Research of the operational dependability of the *Lada Kalina* vehicle systems affecting traffic safety

Ilia V. Denisov, *AG and NG Stoletov Vladimir State University, Vladimir, Russia*
Alexey A. Smirnov, *AG and NG Stoletov Vladimir State University, Vladimir, Russia*


Ilia V. Denisov


Alexey A. Smirnov

Abstract. *The growing number of cars in the Russian Federation means that a large number of vehicles with different performance indicators get involved in the transportation process. One of those indicators is dependability that is a key characteristic of quality. A vehicle's operation is the primary test of its dependability, of which the indicators depend on the used design solutions and the manufacturing process. Defects occurring at various stages of vehicle manufacture significantly affect the dependability indicators. It must be noted that a vehicle is a source of increased hazard. A failure of a vehicle in operation due to a manufacturing defect or non-observance of operation conditions may cause an accident. Therefore it is extremely important to have at one's disposal information on the implemented systems reliability indicators that affect active safety. In this context, the research of automotive vehicles dependability in operation is a relevant scientific task, solving which will enable managing the technical condition of vehicles and ensure traffic safety.* **The aim** *of this research was to evaluate the operational dependability of the systems that directly affect the road safety of Lada Kalina with subsequent use of the obtained information in the development of automated systems for management of automotive vehicle technical condition in operation.* **The methods** *of research are based on the theoretical foundations of vehicle maintenance, the probability theory and mathematical statistics, experimental design theory. Standard methods of processing of statistical information on the operational dependability of vehicles were used. The data was obtained from official OAO AvtoVAZ dealerships in the Vladimir Oblast. As the result of research of the operational dependability of the systems that directly affect the road safety of Lada Kalina a list of defective components in the steering, braking, chassis, lighting and signalling systems was identified. Times to failure of parts, units and assemblies that limit the vehicle dependability, as well as the primary numerical characteristics of random distribution were determined. The defects identified at early stages of operation indicate design and manufacturing flaws of Lada Kalina.*
Conclusions: *In this paper the authors present the findings regarding the defects of the Lada Kalina systems that directly affect traffic safety. This information was obtained by means of analyzing vehicle failures within the warranty period that were recorded based on the owners' applications to the OAO AvtoVAZ dealerships an maintenance facilities in the Vladimir Oblast. Maintenance facilities, when performing diagnostic operations as part of routine maintenance, should take into consideration the list of the least dependable vehicle components given in this paper and directly affecting the traffic safety.*
The manufacturing factory should take note of the indicated defects and develop a plan of their elimination, as well as timely inform the consumers of the identified warranty-specific defects and recall the products.

Keywords: *automobile, Lada Kalina, VAZ-1118, dependability, steering, braking system, chassis, lighting system, defects, warranty period.*

For citation: *Denisov IV, Smirnov AA. Research of the operational dependability of the Lada Kalina vehicle systems affecting traffic safety. Dependability 2017;4: 31-35. DOI: 10.21683/1729-2646-2017-17-4-31-35*

Introduction

A review of current scientific publications [1] shows that today malfunctions of automotive vehicles account for 20 to 25 % of the total number of traffic accidents (TA). Failures of the braking and steering systems, chassis, lighting and signalling devices of vehicles reduce their dependability and cause high risk of situations that enable TAs.

In operation, it is extremely important to have at one's disposal information on the dependability of the components of the above systems as that enables the management of their technical condition. The country's leading colleges and automotive industry's research institutions in close cooperation with the manufacturers, operators and maintenance enterprises that collect and analyze initial information on failures of vehicle units and assemblies are now developing a system for managing the technical availability of transport vehicles.

As part of the automated system for vehicle technical condition management in operation under development [2, 3, 4] the task of this research was to evaluate the operational dependability of the systems that directly affect the road safety of *Lada Kalina*. The research involved official OAO AvtoVAZ dealers in the Vladimir Oblast. This paper presents the findings regarding the assigned task.

Findings regarding the operational dependability of *Lada Kalina*. The diagram in Figure 1 that illustrates mass defects of the steering system shows that non-acceptable steering rack displacements due to increased gear clearance account for the bulk of failures. Their elimination within the warranty period is predominantly performed by means of adjustment of gear transmission clearance or replacement of the whole mechanism. Cardan shaft knocking is caused by gaps in nail bearings of the U-joints.

