The Analyses of the Polymer Materials Use with Multidirectional Friction Properties in the Suspension Elements of Land Transport Vehicles

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Abstract: The work for the decrease of cars cost price without loss of quality and safety demands is of great importance for the salvation of the demands to increase the efficiency of car vehicles exploitation. To achieve this aim on projecting and constructing car vehicles the use of the composite polymer materials is being regarded more actively. Due to the peculiarities of such materials their use can be limited by the outer factors and characteristics of the elements they are used in – extra shock, temperature ratings and friction. These factors can decrease economical effect of their use due to the necessity of frequent replacement. The use of the polymer composite materials in a car suspension elements is mostly dependant on the noted factors. Considering and analyzing different kinds of polymer composite materials a solution of their effective use in the elements can be found. The use of separate car elements in the movable suspension parts made of polymer composite materials lets reduce not only the cost price of cars but increase their durability. The constriction technology, durability and shock rating resistance let use polymer composite materials instead of anti-friction bearings of movable suspension parts which lets reduce expenses to produce car vehicles keeping the safety characteristics.

1 INTRODUCTION

Students' scientific community of the USURT has participated in interuniversity competition of technical projects Formula Student since 2012. The competition sets the aim to project and construct a formula-type open wheel racing car ("open-wheels" body type), and also to provide technical and commercial documentation for the projected car.

In connection with this, the University created a project center where the students project and construct the car. The center is equipped with the complex of constructing equipment, the equipment of quick prototyping and CAD for the models construction and analyses.

The competition sets a range of organizational and technical restrictions and demands including the safety of the designed vehicle. The prototype should pass a range of dynamical tests which contain stability tests, an acceleration characteristics evaluation and a durability run. The list of tests is set by the regulations developed by the Society of Automotive Engineers, SAE (2022 Formula SAE Rules, www.fsaeonline.com).

Moreover, the students' community is obliged to present a technical documentation for a newly designed car reconstructed with not less than 70 % of changes and now-how. Projects participating in the competition for more than a year are not admitted.

These restrictions oblige the design team to develop a vehicle with a high level of durability including the movable parts of the suspension elements under conditions of moderate and extra weight, and frictional shocks.

More than that, due to the demands for the optimization of the dynamic characteristics the design team has a task to find the ways to reduce the car sprung weight. The reduce of the weight lets improve the vehicle speed characteristics and reduces the consumption of energy carriers while moving (Lyu, 2015).

Increasingly important factors in projecting a car prototype are also the expenses for the production

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and the efficiency of the chosen production technologies.

For the demands, the mostly satisfying point within the work on the material collection became an offer to use parts made from polymer composite materials instead of antifriction bearings in the suspension elements shown in picture 1.

The analyses of the researches (Cherkasova, 2011; Imoshkov, 2017) set the fact that such decisions have been realized in some elements in the rail, automobile and other spheres of machinery construction. The efficiency of the use of composite materials in different kinds of knots has been experimentally confirmed (Alshahrani, 2022).

The use of polymer composite materials lets minimize the use of such expensive materials as titan, cobalt, chrome, nickel, molybdenum, and tantrum. The cost and energy expenses for the production and processing of polymer composite materials is much less than the mentioned materials. Also, the wear of the parts and knots caused by friction is reduced due to the optimization of the polymer composite materials anti-friction capacities up to the elimination of the necessity of using lubricating oil (Chukalovsky, 2009). More than that, the cost and customer performance can be optimized with the help of the methodologies of the projecting and implementation of the polymer materials elements (Romero, 2022).

As a result of the research there was the decision to change antifriction bearings in the movable parts of rockers fixings of the shock absorbers of the suspension on the bush (picture 2, 3), made from the domestic material “Oxaphene”.

The structure of “Oxaphene” is based on a complex thermo reactive composition. As a binding element phenolic compounds are used. As a strengthened material the fifth generation organic fiber “Arselon” – a special thermo resistant organic polyoxadiazole filling. The “Oxaphene” use was conducted during exploitation tests on the trolleys of the model 18-100 of freight cars – hoppers (Buyaev, 2005).

The physical properties of the material shown in table 1 increase the demanded indicators of a wide range of the polymer composite materials used in the machine building industry.

The experience of useing the parts produced from this material in the knots of railway rolling-stocks, as well as in the sphere of agricultural machinery engineering let suppose, that the use of “Oxaphene” in the suspension fixing elements can improve a range of an automobile characteristics (Fakhtullin, 2016).

To widen the sphere of using the polymer composite materials and also to study and effective implementation of the features of new polymer materials in the sectors of the national economy, there have been exploitation tests and researches conducted. To evaluate the effectiveness of a polymer material durability with multidirectional friction properties in the suspension elements a series of road tests has been conducted (figure 1-3).

Table 1: Physic-Chemistry Property of “Oxaphene” Material.

Indicator	Value
Solidity, not less than, g/sm^3	1,32
Failure stress, not less than, MPa In tension Compression in direction parallel to pressing Compression in direction perpendicular to pressing stress	 120 140 115
Solidity on Rockwell, scale number	85
Impact properties on Sharpy, kJ/m^3	34
Water absorbing in cold water (24 hours), %	0,14
Specific volume electric resistance, Ohm/sm^3	11*10^{13}
Oil resistance (24 hours), %	0,037
Petrol resistance (24 hours), %	0,005
Shrinkage on the models (80x10x4mm) on value, %	0,15
Coefficient of steel, titan, cast iron friction depending on exploitational conditions	0,05-0,3
Linear wear intensity mm/km	1*10^{-7}
Rider wear	Reduce to 2-3 times comparing to traditional durable materials
Friction heat resistance, ^{0}C	From -80 to +250

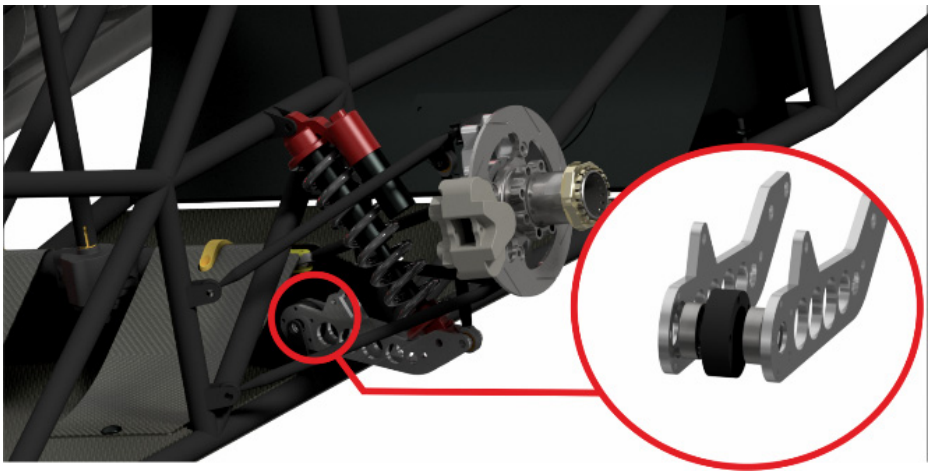

Figure 1: Rocker fixing knot with ball bearings.

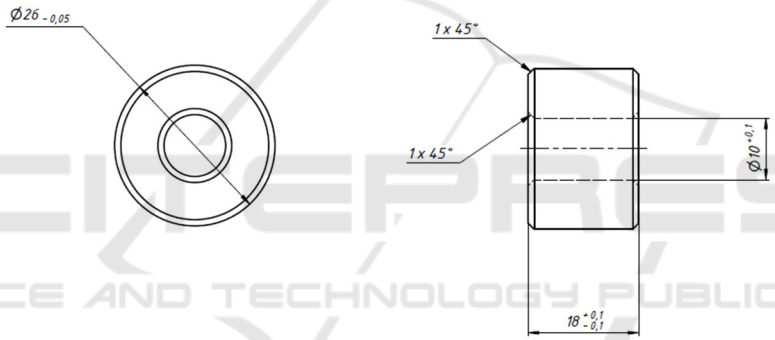

Figure 2: Polymer composite material bush.

