RESEARCH REGARDING THE RELIABILITY OF THE SHOCK ABSORBERS OF A NUMBER OF AUTOMOBILES USING WEIBULL DISTRIBUTION

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Importanța fiabilității automobilelor în economia unui parc auto este motivul pentru care s-a dezvoltat lucrarea de față. Studiul se realizează pe un parc de automobile format din acelaşi tip de automobil.

Cercetarea fiabilității se concentrează pe amortizoarele acestor automobile (față şi spate). Se utilizează distribuția Weibull pentru calculul statistic al defecțiunilor, iar rezultatele se prezintă în formă grafică. Calculele se realizează cu programul Weibull ++7, iar metodologia de calcul este explicată pe scurt în cadrul lucrării. În cele din urmă se vor emite recomandări şi concluzii referitoare la fiabilitatea şi mentenanța amortizoarelor studiate.

The importance of automotive reliability in a car park economy is the reason for which this paper is presented. The study was made on an automotive park composed of the same model of automobile.

Reliability research is focused on these automobiles dampers (front and back). Weibull distribution is used for statistical calculus, with the results being presented in charts. Computation is made by the Weibull ++7 program, with the calculation methodology being explained briefly in the paper. Finally, some recommendations and conclusions based on the reliability and maintenance of the studied dampers are presented.

Keywords: reliability, unreliability, Weibull, shock absorber, maintenance.

1. Introduction

Reliability justifies the importance of quality in the automotive industry. Statistical research created a new path for improvement of the automotive design. Every car manifacturer has collaboration contracts with as many workshops as possible. The importance of having a decent number of collaborations with workshops is partly given by the information the car maker receives, as maintenance feedback from customers. Every failure of an automobile during its lifetime is theoretically documented and sent by workshops to the reliability departments of the manufacturer. Usually, these pieces of information are

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confidential. Therefore, a public research study on a certain number of the same automobile model is helpful, being a good alternative to the lack of certain information due to confidentiality.

Failed automobile parts are kept and studied in special research centers. The most important documented parameters are the time till failure (usually given in kilometers or miles) and the road conditions (if available) in which the failed part worked. The research results are further sent to the design department in order to improve the designated part or model.

Therefore, the importance of reliability justifies the necessity of identifying the cause for failures, the limit in time in which the car can be used before failure, the number of automobiles and parts that can be repaired without affecting the labor capacity of the serving section and the number of changeable parts to be stored in order to kep the immobilization of the vehicle to a minimum [1].

Reliability is based on the matter of designing an item in order to last as long as possible without failure. In maintainability, the emphasis is made on designing a part so that if failure occurs, it can be corrected as quickly as possible. High system availability is the combination of high reliability and high maintainability [2].

Maintenance activity can be divided into two groups: scheduled maintenance and unscheduled maintenance. Scheduled maintenance consists of preventive maintenance inspection, being itself a planned servicing of vehicles. Unscheduled maintenance is work resulting from component failures, which may necessitate road calls, being more costly [3]. The main objective of this paper is scheduled maintenance based on the reliability study presented herein.

2. Theoretical Data

2.1 Vehicle Fleet

The research is focused on a group of 130 vehicles of the same model, with identical equipment and year of fabrication. Because of trademark issues, the manufacturer name will not be revealed.

However, technical and exploitation data is not to be overlooked. All the vehicles have gasoline 1.6 liter engines, the same size of tires (185/65R15) and rims (15 inch). All the vehicles have hydraulic shock absorbers.

The vehicles studied herein were used 40% on urban and 60% on extra-urban roads (most of the time they are driven on express roads, rarely on highways). The conditions of the roads the vehicles were driven on are as follows: 40% good (best condition available), 30% acceptable (good surface except for small bumps every 50-100 m) and 30% bad (many road bumps, holes, or even small portions with no tarmac).

The automobiles are driven by professional drivers and their servicing is made at the correct amount of time and/or number of kilometers the constructor recommended, and only in authorized car workshops. The fleet is the same used for statistical studies as in [4]

The safety of a vehicle is greatly reduced by poor suspension. Failing shock absorbers (dampers) increase the instability of vehicles, meaning increasing pitch movement at acceleration, deceleration or when running over obstacles, even bigger roll movement while steering. Vehicle speed while running over bad roads will significantly reduce the shock absorbers' life. Also, overloading vehicles increases the stress on shock absorbers while running over bad roads.

The shock absorbers studied in this paper are of hydraulic type, meaning the shock is absorbed by fluid (oil) friction inside passing through a narrow orifice.

Failing shock absorbers are usually noticed at maintenance operations, having oil leaks in the lower part. The bigger the oil loss in the shock absorber, the more unstable the vehicle. Therefore, it is of utmost importance that the shock absorber is replaced as soon as an oil leak is observed.

2.2 Statistical Distribution Used

The Weibull probability distribution is used in this study because its graph paper is particularly useful as an exploratory technique in understanding life test or field data from a product. It is a three-parameter distribution, and the reliability function R(t) for $t \geq \gamma$ is given by the following expression [5]:

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta-\gamma}\right)^{\beta}} \tag{1}$$

In this formula, β is "the shape parameter", η is "the scale parameter" (the characteristic life at which about 63% of the population of items would have failed), γ is "the location parameter" or minimum life and t is the place in time when failure occurs (in kilometers) [1].

$$f(t) = \frac{\beta}{\eta-\gamma} \cdot \left(\frac{t-\gamma}{\eta-\gamma}\right)^{\beta-1} \cdot e^{-\left(\frac{t-\gamma}{\eta-\gamma}\right)^{\beta}} \tag{2}$$

$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\eta-\gamma} \cdot \left(\frac{t-\gamma}{\eta-\gamma}\right)^{\beta-1} \tag{3}$$

Wearout failure mechanisms are best described by Weibull distribution, which is very flexible and by using different values of the three parameters it can depict various shapes of the functions mentioned (if β<1 the part is in its early life, if β=1 the part is in its useful life and if β>1 the it is its wearout time) [5].

3. Results

The weibull distribution has a complex range of mathematical methodology. Therefore, to save time and to improve efficiency, a designated program was used [6]. ReliaSoft Weibull ++7 computes graphs and other statistical parameters. As mentioned in paragraph 2, the shock absorbers are considered in this study.

The automobiles are numbered accordingly and the time when the part fails is considered in kilometers. Values are presented in Table 1 and 2. As it can be seen, 45 shock absorbers failed at the front suspension, while 18 shock absorbers failed at the back suspension.

Table 1

Moments in time front shock absorbers fail

Automobile number	Time failure [km]	Automobile number	Time failed [km]
1	61500	24	107211
2	62340	25	113662
3	67351	26	118600
4	69000	27	120000
5	69500	28	120450
6	71351	29	121015
7	71352	30	122348
8	74048	31	122457
9	74335	32	126104
10	74520	33	126240
11	75000	34	126240
12	90511	35	134965
13	97527	36	135000
14	100593	37	135000
15	101527	38	148186
16	103444	39	150000
17	104021	40	150200
18	104021	41	150511
19	104555	42	151457
20	105000	43	162300
21	105000	44	182000
22	105455	45	182420
23	107000		

Table 2

Moments in time back shock absorbers fail

Automobile number	Time failed [km]	Automobile number	Time failed [km]
1	45000	10	92543
2	46728	11	105000
3	46855	12	107000
4	49512	13	133000
5	49560	14	148186

6	75000	15	156331
7	85000	16	163000
8	90000	17	165000
9	91527	18	167284

Next, Weibull distribution was selected in the program Weibull ++7 and inserting all the moments in time mentioned in Table 1 and 2, the program can compute the designated number of parameters (1/2/3/Mixed/CFM). Furthermore, by calling the program's "plot" command, various graphs can be created.

Using the Distribution Wizard's recommendations, Weibull distribution with 3 parameters was used for calculations. Their values are: $\beta=2.3207$, $\eta=80214$, $\gamma=40536$ for the front shock absorbers and $\beta=1.6839$, $\eta=92175$, $\gamma=20800$ for the back dampers. Computed graphs are further presented, for both front and back shock absorbers. As the value of β can be seen in either front and back shock absorbers, the failures occur in the wear out time.

First, Weibull probability plots are presented, in Figs. 1 and 2, for front and back shock absorbers.

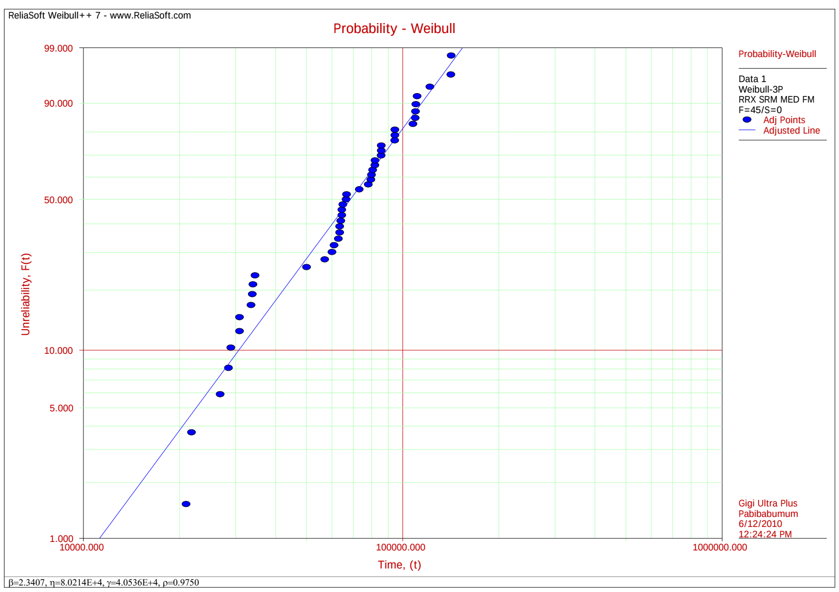

Fig. 1. Weibull probability graphic representation for front shock absorbers

The blue line represents the Weibull probability (unreliability is in percents). It is named "adjusted line" because it was drawn according to the input data in order to create a straight line. For the front absorbers, most of the failures occurred between 60000 and 100000km. On the other hand, studying the plot in Fig. 2, the failure spread is uniform, between 50000 and 110000km.

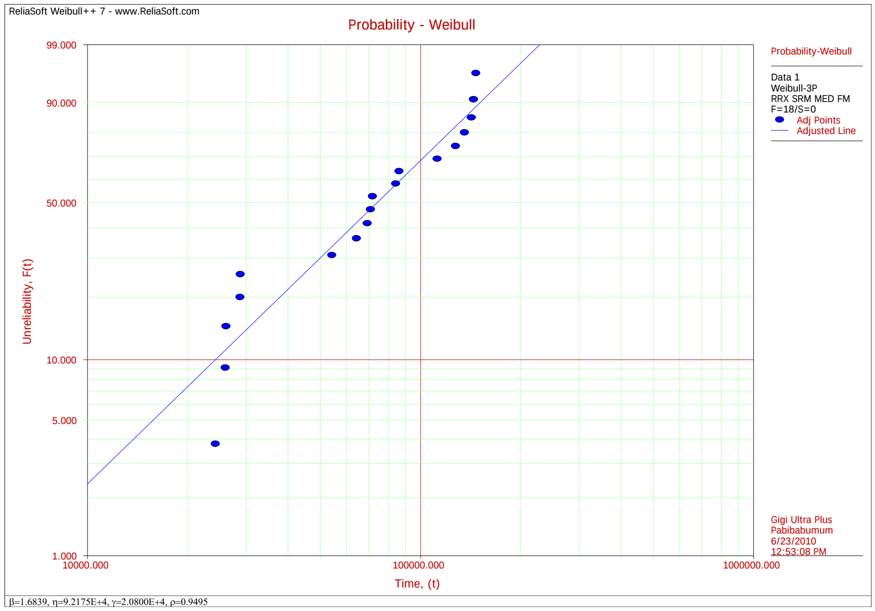

Fig. 2. Weibull probability graphic representation for back shock absorbers

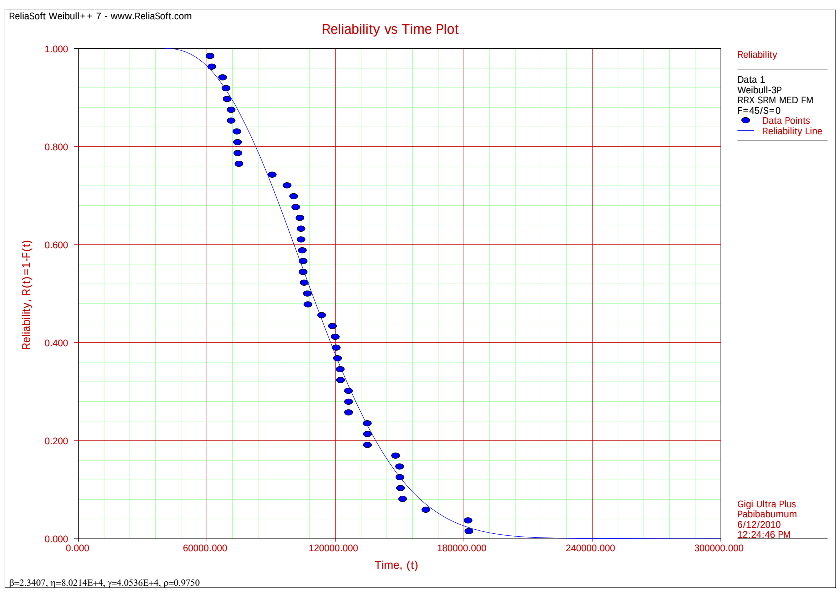

Fig. 3. Reliability plot for front shock absorbers

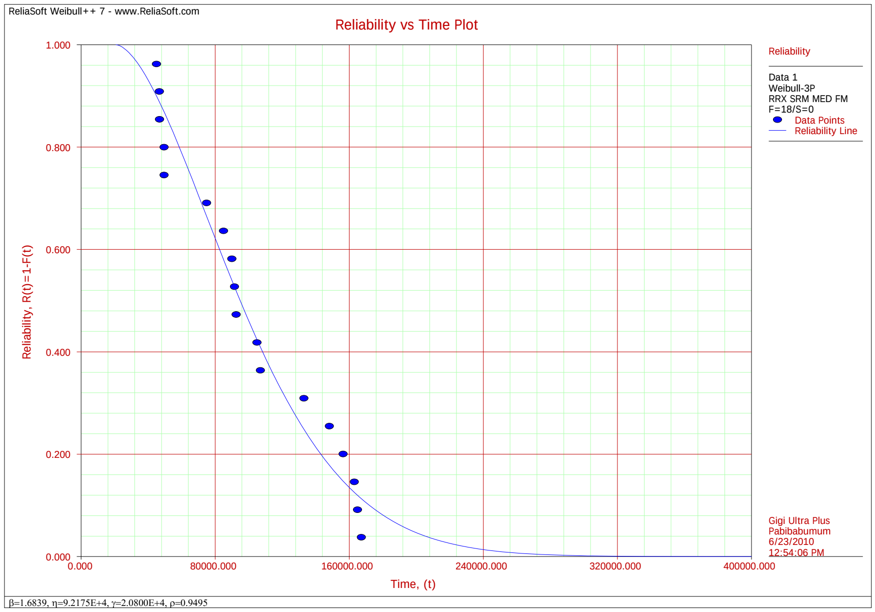

Fig. 4. Reliability plot for back shock absorbers

The reliability function is plotted in Figs. 3 and 4. Just like in theory, the more kilometers an automobile gathers, the more likely the part can fail.

As seen in Fig. 3, for the front shock absorbers, reliability starts to decrease from 50000km, until it reaches zero at about 200000km. According to the plot in Fig. 4, the back shock absorbers have higher reliability than the front ones, reliability function dropping from approximately 30000km, but approaching zero only after 240000km.

Unreliability function is opposed to the reliability function, therefore the plots are similar, because of the following property of both reliability and unreliability:

$$R(t) + F(t) = 1 \qquad (4)$$

Fig. 5 presents the variation of the probability density function, described by formula (2). As seen in the plots presented in Fig. 5 (front shock absorbers) and 6 (back shock absorbers), the value of this function is zero until the first parts fail, then it increases rapidly to its maximum value. After the maximum level is reached, the function drops until it finally reaches zero.

The probability density function is helpful in defining the actual interval in which a certain part is more likely to fail.

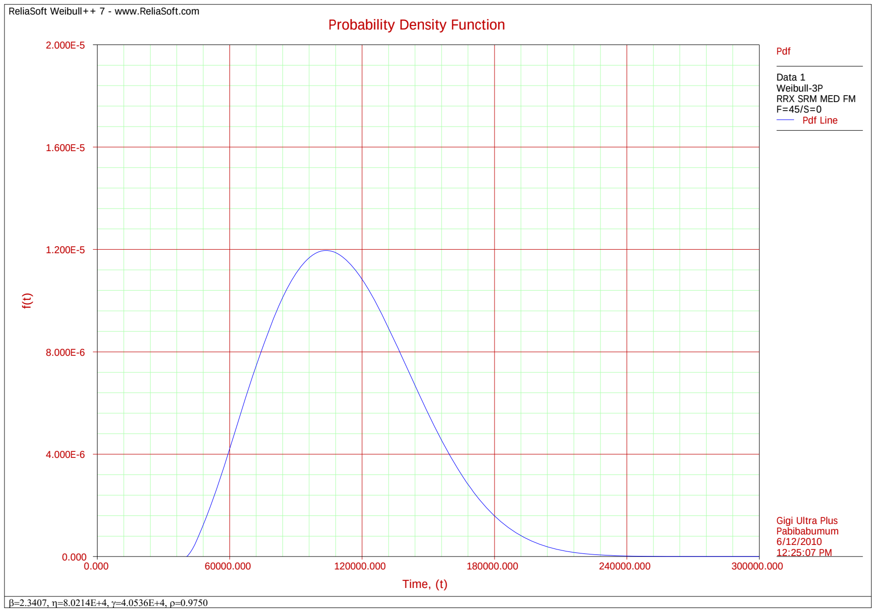

Fig. 5. Probability density plot for front shock absorbers

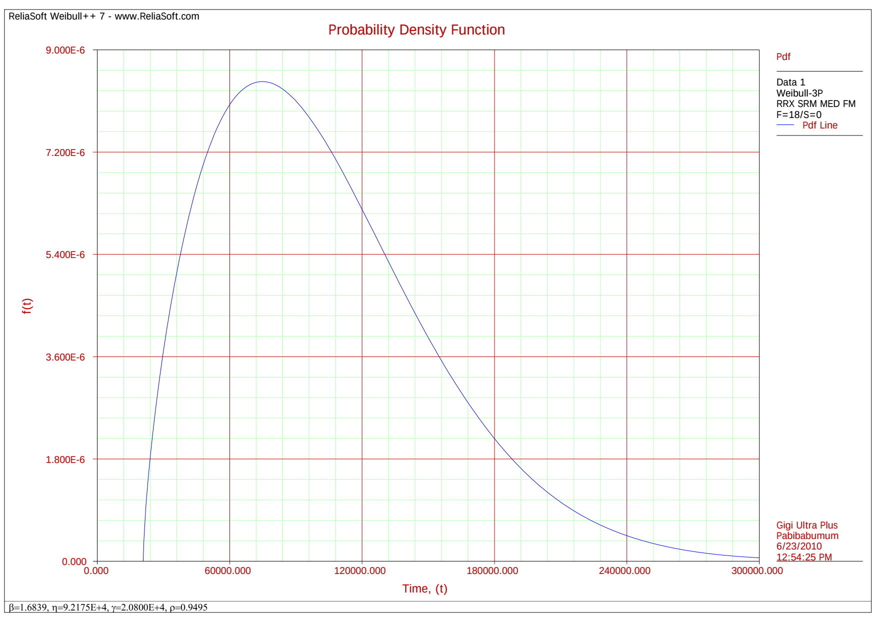

Fig. 6. Probability density plot for back shock absorbers

From Fig. 5, it can be seen that the front shock absorbers are more likely to fail between approximately 70000 and 140000km. For the back shock absorbers, from Fig. 6, the interval is between 40000 and 140000km. The variation of the function in this last plot is steeper in the first half because of the lower number of failures, compared to the front shock absorbers.

6. Conclusions

Because of the importance of safety in the automotive industry, suspension failures are to be avoided. The ability of an automobile to safely avoid an obstacle is strongly decreased by bad shock absorbers. As stated before, as soon as a shock absorber shows signs of failure, immediate replacement is required.

The number of failed shock absorbers is lower for the back suspension, compared to the front suspension. An explanation comes from the road and loading conditions of the automobile routes, since most of the time only two passengers are travelling (the driver and a passenger). Therefore, the back suspension is less likely to handle big stress from the road. Because the engine is positioned in the front, resulting in more mass being handled by the front suspension, these shock absorbers are more likely to fail.

Reliability of the front dampers is lower, compared to the back shock absorbers, mainly because the front suspension handles a higher amount of stress than the back suspension; also maintenance actions need to be enhanced from approximately 60000km (visual check, especially at the front suspension). This conclusion was drawn from the probability plots in Figs. 1-6. The shock absorbers from the back suspension have higher reliability, but maintenance checks can be made at the same time as the front shock absorbers, every 60000km.

Since the vehicles studied herein are part of a public car park, ideally no immobilization due to extensive repair time is desired. However, since rough road conditions are part of daily transportation for some vehicles, as stated in paragraph 2.1, faults do appear, so immediate action is required. By continuously maintaining of new car part stocks and by computing statistical data for further improvement of logistics, a vehicle fleet manager enhances its park availability.

Weibull statistical distribution, among other methods [7], is helpful in approximating the reliability parameters of an automobile. To improve time efficiency, fast computation is required. In this paper a fast calculation program was presented, developed by Reliasoft, along with a brief description of the methodology.

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