Electromechanical power steering (EPS) defects account for one seventh of all of the system's defects. The unit is mechatronic and has a complicated design, therefore diagnosing its technical condition is especially labor-intensive and requires special methods and facilities [5]. In operation, defective EPS functioned incorrectly, i.e. allowed unintentional rotation of the steering wheel with the vehicle's deviation from the straight-line trajectory, as well as reduction of the maximum compensating torque.

The defect of the swivelling mechanism connector that ensures electrical connection between the airbag and the sound signal switch with the dashboard wiring harness is caused by broken spiral cable. In this case a reduced passive vehicle safety due to airbag failure can be observed.

Other steering failures in *Lada Kalina* are due to defects of the steering mechanism and its parts: increased gear transmission clearance and loss of case integrity.

Table 1. Mass defects of the steering system of Lada Kalina

Item	Name of defect	Number	$\overline{X}$, ths km	ν	σ
1	Steering rack displacement too high relative to case	40	17,5	0,68	11,9
2	Cardan shaft knocking	38	18,7	0,68	12,8
3	Electromechanical power steering disabled	26	21,2	0,64	13,5
4	Swivelling mechanism connector defect	21	16,6	0,77	12,7
5	Left steering knuckle out of size	19	18,6	0,58	10,8
6	Rack-to-lock gap out of size	12	15,0	0,94	14,2
7	Rupture of steering rack case	12	22,9	0,61	14,1
8	Steering column cover defect	11	6,9	0,82	5,7

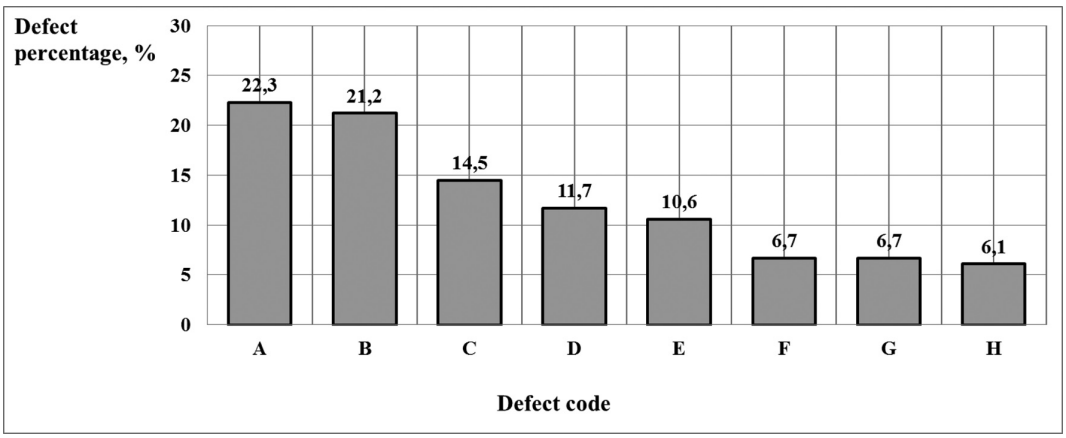

Figure 1. Defects of the steering system of Lada Kalina:
A: Steering rack displacement too high relative to case; B: Cardan shaft knocking; C: Electromechanical power steering disabled; D: Swivelling mechanism connector defect; E: Left steering knuckle out of size; F: Rack-to-lock gap out of size; G: Rupture of steering rack case; H: Steering column cover defect

