Failure Analysis of Brake System in Light Commercial Vehicles using SQC Tools

Abstract—Brake system is one of the most important sub-systems in an automobile. The safe operation of a vehicle is very much determined by brakes. Disc brake and Drum brake are the two different types of brakes used in automobiles. Drum brakes are one of the very commonly used rear brake in today’s automobiles. There are varieties of drum brakes available and each has its own advantages and disadvantages. The current system brakes running in the field has the complaint of frequent brake adjustment which leads to higher vehicle down time. Further, the other problems in using this manual adjuster hydraulic brakes are wheel cylinder kit leak, wheel cylinder jam etc. Due to lining wear of the brakes during usage, often the pedal bottoms up while driving. The driver has to adjust all the wheel cylinders and make the pedal to come up. The boots may get damaged during adjustment, and it leads to dust and other impurities entering into the system and consequently leads to leak in system. Also as the brakes are operating at higher temperature (especially in hilly regions), there is a possibility for the seals and boot to be damaged and may result in leak. Due to these leaks, the system failure can occur and it may lead to major fatal accidents.

Even though these brakes are well established, there is continuous research by brake manufacturers to improve the performance and effectiveness of drum brakes. Questionnaire was prepared for collecting data from 120 customers. Survey method was used to collect the data. The data was analyzed by applying statistical tools and Statistical Quality Control tools.

Keywords—Disc brake, Drum brake, Hydraulic brake, lining wear, automobile

I. INTRODUCTION

Brakes function because of a special hydraulic, or liquid-based, system. Brake fluid moves from the pedal through the brake-line system. Because liquids can't be compressed, they move. It is this movement that pushes against the mechanism that stops the vehicle. So when this fluid runs low, brake problems will occur. If the brake system is failing, the vehicle may pull to one side. This situation can cause accidents that range from fender-benders to serious collisions. Early automotive brake systems, after the era of hand levers of course, used a drum design at all four wheels. They were called drum brakes because the components were housed in a round drum that rotated along with the wheel. Inside was a set of shoes that, when the brake pedal was pressed, would force the shoes against the drum and slow the wheel. Fluid was used to transfer the movement of the brake pedal into the movement of the brake shoes, while the shoes themselves were made of a heat-resistant friction material similar to that used on clutch plates. The National Transport Safety Board (NTSB) study found that many motor carriers and drivers of commercial vehicles fail to understand the need for well-maintained brake systems. This lack of understanding is easy to comprehend - poorly-adjusted brake systems give little driver "feedback" and in routine operations may perform adequately - but in emergency situations, with high brake temperatures and hard applications, adequate braking may not be available [1]. Brake systems require routine checks of fluid levels and pad condition, leading to periodic brake pad replacement.[2]. To enhance the braking safety and improving the braking performance of the tractor/trailer vehicle a slip-rate-based braking force distribution algorithm is proposed for the electronic braking system of tractor/trailer combination vehicle. The algorithm controls the slip-rates of the tractor's rear wheels and the semi-trailer's wheels changing with the slip-rate of tractor's front wheels, making tractor's front wheels lock up ahead of the tractor's rear wheels and the semi-trailer's wheels. The algorithm protects the combination vehicle from jackknifing and swing, guaranteeing that the combination vehicle has better driving stability and steering capability. The simulation results shows that the algorithm can control the wheels' slip-rate changing in the settled range and shorten the braking time, thus improves braking performance of tractor/trailer combination vehicle. [3] A new hydraulic booster concept with internal stability and steering capability. The simulation results shows that the algorithm can control the wheels' slip-rate changing in the settled range and shorten the braking time, thus improves braking performance of tractor/trailer combination vehicle.
This is also the reason why the ABS booster requires the same number of modulators and control channels independent of the brake split. The control philosophy with MIR (modified individual control) at the front axle and individual control at the rear axle is recommended for all drive train concepts. Even with locked differentials the ABS-control remains active. The special booster concept permits easily a system extension for the purposes of drive slip control [4]. Two commercially available alternatives that produce higher output are Air Disc brakes and larger sized S-Cam brakes. Using one type, or a combination of these brakes (discs and drums on different axles) warrants a comparative study. The goal is to improve the effectiveness of the brake system, while maintaining or improving upon vehicle stability during braking. Richard L.Hoover et al reported the effect of the semitrailer brake on dry surface stopping performance and stability of combination tractor-semitrailer rigs. The data analyses include the effect of semitrailer and brake type on the rankings of full combination braking tests [5].

In this study the researcher has made an attempt to analyze the performance of existing brake system used in light commercial vehicles. The current system brakes running in the field has the complaint of frequent brake adjustment which leads to higher vehicle down time. Further the other problems in using this manual adjuster hydraulic brakes are wheel cylinder kit leak, wheel cylinder jam etc. 

