well.

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