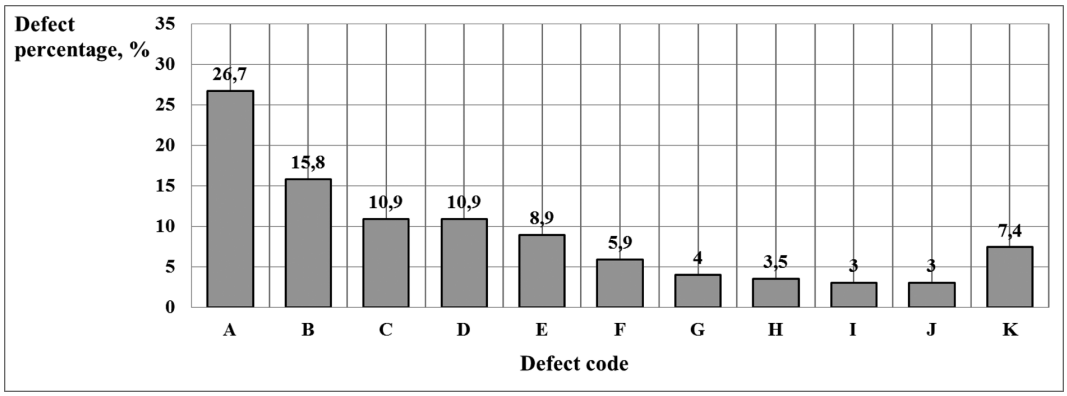

Figure 2. Defects of the braking system of Lada Kalina:
A: Loss of wheel cylinder integrity; B: Loss of main braking cylinder integrity; C: Loss of vacuum booster integrity; D: Main braking cylinder bleed off; E: Brake drum vibration/ovality; F: Vacuum booster wedging; G: Braking pressure regulator valve not adjusted; H: Right calliper leak; I: Rupture of cooling hose; J: Left calliper leak; K: Other defects

Table 2. Mass defects of the braking system of Lada Kalina:

Item	Name of defect	Number	$\overline{X}$, ths km	ν	σ
1	Loss of wheel cylinder integrity	54	25,6	0,54	13,8
2	Loss of main braking cylinder integrity	32	22,5	0,51	11,4
3	Loss of vacuum booster integrity	22	16,8	0,74	12,3
4	Main braking cylinder bleed off	22	15,5	0,65	10,1
5	Brake drum vibration/ovality	18	19,9	0,39	7,8
6	Vacuum booster wedging	12	6,2	1,37	8,5
7	Braking pressure regulator valve not adjusted	8	0,68	1,02	0,7
8	Right calliper leak	7	29,4	0,4	11,7
9	Rupture of cooling hose	6	5,0	1,16	5,8
10	Left calliper leak	6	28,9	0,57	16,3
11	Other defects	15	-	-	-

Figure 2 shows the percentage of vehicle braking system defects.

The figure shows that due to reduced performance of rubber components (sleeves and seals) the loss of wheel cylinder integrity accounts for a quarter of all failures. Braking fluid leaks and its bleeding off between brake circuits can also be observed in the main braking cylinder and front disk brake calliper. Thus, the defects of the main and wheel brake cylinders form over a half of all system failures.

Air intake into the vacuum booster cylinder and the wedging of its rod cause malfunction in sixteen out of a hundred vehicles with a failed braking system. Pressure regulator valve malfunctions were observed in only four percent of vehicles with the system's failures.

Among the «Other» malfunctions we should emphasize the defect of calliper seal, broken front brake block spring, failure of brake fluid level switch, as well as scuffing of rear brake friction pad.

Table 2 shows that times to failure of most brake control components correlate to the service interval as per the vehicle's log book, except for the main and wheel brake cylinders and brake hoses. In operation, those components must be checked as part of routine maintenance at service stations. It should be noted that of a special hazard to the vehicle owner and passengers are the brake hoses with the time to failure of just 5000 km and coefficient of variation of 1.16.

A special attention should be given to the braking pressure regulator valve installed in basic configurations of *Lada Kalina*. The average time to failure is about 700 km, which is unacceptably low. Premature blocking of lockup of rear axle brakes during braking caused by incorrect valve operation may cause skidding of the back wheels and loss of vehicle stability.

Figure 3 shows the distribution of chassis failures of the vehicle under investigation.

Defects of front suspension ball joint and destruction of rear brace joint that manifest themselves with knocking and clicking during vehicle acceleration are the most common in operation and require the replacement of components in order to eliminate the above defect symptoms.

Increased clearances in the supporting bearers of the right and left rotary racks cause knocking when passing bumps in the road, as well as distinctive creaking when the steering