Hence to identify the various problems in the manual adjuster hydraulic brake system the researcher wants to collect the feed backs from the clients who manufacture the commercial vehicles and from the end users of the vehicles. In this study the researcher used descriptive and analytical type of research. The data from end users can be collected through the structured questionnaires given to end users or from the customers to whom the brakes are being supplied. The researcher can use both the primary data and secondary data for the analysis. The main scope of the study is to find out the issues in the manual adjuster brakes.

1.1 PROBLEM IDENTIFIED
The current system brake of light commercial vehicle running in the field has the complaint of frequent brake adjustment which leads to higher vehicle down time. Further the other problems in using this manual adjuster hydraulic brakes are wheel cylinder kit leak, wheel cylinder jam etc. 

Due to lining wear of the brakes during usage, often the pedal bottoms up, while driving. The driver has to adjust all the wheel cylinders and make the pedal to come up. The boots may get damaged during adjustment, and it leads to dust and other impurities entering into the system and consequently leads to leak in system. Also as the brakes are operating at higher temperature especially in hilly regions, there is a possibility for the seals and boot to be damaged and may result in leak. Due to these leaks, the system failure can occur and it may lead to major fatal accidents.

I. Identify the possible areas of improvement and suggesting improvement methods / new concepts to satisfy the customer needs keep the competition at bay and improve the business.
II. Help in finding out the issues in the manual adjuster brakes and suggest a possible solution to overcome the same.
III. By doing so, not only we can solve the problems in the existing products, we can also bring about satisfaction to customers, eventually leading to a platform for customer retention, attracting new customers and increasing the profit margin of the company.
IV. Based on the study, researcher can suggest suitable solution / alternatives to reduce / eliminate the cause of issues.

2.0 OBJECTIVES & SCOPE OF THE STUDY

2.1 Primary objective
The primary objective is to identify and analyze the risks in the brake systems for light commercial vehicles.

2.2 Secondary objective
a) The secondary objective of the study is to find out the root cause for the problems in the current manual adjuster brake systems.
b) To find out the impact of the problems.
3.0 RESEARCH METHODOLOGY

3.1 Type of Research design
Research design is the basic framework which provides guidelines for whole research methodology. The researcher has used descriptive type research. Descriptive research includes surveys and fact-finding enquiries of different kinds.

3.2 Sources of data
Both primary and secondary data are to be collected. Primary data is collected directly from the field by distributing standard questionnaire for understanding the customer feedback about the current brake system. Secondary data was collected from previous literature.

3.3 Sampling Design
The procedure of selecting people for taking part in answering the questionnaire is based on simple random sampling method. The respondents for the study are the end users of light commercial vehicles. In case of end users the study is restricted to Ernakulum and Kottayam district in Kerala.

3.4 Sample Size
Total of 600 Light commercial vehicle owners from two districts were approached by the researcher for the survey. 120 Respondents were selected from the total 600 vehicles and fixed as the sample size for the research work conducted.

3.5 Tools for Data Collection
Questionnaire is used for collecting the data. This questionnaire method is also known as survey method. The questions are of form open ended and close ended.

3.6 Tools for Analysis
Different type of analysis for studying the hypothesis of this research has been used as following:
- Percentage Analysis
- Cause and effect diagram
- Weighted average method
- Chi-square Test
- Pareto chart
- QFD process

4. DATA ANALYSIS AND INTERPRETATION

4.1 Percentage Analysis

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Response</th>
<th>No of respondents</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 4.1.1. Response of customer towards problem in brakes

INTERPATION: From the above chart and table, it was inferred that majority (75%) of the customers faced problems in the brakes followed by 25% responded that they do not face any problems in the brakes.

4.2 Opinion of customer towards quality of current brake system

<table>
<thead>
<tr>
<th>s.no</th>
<th>Opinion</th>
<th>No of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>90</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 4.1.2. Opinion of customer towards quality of current brake system

INTERPATION: From the above chart and table, it was inferred that majority (75%) of the customers were not satisfied with the quality of brake systems Only 25% of the customers are satisfied with the Quality of brake systems.
**Table 4.1.3 Opinion of customer towards time taken for wheel cylinder adjustment**

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Opinion</th>
<th>No of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 min</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>15-30 min</td>
<td>70</td>
<td>58.33</td>
</tr>
<tr>
<td>3</td>
<td>30-45 min</td>
<td>10</td>
<td>8.33</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 45 min</td>
<td>10</td>
<td>8.33</td>
</tr>
</tbody>
</table>

**Table 4.1.4 Response of customers towards brake application (approx) per km**

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Response</th>
<th>No of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3-5 stops</td>
<td>10</td>
<td>8.33</td>
</tr>
<tr>
<td>2</td>
<td>5-8 stops</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>8-10 stops</td>
<td>40</td>
<td>33.33</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 10 stops</td>
<td>10</td>
<td>8.33</td>
</tr>
</tbody>
</table>

**Table 4.1.5 Response of customers about the vehicle plying roads**

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Response</th>
<th>No of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Highways</td>
<td>20</td>
<td>16.7</td>
</tr>
<tr>
<td>2</td>
<td>city roads</td>
<td>20</td>
<td>16.7</td>
</tr>
<tr>
<td>3</td>
<td>hilly areas</td>
<td>15</td>
<td>12.5</td>
</tr>
<tr>
<td>4</td>
<td>all type of road</td>
<td>65</td>
<td>54.2</td>
</tr>
</tbody>
</table>

**Figure 4.3 Opinion of customer towards time taken for wheel cylinder adjustment**

**INTERPATIONATION:** From the above chart and table most (58%) of the customers responded that 15-30 min time would be taken for wheel cylinder adjustment followed by 25% of customers responded with 15min, 8% of customers with 30-45min and only 8% of customers responded that it took less than 45 minutes for wheel cylinder adjustment.

**Figure 4.4 Response of customers towards brake application (approx) per km**

**INTERPATIONATION:** From the above chart and table most (50%) of the customers responded that 5-8 stops per km followed by 8% of customers with 3-5 stops, 8% of customers with 8-10 stops and 8% of customers with >10 stops.

**Figure 4.5 Response of customer towards the wheel cylinder adjustment interval**

**INTERPATIONATION:** From the above chart and table most (54%) of the customers responded that they used all type of road followed by 17% of highways, 17% of city roads and 12% of hilly areas.
INTERPATION: From the above chart and table most (50%) of the customers responded that they frequently adjusted the wheel cylinder once in 400-500 km

4.2 CAUSE AND EFFECT DIAGRAM

![Diagram showing causes of brake failure]

Figure 4.2.1 CAUSES OF BRAKE FAILURE

INFERENCE: From the cause and effect diagram we inferred the root causes for the brake failure and the effects for the same.

4.3 PARETO CHART

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Nature of Failure</th>
<th>Respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brake Failure</td>
<td>78</td>
<td>65</td>
</tr>
<tr>
<td>2</td>
<td>Clutch Failure</td>
<td>26</td>
<td>21.67</td>
</tr>
<tr>
<td>3</td>
<td>Accelerator Failure</td>
<td>10</td>
<td>8.33</td>
</tr>
<tr>
<td>4</td>
<td>Engine Problem</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 4.3.1 Response of customers towards the brake failure in the vehicle

Figure 4.3.1 Response of customers towards the brake failure in the vehicle

INFERENCE: From the Pareto analysis it was inferred that the major problems in the vehicle was brake failure and clutch failure (It accounts together 87%). If more effective measure to be taken to eliminate this then the majority of problems will be solved.
4.4 QFD Chart:

**Inference:** From this QFD chart we inferred that the customer requirements, and enables the design phase to concentrate on customer requirements thereby spending less time on redesign and modification. Higher the absolute and relative ratings identify the areas where the engineering efforts need to be concentrated.

5.0 FINDINGS FROM VARIOUS SQC TECHNIQUES

- From the study it was identified that most of the respondents faced problem in the brake system used in the light commercial vehicles.
- Most of the customers were not satisfied with the quality and performance of the current brake system in the light commercial vehicles.
- The study reveals various problems in light commercial vehicle brake system and some of the main problems are wheel cylinder adjustment pedal travel, seal failure and boot failure.
- From the study it was found that many customers find it very difficult to adjust the wheel cylinder due to no better accessibility. It takes more time for the customers to do the wheel cylinder adjustment.
- It was found that many customers faced the problem of pedal going down followed by seal failure and boot failure.
- The study reveals that many customers does not follow the maintenance schedule of the vehicle.

6.0 CONCLUSION

This study shows that the light commercial vehicle manufacturers should design and develop the new self-adjusted brake system which will deliver the following benefits to customers. The self-adjusted brake will deliver better quality and performance in the brake system of light commercial vehicles. This new system will satisfy the customer needs which will improve the customer satisfaction level higher.

7.0 REFERENCE

[1] Hank Seiff, “Heavy Truck Brake Adjustment-Problems and Solutions” ATA Foundation, Trucking Research Institute, USA, Journal of Truck safety, - Volume 1, April 1992; Page no 575

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