An Investigation into Productivity Improvement Techniques for Extruded Rubber Products in the Rubber Manufacturing Industry (As a Case study in Sri Lankan Rubber Manufacturing Organization)

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ABSTRACT

The present study was carried out in Sri Lankan Rubber Manufacturing Organization and they mainly produce Extruded and Moulded rubber products. Generally the rubber production has its inherent difficulties. Among its products the extruded rubber products have more difficulties than moulded rubber products. Therefore, this study was mainly focused to analyze the solutions to improve the productivity through the wastage minimization in the extruded rubber products. During the study, an attempt has been made to identify how productivity is changing in the extruded rubber products with the wastage occurred therein. Therefore the study design has been established by covering two major parts. In the first part, it helped to identify the problems of lower productivity with special reference to the wastage. Then in the next part an experiment was carried out to identify methods of recycling the wastage. Finally, the alternative solutions were identified. Then, by carrying out feasibility studies in financial, environmental and technical aspects of those solutions, a best alternative was recognized and suggested to the organization. However the findings of the present study can be applied into the moulded rubber products as well. Thereby, it is leading to future research opportunities in this industry. Further, since Productivity Standard is very much essential for any industry, it is necessary to prepare such a standard through a collaborative work with Rubber Research Institute and Rubber Manufacturing Companies in Sri Lanka for this industry as well.

KEYWORDS: **Extruded Rubber Products, Productivity, Rubber Manufacturing Industry, Wastage Percentage**

INTRODUCTION

Rubber Industry is major industry in Sri Lanka, which has a significant contribution to national economy. Also Rubber Industry generates many employment opportunities to rural population which requiring a lower level of education. The technology used by most of raw rubber manufacturers is very old. Therefore, it results in low productivity and high environmental damage by which people could not be tolerated any longer.

Therefore, Wastage minimization is important because it helps to protect the environment and it makes good business sense. The wastage minimization saves money through avoided disposal costs, create safer working conditions for employees, and protect human health and the environment.

Generally the rubber industry has unavoidable wastage. Therefore, it has to keep standard for wastage percentage. But many organizations keep standards for their rubber products in individually. Currently, there is a gap between the target wastage percentage and the actual wastage percentage and it is caused to lower productivity.

The organization in which the present study was carried out kept their standards for the wastage percentage of 6.0% for the rubber bands during last eight orders of their production in May – July 2008. But their actual wastage percentage showed higher value than their standard.

The following graph shows the actual wastage percentages occurred during the last eight orders of the set period.

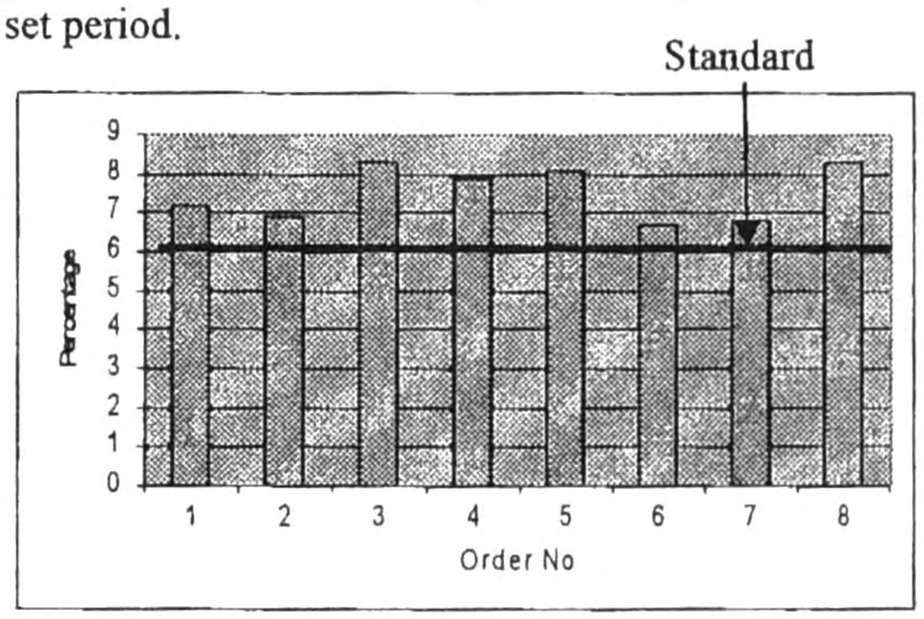

Figure 1: Wastage Percentages

According to above Figure 1, since the actual wastage percentages are higher than the standards, the organization should have to reduce these wastage percentages to improve their productivity.

In many cases, the rubber recycling applies to wastage rubber and the damaged rubber products. The most common uses of such used rubber products are burning for energy recovery and grinding and mixing into asphalt for roads constructions. The present study was done for identifying root causes for low productivity in the extruded rubber

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products. Therefore, the main objective of the present study was to investigate the root causes for lower productivity in extruded rubber products and the barriers to improve the productivity. To achieve the above objective, a hypothesis was established and it was as follows,

H_0 :There is no correlation between the productivity and the wastage

H_1 : There is a correlation between the productivity and the wastage

LITERATURE REVIEW

Productivity

Productivity is a ratio to measure how well an organization (or individual, industry, country) converts input resources (labor, materials, machines etc.) into goods and services. This is usually expressed in ratios of inputs to outputs. Productivity in economics is the ratio of what is produced to what is required to produce. Such ratios are as follows;

Material Productivity = Output / Input material
Labor Productivity = Output / Number of labor hours
Machine Productivity = Output / Number of machine hours

(David 1987)

There are six grounds to improve the productivity ratio of an organization and they are;

- Improve basic process by research and development (Long term)
- Improve and provide new plant, equipment, and machinery (long term)
- Simplify product and reduce variety (medium term)
- Improve existing methods and procedures (short term)
- Improve the planning of work and the use of manpower (short term)
- Increase the overall effectiveness of employees (short term)

Processing of Rubber

The processes involved in the conversion of raw rubbers to finished products are as follows.

1. Mastication process
2. Mixing process
3. Shaping/Forming process
4. Moulding and curing processes

METHODOLOGY

As raw natural rubber is extremely tough and elastic, it must be rendered into a soft and pliable condition before adding with compounding ingredients and shaping into useful articles. To achieve this breakdown, the rubber is subjected to severe mechanical treatment on a two roll mill. This treatment which is resulting in gradual plasticization is termed as *mastication*. After the mastication process, the compounds were passed into the forming process which was carried out by the strainer and extruder machines. Finally, extruded products were vulcanized in the auto clave machine (Subramaniam 2002.)

Physical Testing for Rubber Products

Physical tests on rubber are generally carried out to determine its suitability for a particular application, for quality control purposes or for research and development. These tests can be classified into two groups. Namely, tests on raw rubbers unvulcanized rubber mixes and vulcanized rubber mixes. Then the determination of plasticity test and the specific gravity test are done into the unvulcanized rubber mixes and hardness and tensile tests are done in to the vulcanized rubber mixes (Subramaniam 2002.)

Common Wastage Factors

According to the Fred Barlow (1998) there are common wastage factors in the rubber products manufacturing process. They are;

1. Rubber and chemical wastage in compounding process.
2. Energy wastages in machineries such as mill machines, conveyors, extruder and strainer machine.
3. Steam wastage by leaking steam in pipe lines.

Summary of Related Research Findings

A research which was carried out by Champa Wellappili, Karnika de Silva and Indra Denawaka in 2006 to investigate the Rubber and Plastics Recycling Technologies in Sri Lanka and objective of this research was to obtain natural rubber blends of improved properties with buffing dust, at a minimum cost in value added applications. Then they checked the feasibility of usage of buffing dust as rubber compounds and tried to identify good reinforcing filler which will increase the physical properties of rubber. A Rheometer was used to get relevant Rheographs and have checked compound behavior pattern of them. In this research 13 compounds were extracted from the production process and tested by changing quantity of buffing dust percentage in relevant batches. The Fatty Acid and De-link were used as Reinforcing Fillers from which can increase physical properties of rubber compound. According to the findings of their treated batch showed good physical roperties in rubber compounds that delink treated batch.

The present study was carried out by using primary and secondary data. Then those data were tested quantitatively. As a result following statistical tests were used. They are;

Simple Correlation Coefficient Test

The Karl Pearson Correlation Coefficient was used to measure correlation coefficient between the variables of productivity (X) and wastage (Y). The following formula was used to measure the simple correlation coefficient between the X and Y.

$$\text{Correlation} = \frac{\Sigma XY - n\,X\,Y}{\sqrt{[(\Sigma X^2 - nX^2)(\Sigma Y^2 - nY^2)]}}$$

Hypothesis Testing

To check significance of correlation coefficient should have to develop Hypothesis as null and alternative hypothesis.

In here, have to test;

$Ho : \rho = 0$

$H1 : \rho \neq 0$

ρ is the population correlation coefficient and n is the number of observations considered to get r value. And have to use t table. Test statistic as follows;

$$r \sqrt{\frac{(n-2)}{(1-r^2)}} \sim t_{n-2}$$

If calculated test statistic is greater than tabulated value, then Ho is rejected. Using the sample r value if n is large (≥ 30) its sampling distribution is $r \sim N(1, 1/n)$ and this enables us to develop the following rule of thumb.

Rule of Thumb for significance

Accept $Ho : \rho = 0$ if $r <= 2/\sqrt{n}$
Reject $Ho : \rho = 0$ if $r > 2/\sqrt{n}$
According to the hypothesis, can conclude, ρ is zero or not.
If $r > 2/\sqrt{n}$, then, r is significant.

DATA PRESENTATION & ANALYSIS

Data Presentation

Data were collected in relevant to wastage and productivity. By considering labor hours, machine hours, input, output data, productivity were calculated as labor, machine and material. The labor and machine hours were considered in daily and material data were calculated in order wise it was difficult to get those in daily. Production floor was divided into three sections. Namely production, cutting and packing. The following Table 1 shows the productivity data on these three sections for eight production orders during August – November.

Where LP – Labour Productivity, MP – Material Productivity, Pro – Production, C – Cutting P – Packing

The following Table 2 shows the total wastage occurred for these eight orders during the same period.

Order No	Machine Productivity (kg/hr)			L P (Kg/hr)	M P
	Pro	C	P		
1	180.504	181.539	174.961	2.979	0.9144
2	161.872	164.728	158.21	3.149	0.9097
3	209.991	204.672	192.616	3.229	0.9087
4	220.108	212.892	209.791	3.367	0.9113
5	201.313	203.874	222.652	3.380	0.8943
6	241.588	191.110	201.863	3.212	0.9243
7	265.93	216.159	230.619	3.469	0.9361
8	223.942	206.076	206.172	3.033	0.9290

Table 1: Productivity Data

Order No	Total wastage (kg)
1	1478.275
2	1818.500
3	1663.000
4	1849.629
5	2014.000
6	1874.500
7	1527.000
8	1853.000

Table 2: Wastage Data

Data Analysis

The correlation between productivity and wastage was calculated and it is shown in Table 3.

Productivity		Wastage
Labor Productivity		-0.325
Machine Productivity	Production	-0.243
	Cutter	-0.232
	Packing	-0.190
Material Productivity		-0.546

Table 3: Correlation Values

To check the significance of these correlation values, 78 numbers of observations were used and the test statistic values of relevant correlation values are given in following Table 4.

Factors		Correlation Value	Test Statistic	Tabulated value
Labor Productivity		-0.325	2.995	1.671
Machine Productivity	Production	-0.243	2.184	1.671
	Cutting	-0.232	2.079	1.671
	Packing	-0.190	1.687	1.671

Table : Correlation and Test Statistic Values

According to the above Table 4, the calculated test statistic is greater than tabulated value. Therefore Null Hypothesis (H_0) is rejected. That means, there is a correlation between wastage and productivity in a population. Therefore, this enables to develop Rule of Thumb for significance.

The following Table 5 shows the values of correlation and test statistic values for rule of thumb experiment in order to which is used to check the significance of the correlation coefficient.

Factors		Correlation Value	Observations (n)	Test Statistic value ($2/\sqrt{n}$)
Labor Productivity		-0.325	78	0.226
Machine Productivity	Production	-0.243	78	0.226
	Cutting	-0.232	78	0.226
	Packing	-0.190	78	0.226

Table 5: Correlation and test statistic values for Rule of Thumb

According to the given in above Table 5, the modules of correlation values are greater than test statistic values. Therefore, Null Hypothesis (Ho) is rejected. That means there is a significant correlation between productivity and wastage data.

The line of best fit (trend line) was drawn in order to study the correlation between the variables of productivity and wastage and equation for the correlation between the variables were determined by them.

The following Table 6 shows the least squared regression equation established for productivity categories of labor, machine & material and wastage.

X axis label		Y axis label	Least Squared equation
Labor Productivity		Wastage	Y = 206 – 8.54 X
Machine Productivity	Production	Wastage	Y = 1870 – 0.52 X
	Cutting	Wastage	Y = 2223 – 2.54 X
	Packing	Wastage	Y = 2360 – 3.19 X
Material Productivity		Wastage	Y = 7467 – 6231 X

Table 6: Least Squared Equations

RESULTS AND DISCUSSION

According to the correlation values, there is inverse relationship between productivity and wastage. Therefore this implies that to increase the productivity it has to minimize the wastage.

According to the Table 3, when considering correlation values between productivity and wastage, the relationships are lower in labor and machine productivity with wastage. However, there is a high impact of wastage on material productivity. Therefore, the organization should have to plays a high emphasis on wastage minimizing techiniques for material. By considering above findings, the following solutions were identified as wastage minimizing techniques on material.

Solution 1: Creation of byproducts through Recycling Wastage and Damaged Products

According to this solution, the wastage of extruder rubber products can be recycled by using the formulas that were identified in the research which was carried out by Champa Wellappili, Karnika de Silva and Indra Denawaka (2006)

Accordingly, three batches were identified by using general rubber compounding formula and reinforcing fillers formulas. The general rubber compounding formula shows in the Table 7 below amd one batch was prepared based on that formula

Ingredient	Parts by weight
NR	100
Zinc oxide	5
Stearic acid	3.5
Carbon Black (N330)	45
Process oil	5
I.P.P.D.*	1

Table 7: General Rubber Compounding formula

Then the second batch was treated from fatty acid and it can be shown in Table 8. The third batch was treated from delink and it can be shown in Table 9 below.

Ingredient	Parts by weight
Wasted Rubber band	100
FA	10

Table 8: Fatty Acid treated Batch

Ingredient	Parts by weight
Rubber band wastage	100
De-link	6
Premasticated raw	6
Processing aid	2

Table 9: De-link Treated Batch

By using above three batches, 13 compounds were prepared. The first five compounds were added with wasted rubber without treating fatty acid and delink. However, among these five compounds, the first compound was not added with wasted rubber. These data can be represented in below Table 10.

Compound No.	1	2	3	4	5
RMB	159.5	143.1	126.4	110.6	79.0
Rubber wastage	-	10	20	30	50
Sulphur	2.5	2.25	2.0	1.75	1.25
Santocure	0.8	0.72	0.64	0.56	0.4

Table 10: Untreated Compounds with wasted rubber

A Rheometer was used to obtain rheographs and to check behavioral pattern of these compounds and it can be shown in Figure 2 and 3.

Normal Rubber Compound Rheograph shows in Figure 1.

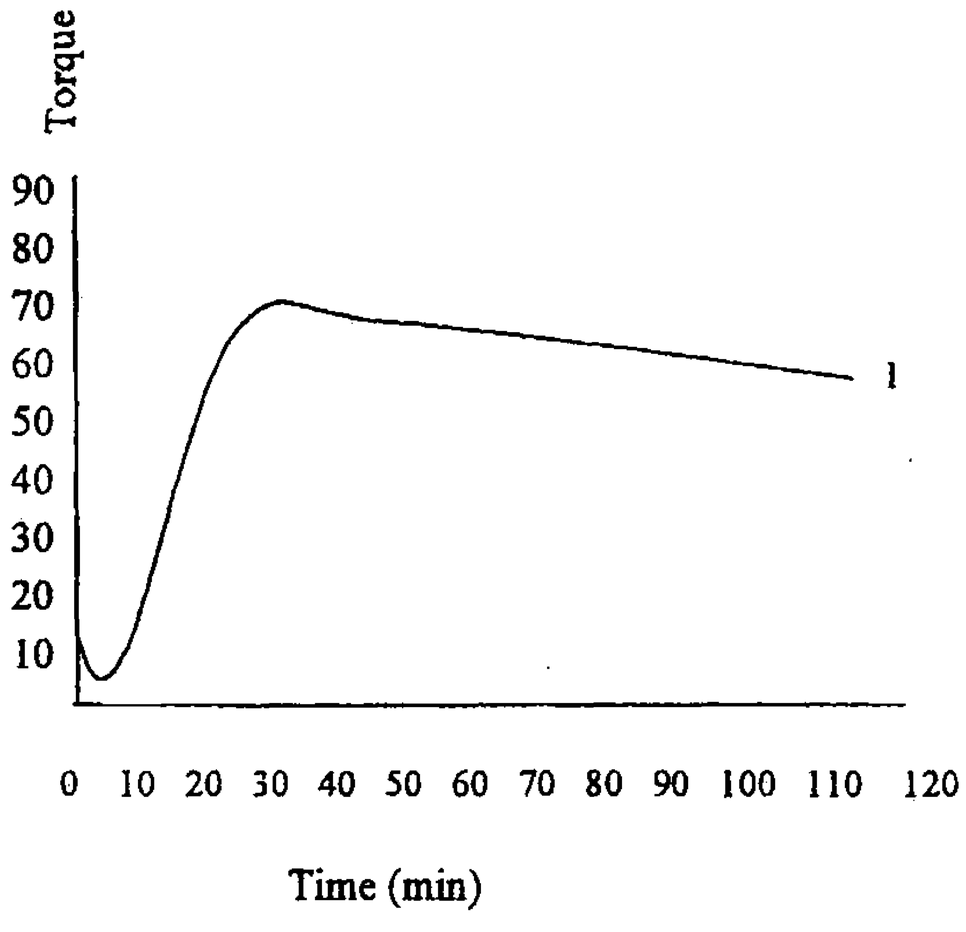

Figure 2 - Behavioral pattern of Compound 1

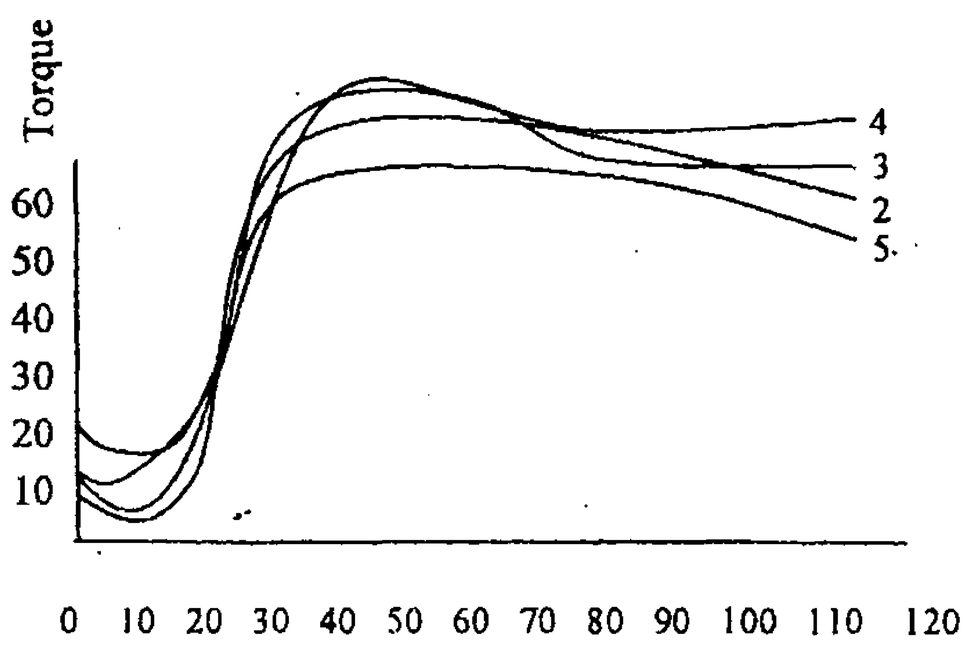

Figure 3 – Behavioral pattern of Compound 2 to 5

According to above Figure 2 and 3, rheographs of all five compounds show the same behavior pattern. Therefore, it can be concluded that the wasted rubber can be used in the rubber compounding process.

Table 11: Fatty Acid Treated Rubber Wastage Batch

Compound No	6	7	8	9
RMB	143.1	126.4	110.4	79.0
FATMB	11	22	33	55
Sulphur	2.25	2.0	1.75	1.25
Santocure MOR	0.72	0.64	0.56	0.4

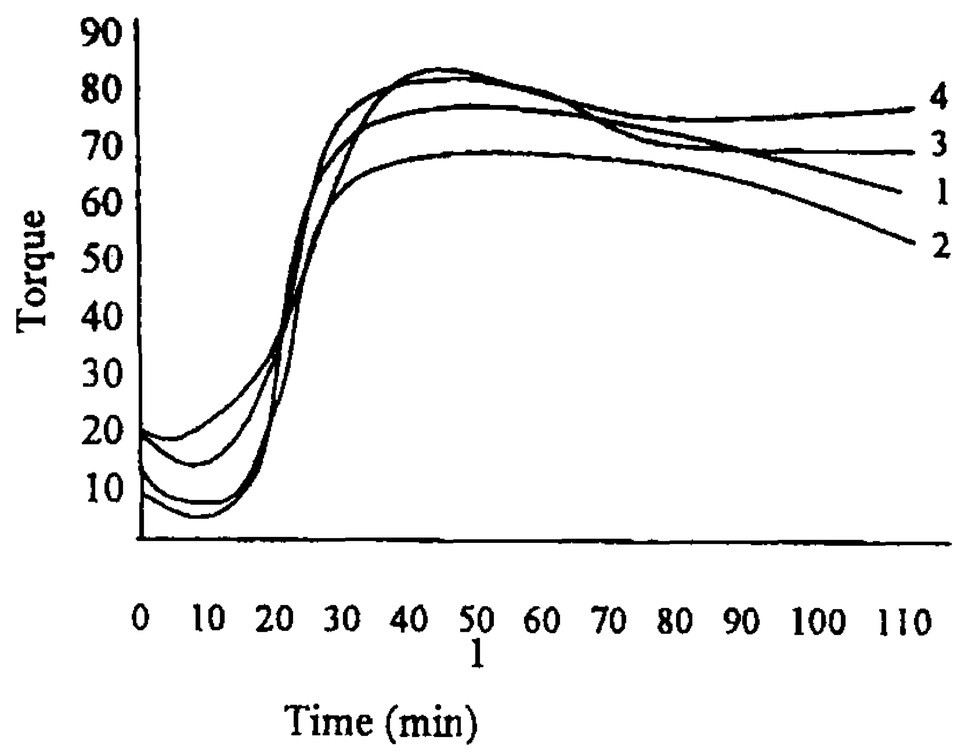

Figure 4 – Behavioral pattern of Compound 6 to 9

Sample	10	11	12	13
RMB	143.1	126.4	110.4	79.0
DTMB	11.4	22.8	34.2	57
Sulphur	2.25	2.0	1.75	1.25
Santocure	0.72	0.64	0.56	0.4

