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Dynamic parameters of composite leaf springs

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In this paper, results of research on vibration suppression in steel and composite leaf springs are presented. Polymeric composite leaf springs and steel springs are studied. Composite leaf springs were made of an epoxy-glass composite reinforced with glass fibre. Composite springs were designed in such a way that they could replace steel springs in a van. Static and dynamic examinations of both the springs were performed. The amplitude of vibrations and the reaction of props were measured and recorded. These parameters rendered it possible to calculate the logarithmic decrement of vibration suppression and the coefficient of vibration suppression for steel and composite leaf springs. The results are presented in tables and graphs. It is concluded that composite leaf springs in comparison to steel springs about three times better suppress vibrations, they are about five times lighter and generate smaller dynamic burdens to vehicle bodies. Wide applying of composites materials on structures of the vehicles will contribute to lower a vehicles mass and to decrease an emission of greenhouse gases.

1. Introduction

The growing oil prices as well as restrictions related to exhaust emission force engineers worldwide to search for alternative energy sources for mobile transportation and new materials for the construction of car bodies. The emissions from the transport sector have to be reduced. The EU has set goals for the reduction of greenhouse gas emissions by 20 % by 2020. An increased use of composite materials for the construction of car bodies is one of the solutions to reach these goals. Others are more energy efficient cars and a changeover to cleaner transport models. The use of polymer composite materials for the construction of vehicle suspension elements is not only a simple replacement of steel with a different material. Composite materials allow any formation of transverse sections of elements being produced, at the same time affecting the stiffness of such elements. