IDENTIFICATION AND STRENGTHENING OF ASSEMBLY LINE WEAK LINKS OF A REFURBISHING WORKSHOP USING ROAD TEST OBSERVATION DATA

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Abstract

Abstract: Quality of refurbished motor vehicle is an essential requirement for the users to get their values for invested money. High quality output is combined responsibilities of all the agencies involved in refurbishment process involving both internal and external agencies. Procurement of genuine spare parts is the major factor for controlling of external agencies. Major challenge to ensure high quality output lies in the fact of monitoring the internal agencies continuously. These involve good infrastructure, skilled manpower and more importantly functioning of small repair groups in the assembly line of the workshop. Thus strong assembly line consisting the repair group needs to function as a chain and contribute immensely to ensure quality output in a time bound and profitable manner. Any weak link in the chain would reduce the strength of the complete system which in turn affects the quality and hence needs to be identified for weeding out. In order to achieve high quality output improved functional capabilities of assembly line needs to be ensured by identification of weak links and addressing the problems. Frequencies of various defects noticed during road test of vehicle under refurbishment thus become very important performance indicator of repair groups. In this paper, a method to identify the weak links in the chain of assembly line have been brought out and remedial method suggested to strengthen it by using road test observation data. By implementation of remedial measures, considerable reduction of defect frequencies has been noticed during subsequent road test of vehicles resulting in better quality output.

Index Terms: *Heavy motor vehicle, Refurbishment, Route card, Quality Control, Road test observation data, Assembly Line, Sample size, Defect frequency.*

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1. INTRODUCTION

Refurbishing of heavy motor vehicles (HMV) is carried out by Workshops to induce a new lease of life and making it as good as new. The work involves complete stripping, washing/cleaning, replacement of assemblies and components on ‘must change’ and ‘could change’ basis. Overhaul process is executed as a parallel process where various sub-groups work as gangs. During final stage of re-assembly, operational synchronisation of various assemblies and sub-assemblies and final painting-marking work is done in serial manner as per sequence of operations.

After re-assembly, extensive static test is carried out for synchronisation and adjustment of various assemblies. It is followed by road tests where the defects/inadequacies are recorded. Frequencies of various defects can be observed by analysing this data. High defect frequencies are indicators of assembly line weak link and need be addressed to improve quality of overhaul.

In this paper, a method to identify the weak links in the chain of assembly line and to strengthen it by using road test observation data has been discussed, remedial measures suggested and implemented.

2. TESTING OF VEHICLES

After reassembly, the vehicle undergoes three stage testing. First two stages are carried out within the workshop premises and the third stage is carried out on the highway. During third stage, in addition to carry out the checks as done in first and second stages, high speed checks of the vehicle are also carried out, to ascertain maximum road speed, vehicle pulling power, steering wobbling, vibrations etc. Routes for all the tests are well designated and approved by competent authorities.

2.1. First Stage Road Test

First stage is conducted in two parts. First part of the test, also called static test is done after re-assembly of all components and assemblies to check functionalities in a synchronised manner. HMVs are generally pneumatically assisted hydraulically controlled; hence functional synchronisation of various assemblies and sub-assemblies is very important. This part of the test is basically a static test of the vehicle which is carried out by a team of inspectors deputed by the group. After satisfactory static test, road test is carried out by the same team. This is second part of first stage in which operation of major control systems like brake and steering are checked. The vehicle is returned to the group if any inadequacy, abnormality and defect are noticed during this test. On rectification of observation(s), the test cycle is repeated. On completion of first stage, the vehicle is sent to paint shop for painting and marking.

2.2. Second Stage Road Test

The vehicle is offered to the team of In-house Inspector (II) and the test is conducted by them in the presence of group representatives. This is similar to first stage test but conducted by independent II team. During this stage more stringent norms are imposed and performance parameters of both major and minor components are closely monitored. Like in the first stage, the vehicle is returned to the group if the test results are not satisfactory. On rectification of observation(s), the test cycle is repeated.

2.3. Third Stage Road Test

On successful completion of first and second stage of tests, II staff offers the vehicle to Quality Control (QC) team, who are deputed as independent team. Their role is to ensure high quality output of vehicles being refurbished by the workshop and issue the same as zero km state. The third stage of the test is carried out in three parts. In first part, records of previous inadequacies, abnormalities and defects noticed are perused and remedial measures carried out are checked. If the result of these checks is satisfactory, the vehicle qualifies for second part of the test. Here operation of major control systems like brake, steering, gear engagement, all wheel drive etc are checked through an internal road test. Defects noticed during this test are endorsed in the route card. A vehicle free from all these defects qualifies for third and final part of the test. A team is detailed to test the vehicle up to 40 km on the highway. The team comprises of user representative and qualified inspectors of QC, II and Repair Team. Before the test, the vehicle is checked for adequate diesel in the tank, availability of spare wheel and tool box etc. It is ensured that authorised pattern of marking and meeting of all RTO regulations are met. Driver must be in possession of all documents like vehicle move order indicating the details of the vehicle and its passengers (checked at the workshop gate), accident forms, identity card and Route Card (already opened during first part of third stage road test). On taking the vehicle to the highway, the velocity is gradually increased to its peak and checked for any inadequacy, abnormality or defect. All the observations are noted in the Route Card and the vehicle is returned to the workshop for defect rectification and re-offer for test. On rectification of all the defects, the vehicle is passed and declared as output.

3. ROAD TEST OBSERVATIONS DATA

Observations raised by the inspectors during third stage of road test are endorsed in the Route Card. The observations include inadequacies noticed during static test and abnormalities noticed during road test. The Route Card remains open till all observations are settled. Closure of Route Card indicates fitness of the overhauled vehicle in all respect and readiness to declare it as output.

In route card frequency of offering the vehicle to check the defect rectification by the group is noted against each defect along with the date of offer. When a particular defect is rectified, 'R' (indicating that the defect is repaired) is marked against it and signed by the inspector. If necessary, the vehicle may be taken out for highway test once again to check the quality of defect rectification.

4. ANALYSIS OF ROUTE CARD

Data indicating defects, inadequacies and abnormalities in a vehicle observed during road test are noted in the Route Card. It provides the information regarding the state of readiness and skills of technical manpower, output of machines and quality spares including expendables. A statistical analysis of this data can point to the assembly line weak link and offers scope to improve.

4.1. Terms of Reference

Route Cards generated for HMVs refurbished during the past two years have been analysed for the study. During the analysis, it is observed that most of the vehicles have been repaired during first re-offer. Hence the defects noticed during first offer only have been considered. The terms of reference are as brought out below.

(a) Period – Two years (Route Card generated during the period).
(b) First offer of the vehicle has been considered. Defects noticed during re-offer have been neglected being very small in numbers.
(c) 117 vehicles have been offered during the above period.
(d) Sample size for the analysis is 117.

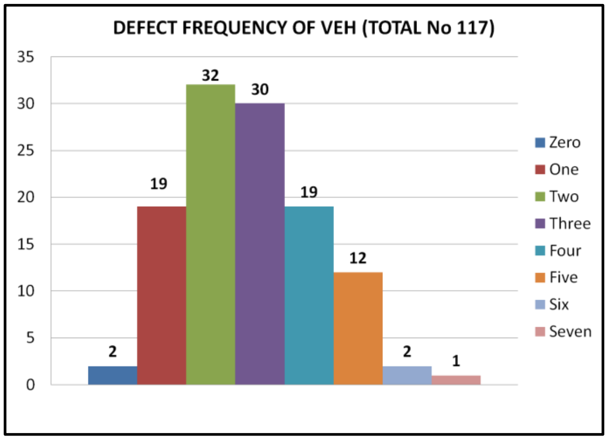

Fig-1: Defect Frequency

4.2. Defect Frequency

Number of defects per vehicle varied between 0 to 7. However, most of the vehicles had 2 to 3 defects. Two vehicles have been found to be without any defect and hence passed on the first offer. One vehicle has been received with highest number of defects (seven). These are represented by a histogram at Fig 1.

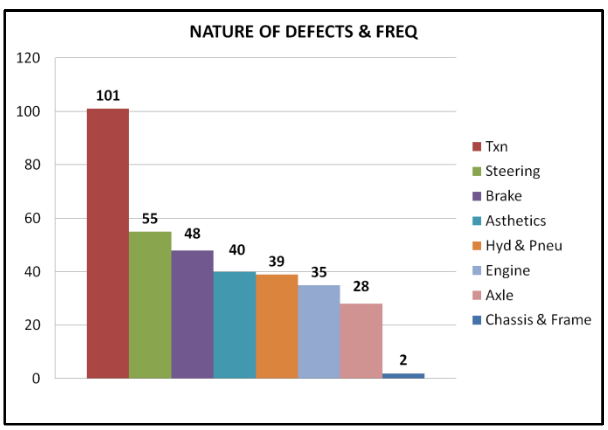

Fig-2: Nature of Defects and Frequencies

4.3. Nature of Defects & Frequencies

For the ease of analysis, the defects are divided into eight groups. Alphabetically, the groups are Aesthetics of the vehicle, Axle (front and rear), Brake system, Chassis and Frame, Engine, Hydraulic and Pneumatic system, Steering system and Transmission (Clutch and Gear Box assemblies only) system. The nature of defects is represented by a histogram at Fig 2.

It is observed that chassis and frame has minimum defect frequency where as the transmission has maximum number of defects (more than 100).

4.4. Transmission System Defects

It is observed that maximum numbers (14 types) of defects are related to transmission system. The defects are related the abnormal noise in gear box, transfer case, propeller shaft and clutch, malfunctioning of low/high change over gear, gear shifting hard, pulling power weak (due to clutch only), clutch operation hard and clutch plate worn out, all wheel drive not getting engaged, excessive gear lever play, leakage from transfer case and clutch booster. Out of these, maximum defects frequency of 22 has been observed for gear box operation noisy. Minimum defect frequency of one each has been observed for clutch booster leakage and clutch plate worn out. The nature of transmission system defects involving the functioning of clutch and gear box assemblies is represented by a histogram at Fig 3.

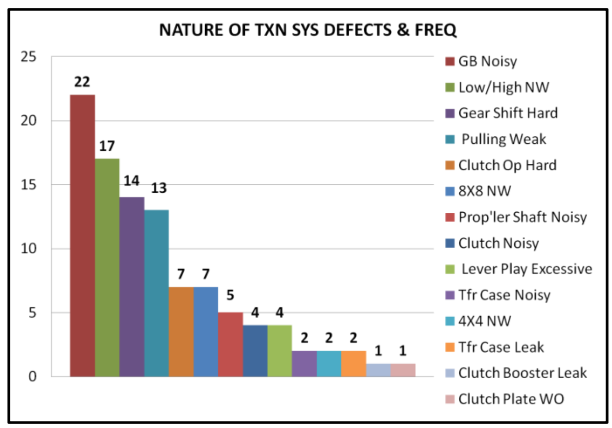

Fig-3: Nature of Transmission System Defects & Frequencies

5. Weak Links Identification

It is brought out that maximum number of defects has been noticed in power transmission system involving clutch and gear box. Hence assembly line weak link is located in this system. Mean frequency of defect is 7.21 and all the defects falling above the mean value are considered to be critical. There are four types of defects having frequencies above the mean which constitute the weak link. The defects brought out here are gear box operation noisy, low/high change over system not functioning, gear shifting hard and pulling power weak (due to defects in clutch only) having frequencies 22, 17, 14 and 13 respectively. These defects need to be eliminated to strengthen the process in the assembly line. Probable causes for these defects are disseminated below. The list is only indicative and not exhaustive. Lay out of power transmission system if given in Fig 4.

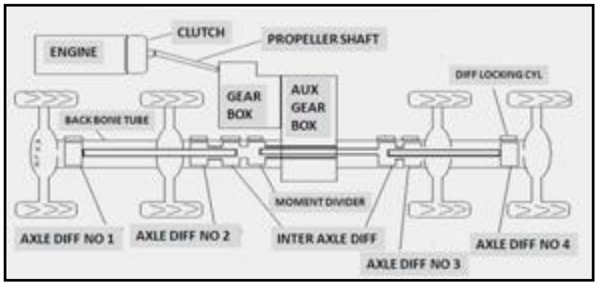

Fig-4: Layout of Power Transmission System

5.1. Gear box operation noisy

The defect has the highest frequency (22). This may be due to wearing out of internal bearings/enlargement of bearing seats, loose fitment/play in gears/incorrect meshing, worn out/misaligned shafts, low oil level, clutch rattle, some ghost noise and so on.

5.2. Low/high change over system defective

This defect has occurred 17 times. Probable causes of the defect are failure of pneumatic sub-system, gear box synchronizer rings worn out/misaligned, gear selector fork bend/worn out/jam, clutch shaft splines worn out/misaligned, clutch shaft bearing excessive play or its seat worn out, connecting linkages bend/jam/excessive play, electrical circuit and switch faulty etc.

5.3. Gear Shifting Hard

This defect has the frequency of 14. This defect may be attributed to incorrect gear meshing, improper adjustment of gear shifting mechanism or lay shaft, gear box synchronizer rings worn out/misaligned, main shaft splines worn out/misaligned. Origin of the defect may also be in clutch assembly due to improper adjustment of clutch, defective booster or master cylinder, clutch drag, linkage bent/jam/misaligned and incorrect adjustment of free play etc. Additionally, the causes resulting in non functionality of low/high change over system discussed above may also be attributed to the defect of gear shifting hard. Gear shifting hard has also been observed to be driver intensive. Some driver may find it easy and some may not. Hence gear operating habit of the driver is also required to be scrutinized.

5.4. Pulling Power Weak

There may be numerous reasons for weak pulling power of the vehicle and the most important is related to engine. However, in this case, the defect under consideration has occurred in transmission system due to the problem in clutch. Frequency of this defect has been found to be 13. Major defect in clutch assembly may be due to slippage, pulsation, judder, grabbling, dragging, wearing and glazing of clutch plate and seizure on spline. Weak pulling power may also be caused due to worn out pressure plate and incorrect adjustment, jamming, bending of linkages and operating levers. Weak or broken clutch spring, defective release bearing etc also contribute towards weak pulling power of the vehicle.

6. STRENGTHENING OF WEAK LINKS

Once the weak link has been identified and probable causes known, strengthening of assembly line and overcoming the defects becomes surmountable. In the present scenario defects related to gear box, transfer case and clutch housing have been addressed by compulsory stripping, overhauling and dynamic testing of the assemblies on the test bed before synchronizing with the vehicle. The following points have also been ensured which are adding to the quality of overhaul.

(a) Use of genuine spares
(b) Stripping of all gear box and other transmission assemblies up to component level and performance checking individually on test bed after overhaul
(c) Use of test jigs and fixture
(d) Replacement of 100% 'Must Change' spares
(e) Liberal replacement of 'Could Change' spare
(f) Review of overhaul scale to add/delete spare parts
(g) Individual and collective training of technical manpower
(h) Implementation of quality policy in letter and spirit.

6. CONCLUSION

High quality output is a combined responsibility of all the agencies functioning in the workshop. Strong assembly line in the repair group which functions as a chain is a major contributor to ensure this in a time bound and profitable manner. Thus strong assembly line consisting the repair group needs to function as a chain and contribute immensely to ensure quality output in a time bound and profitable manner. Any weak link in the chain would reduce the strength of the complete system which in turn affects the quality and hence needs to be identified for weeding out. In order to achieve high quality output improved functional capabilities of assembly line needs to be ensured by identification of weak links and addressing the problems. Frequencies of various defects noticed during road test of vehicle under refurbishment thus become very important performance indicator of repair groups. In this paper, methods to identify the weak links in the chain of assembly line have been brought out and remedial method suggested strengthening it by using road test observation data. By implementation of remedial measures, considerable reduction of defect frequencies has been noticed during subsequent road test of vehicles resulting in better quality output.

ACKNOWLEDGEMENT

The author expresses sincere thanks to Managing Director of the Workshop for his guidance, valuable inputs, review of manuscript and bring the article to its present shape in spite of his pressing commitments.

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BIOGRAPHY

Dr Probhas Bose, born in West Bengal, India, obtained his ME in Mechanical Engineering (Heat Power) in 2006 from Birla Institute of Technology, Mesra, Jharkhand, India. He has successfully completed two professional advanced courses in armament and weapon technology in 1993 & 1998 from EME School, Vadodara, India and Institute of Armament Technology, Pune, India respectively. He received PhD in 2014 from NIT Silchar. He has guided 47 PG students. He has published and presented 30 papers in International & National Conferences and Journals.

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