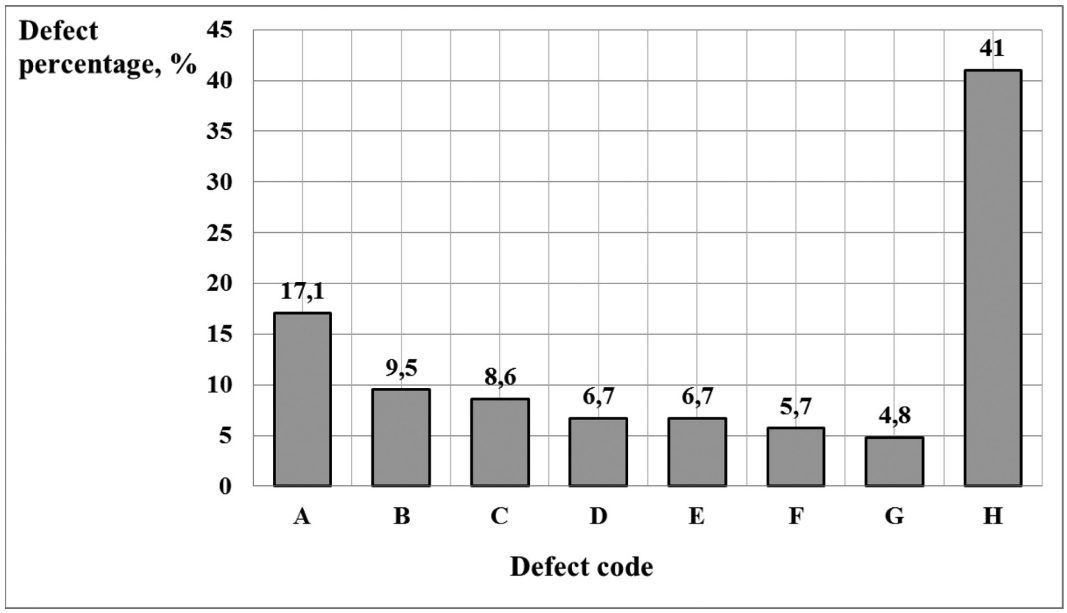

Figure 3. Defects of the chassis of Lada Kalina
A: Knocking/clicking in the front suspension during rotation; B: Knocking of the top mount of right front wheel support; C: Knocking of the top mount of left front wheel support; D: Rear wheel hub wobble; E: Destruction of rear brace joint of front suspension; F: Falling of rear suspension arm pad; G: Rear wheel hub bearing noise; H: Other defects

Table 3. Mass defects of the chassis of Lada Kalina

Item	Name of defect	Number	$\overline{X}$, ths km	ν	σ
1	Knocking/clicking in the front suspension during rotation	18	20,5	0,66	13,5
2	Knocking of the top mount of right front wheel support	10	22,9	0,67	15,4
3	Knocking of the top mount of left front wheel support	9	22,4	0,54	12,1
4	Rear wheel hub wobble	7	16,7	0,59	9,9
5	Destruction of rear brace joint of front suspension	7	22,9	0,51	11,7
6	Falling of rear suspension arm pad	6	20,5	0,66	13,6
7	Rear wheel hub bearing noise	5	14,4	0,7	0,69
8	Other defects	43	-	-	-

wheel is turned. The defect is due to the loss of component integrity that entails sand collection and excessive tear and wear of the ball and destruction of the retainer. Increased noise during rear wheels rotation and their wobble are due to gaps in the hub bearings that are eliminated by means of adjustment or replacement.

Table 3 shows mean times to failure of defective vehicle chassis components.

Figure 4 shows the percentage distribution of lighting and signalling devices of *Lada Kalina*: Mass defects of lighting devices associated with the loss of integrity of headlamp units, tail lights and fog lights manifest themselves in the form of misting of their glasses in operation caused by ingress of moisture and are due to distortional stress at the mounting spots on the vehicle body.

Failures of auxiliary stop signals are caused by failures of one or more semiconductor elements. Table 4 shows information on the operational dependability of a vehicle's lighting components.

Conclusion. The findings regarding the dependability of *Lada Kalina* safety system elements within the warranty period are an important part of the vehicle's technical condition management system. The defects identified at early stages of operation indicate design and manufacturing flaws.

Maintenance facilities, when performing diagnostic operations as part of routine maintenance, should take into consideration the list of the least dependable vehicle components given in this paper and directly affecting the traffic safety.

The manufacturing factory should take note of the indicated defects and develop a plan of their elimination, as well as timely inform the consumers of the identified warranty-specific defects and recall the products.

References

Denisov IlB, Smirnov AA. Issledovanie vliyaniya tekhnicheskogo sostoyaniya avtotransportnykh sredstv na dorozhno-transportnouyou avariynost v Rossiyskoy Feder-