Table 12:De-link Treated Rubber Wastage Batch

Following Figure 4 shows Rheohraphs of above 4 samples

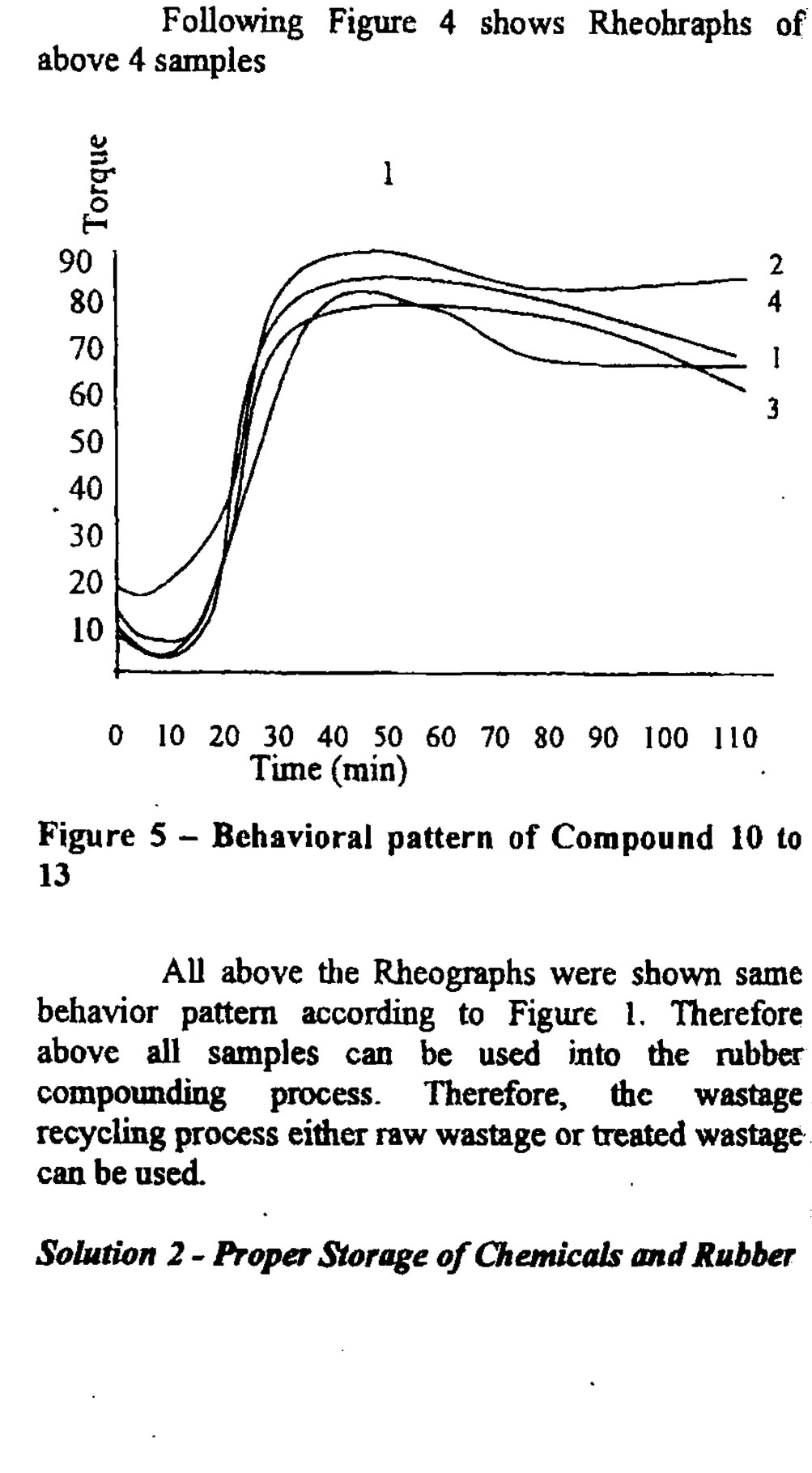

Figure 5 – Behavioral pattern of Compound 10 to 13

All above the Rheographs were shown same behavior pattern according to Figure 1. Therefore above all samples can be used into the rubber compounding process. Therefore, the wastage recycling process either raw wastage or treated wastage can be used.

Solution 2 - Proper Storage of Chemicals and Rubber

By following below mentioned procedure, an organization can reduce the wastage that is occurring from chemicals.

Description of Procedure

1. All the chemicals in the stores must be labeled according to the category.
2. Inventory in-charge must have a list of storing condition of all the chemicals.
3. He must advise workers to arrange the stores accordingly and should keep chemicals in properly sealed containers.
4. Once a week Inventory In-Charge must check up whether the storing is proper and should record it in a record sheet.
5. Further if he found that the storing is not proper then he must take an immediate action to correct it.
6. As soon as the spillage of chemical occurs the worker, should have to inform it to the supervisor and the supervisor should identify the type of that chemical.
7. According to the type of the chemical an appropriate disposal method should be carried out by a worker under the supervision of the supervisor.

   - Spillage should be handled using gloves and boots etc.
   - Based on the amount of spilling and the place, decision has to be made by the supervisor for reusing the chemicals.
   - If reusable collects into the correct bins otherwise collect it to the wastage chemical bin.

Solution 3 – Reuse wire meshes in the Strainer process

Natural Rubber contains various types of foreign matters such as bark, leaves and siliceous grit, those should have to be strained for certain applications by using the strainer machine. To strain those foreign matters, it can use a wire mesh. After using those wire meshes for the strainer process those are to be discarded. Tiny rubber particles and some foreign matters are attached to the mesh after the straining. If those are remove from wire meshes, then it can be able to use wire meshes again in the straining process. Following liquids can use to dissolve rubber particles.