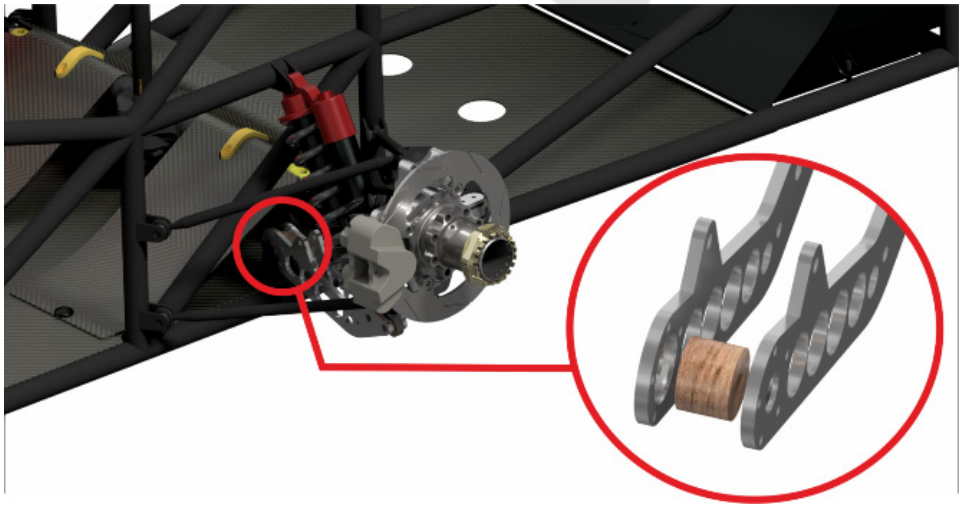

Figure 3: The construction of the rocker fixing knot with a polymer bush.

2 MATERIALS AND METHODS

A set of parts for the fixing knot of a rocker shock absorber of the front and rear suspension has been developed – 4 bushes – one for each point of fixation of rockers bases. A bush is set instead of a pair of rolling bearings and interposing spacer. Weight pressure on the elements of the front and rear suspension is determined proportionally: 46% front axle, 54% rear axle (the total car weight is 254 kg).

Series of road tests in real conditions was conducted by the design team. As a test field an asphalt road and a pathway with straight parts not more than 70 m and curves of 9 m radius had been chosen. The tests were conducted within the speed ratio from 50 to 80 km/h, which corresponds to the speed usually achieved in this class. In real conditions the profile of the racing track is full of the curves of both directions of a small radius – not less than 9 meters, and short straight parts – not more than 75 meters aiming to create "Testing" conditions for the machinery. An approximate race mileage is 50 km. That is, the action is organized to create the most complicated conditions for the cars. Preparatory and test tracks duplicate the same conditions close to the real road conditions.

The total mileage of the tested models is 1000 km. The wear control was conducted step by step within the period of autumn-winter. Table 2 contains the results of the sensor monitoring of the bush wear from the polymer composite materials in the rocker suspension elements. The monitoring of the elements was conducted by a digital caliper Matrix with the accuracy of 0,01 mm.

The data analyses of table 1 lets conclude, that at the first stage (mileage 110 km) all the models show an attrition wear (within the measurement accuracy of the tool). In the end of the tests cycle the total wear for NN 1 and 2 models is 0,03 and 0,02 mm respectively. At the same time, the intensity of the wear for the car front axle is 0,0025 mm per 100 km mileage and for the rear axle 0,0035 mm respectively. Such wear difference is explained by the car weight split – rear axle is pressed 8 % more than the front one.

Based on the fact that for the test period the car mileage is 100 km during the tests and not more than 100 km during the races, the use of the elements provides minimum 5 race cycles without geometry changes and the need of changing the elements.

Before the beginning of the initial run there was the control weighing of the set of bearings (the previous knot version) and the installed bushes (instead of the bearings) made from "Oxaphene". Taking into account that the set of bearings for one of four suspension rockers – two bearings and one plastic positioning spacer is 63,34 g., and the weight of one composite polymer materials bush "Oxaphene" is 10,31 g. the total weight economy is 212,12 g. It means that the weight of the movable elements of the rockers fixings is reduced to more than 6 times.

The costal price component of the decision to change the antifriction bearings to the bush made from "Oxaphene" has also a vivid effect. The cost of one of the four fixing sets is 420 rubles – two bearings 6200-2RSH [10x30x9] SKF is 175 rubles each and the plastic spacer costs 70 rubles (TreidImport, treidimport.ru). The cost of one

Table 2: Sensor monitoring results of the bush wear from the polymer composite materials in the rocker suspension elements.

Mileage, km	Model N1 (front left)		Model N2 (front right)		Model N3 (rear left)		Model N4 (rear right)	
	The bush inside diameter, mm	Wear, mm	The bush inside diameter, mmм	Wear, mm	The bush inside diameter, mm	Wear, mm	The bush inside diameter, mm	Wear, mm
0	10,08		10,10		10,04		10,06	
110	10,08	0,00	10,10	0,00	10,05	0,01	10,07	0,01
219	10,09	0,01	10,11	0,01	10,06	0,02	10,07	0,01
304	10,09	0,01	10,11	0,01	10,06	0,02	10,07	0,01
407	10,10	0,02	10,11	0,01	10,06	0,02	10,08	0,02
505	10,10	0,02	10,11	0,01	10,06	0,02	10,08	0,02
623	10,10	0,02	10,11	0,01	10,07	0,03	10,08	0,02
770	10,10	0,02	10,12	0,02	10,07	0,03	10,08	0,02
854	10,10	0,02	10,12	0,02	10,07	0,03	10,08	0,02
906	10,11	0,03	10,12	0,02	10,07	0,03	10,09	0,03
1000	10,11	0,03	10,12	0,02	10,08	0,04	10,09	0,03

"Oxaphene" bush is 193 rubles (retail price for February 2022). Totally the economy for the four fixing elements of the rockers suspension fixing elements is 908 rubles.

To get a more detailed data on the elements work, the decision to continue the test run and to increase the mileage for determining the life time of the elements until their critical wear, deformation, or failure was taken. Also, taking into account the developing tendency of the increase of the amount of polymer elements in the automobile manufacturing (Hagnell, 2020), it is supposed to set "Oxaphene" bushes to other movable elements of cars.

3 RESULTS AND DISCUSSIONS

According to the program of the tests the installed bushes were under a non-destructive testing every 100 km approximately. The evaluation of the condition of the tested models on the results of the run of 1000 km did not show mechanical or thermal failure of any model. The frictional area – the inner bush surface – is not deformed and has insignificant grinding traces. The rider surface is not deformed and also has insignificant grinding traces. The contact area with the movable parts – rockers, as well as the surface of rockers themselves is not deformed. Taking into account overweighting of rear suspension against the pressure on the elements of rear suspension, while carrying out the test activities, the greatest attention was paid to the rockers bushes of the rear suspension. The results of the track tests of the rockers bushes of the front and rear suspension are identical.

The crushed and fallen out bushes are not identified. The bushes are tightly set in their mounting seats and are contiguous tightly enough to the contact areas.

The determined by the tests 1000 km bushes life-time, taking into account that the run does not exceed 200 km per season, let use the "Oxaphene" bushes in the suspension of rockers fixings during not less than five cycles. The regulations set an obligatory annual renovation of the vehicle. However, up to 30 % of the elements may be installed into a new evolutionary model. It means that providing the bushes to be reinstalled within their life-time period, it is possible to save not less than 4540 rubles.

4 CONCLUSIONS

The use of the composite polymer materials allows to greatly reduce the wear of the contact area of the fixing knots of the car suspension movable elements.

The use of "Oxaphene" in the suspension elements is admitted. It is more effective, in some cases, against the use of bearings due to over-abrasion and dust in the fixing elements, and as a result an over-wear of ball bearings.

Under moderate friction, weight and shock ratings the use of "Oxaphene" in the fixing elements of the car suspension is possible without any lubrication, dust cover and other additional mechanical protection.

Moreover, the ball bearings changed to the "Oxaphene" bushes reduced the sprung weight of the car, as well as it reduced the expenses for the vehicle construction and it simplifies the process of the elements production.

It is necessary to increase the test run for a further research of the elements durability. The durability tests in mostly shocked elements are also needed.

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