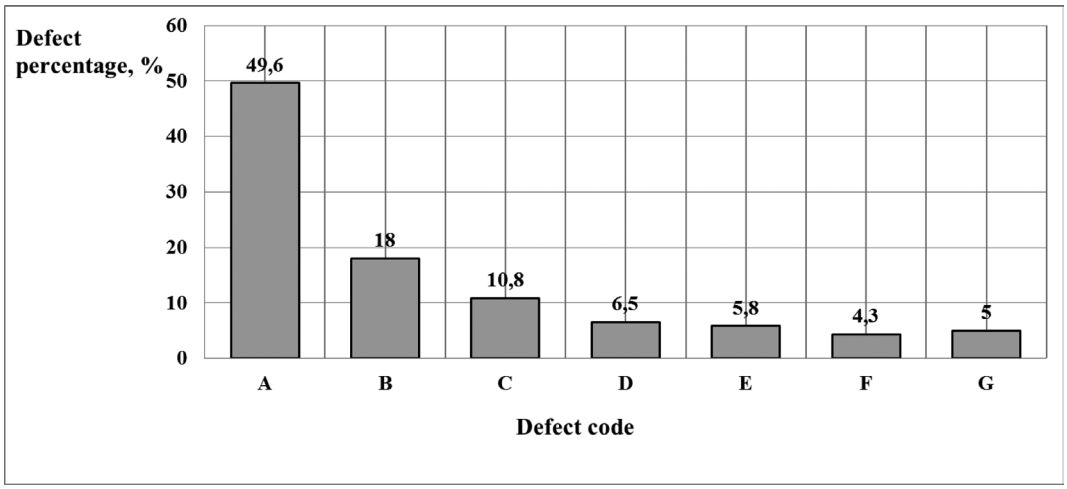

Figure 4. Defects of the lighting system of Lada Kalina:
A: Loss of integrity of left headlamp unit; B: Loss of integrity of right headlamp unit; C: Defect of right tail light; D: Defect left tail light; E: Loss of integrity of fog light; F: Defect of auxiliary stop signal; G: Other defects

Table 4. Mass defects of the lighting system of *Lada Kalina*:

Item	Name of defect	Number	$\overline{X}$, ths km	ν	σ
1	Loss of integrity of left headlamp unit	69	10,8	0,73	7,9
2	Loss of integrity of right headlamp unit	25	13,9	0,85	11,8
3	Defect of right tail light	15	19,7	0,51	10,1
4	Defect of left tail light	9	18,3	0,82	15,0
5	Loss of integrity of fog light	8	15,3	0,97	14,8
6	Defect of auxiliary stop signal	6	19,7	0,94	18,6
7	Other defects	7	-	-	-

atsii [Research of the effect of the condition of automotive vehicles on the rate of traffic accidents in the Russian Federation]. In: Zakharov DA, editor. Proceedings of the VIII Russian national research and practice conference Organization and Safety of Road Traffic. Tyumen (Russia): TyumGNGU; 2015. p. 71-77 [in Russian]. ISBN 978-5-9961-1027-8.

Bazhenov YuV, Denisov IlB, Denisov IvV. Veroyatnostnaya model predotkaznogo sostoyaniya avtomobilia [The probabilistic model of an automobile's prefailure state]. Biulleten transportnoy informatsii 2010;9(183):35-38 [in Russian].

Denisov IlV, Denisov IvV. Innovatsionnyi podkhod k obespecheniyou bezopasnoy ekspluatatsii avtotransportnykh sredstv [An innovative method of ensuring safe operation of automotive vehicles. In: Anisimov IA, editor. Proceedings of the international research and practice conference Matters of Transportation Systems Operation. Tyumen (Russia): TyumGNGU; 2010. p. 85-88 [in Russian]. ISBN 978-5-9961-0277-8.

Denisov IlV. Naouchnie predposylki avtomatizatsii tekhnologicheskikh protsessov oupravlenia rabotosposobnostiu avtotransportnykh sredstv v ekspluatatsii [Scientific premises of automation of operability management processes of automotive vehicles in operation]. In: Proceedings of the XVI International research and practice conference Topical Matters of Automotive Vehicles Operation. Vladimir (Russia): Vladimir State University Publishing; 2014 [in Russian]. ISBN 978-5-9984-0549-5.

Denisov IlV, Smirnov AA. Metodika diagnostirovania elektromekhanicheskogo ousilitelia roulevogo oupravlenia bezredouktornogo tipa [Method of diagnosing direct action electromechanical power steering]. Elektronika i elektrooboroudovanie transporta 2016;5:22-25 [in Russia].

About the authors

Ilia V. Denisov, Candidate of Engineering, AG and NG Stoletov Vladimir State University, Senior Lecturer in Automotive Transportation, Vladimir, Russia, e-mail: denisoviv@mail.ru

Alexey A. Smirnov, AG and NG Stoletov Vladimir State University, second year master degree student, Vladimir, Russia, e-mail: AlexiFoX@yandex.ru

Received on 19.12.2016