- Methyl Ethyl Ketone (MEK)
- Benzene
- Petrol

Solution 4 - Reduce Length Differences in the Mover Bands

Most of the mover bands are rejected because of the length differences and rejected bands are not used. Therefore to minimize waste it can use following method.

- Get two metal pieces
- Put mover bands across the metal pieces
- Then keep those on the pan.

Solution 5 – Prepare Wastage Reconciliation Reports

While preparing wastage reconciliation reports, organization can get clear picture about wastage percentage at any time, can understand areas in which more wastages are ocurring and can get an idea to lower the wastage percentage in future product orders.

Solution 6 - Preparing Procedures for Processes

Some processes are identified in monitoring fuel consumption of the boiler house and monitoring of steam usage.

Monitoring Fuel consumption of the Boiler House

This procedure enables to reduce fuel wastage of the boiler house.

1. Fuel consumption, starting time and Stopping time of the boiler should record in the Boiler Record Sheet daily by the Boiler Operator, for each boiler
2. Boiler In-charge must check the above records daily.
3. If he would able to find out that the fuel consumption is high he must find out the reason and should inform it to the Maintenance Engineer.
4. Maintenance Engineer must take immediate action for that failure and should correct it, and record it

Monitoring of Steam Usage

This procedure enables to minimize the steam wastage

1. At the beginning and end of each shift the boiler operator should record the steam flow meter reading in the steam consumption record sheet.
2. At the beginning and end of the shift each machine operator must write the steam flow meter of the reading of their machine in the daily production sheet.
3. At the end of each shift each machine operator must find out the steam consumption of their machines.
4. The appointed leader of the shift must find total steam consumption of their shift and must hand over that figure to the boiler in charge.
5. Boiler in charge must check the both values and if there is any wastage he must find out the reason and should inform it the respective person and he must take action immediately to correct it.

Feasibility Study of the solutions

Technical Feasibility

The above mentioned solutions required machineries such as mill machines which should have particular size, electronic scales, etc. In this feasibility it is checked that those machines can be used in the factory and workers can adapt to the new machines.

Financial Feasibility

Each solution required some amount of money for raw materials, chemicals, new machineries and payments to workers. However studied organization has already process most of these requirements.

Environmental Feasibility

Some raw materials and chemicals which are required implementing these solutions are occurring environment pollution and air emissions.

The following Table 13 summarizes the feasibilities for each solution.

	Solution	Technical	Financial	Environmental
1	*Recycling waste and damaged products*	√	?	√
2	*Proper storage of chemicals and rubber*	√	√	√
3	*Reuse wire meshes in the Strainer process*	√	?	√
4	*Reduce length differences in the mover bands*	√	√	√
5	*Preparing Wastage Reconciliation Reports*	√	√	√
6	*Preparing procedures for processes*	√	√	√

Table 13: Feasibility Study of solutions

According to Table 13 the solutions 2,4,5 and 6 are feasible for the organization and the solution 4, 5 and 6 were already implemented in the organization. Therefore solution 2 can be implemented in to the organization. But the organization should have to consider the implementation of solution 1 and 3 in future.

CONCLUSIONS

The main objective of the study was to investigate the root causes for lower productivity in extruded rubber products and barriers to improve the productivity. By carrying out this study it was founded that the productivity was declined due to the occurrences of high percentages of wastage.

Therefore, the productivity can be improved, if the organization can control the wastage. Due to the lack of consideration to the wastage percentage of the product at present productivity has reduced to certain extend. Therefore, by paying more attention to reducing the wastage percentage than increasing the production, management can enhance the productivity. Otherwise, although the production plant is producing a large amount of quantity with a high percentage of wastage, the organization might not be increased its profitability.

By using the findings of the present study analysis the organization can adopt the suggested solution one of recycling the wastage. However, which was already tested in laboratory and has not implemented into the factory. Therefore, the organization has the potential of implementing this solution with good supervision and application of skilled workers to the relevant operations. The studied organization has already implemented 5S technique as well. But they have to think about a step ahead such as Kaizen which is the consideration of continuous improvement in their operations.

Further, the organization has already established a standard for the wastage for their own there is no common standard for this industry because the occurrence of wastage in all rubber production is a inherent problem. Therefore, such a standard has to be established as a collaborative work with all rubber manufacturing organizations and the governing body of industry, rubber research institute of Sri Lanka.

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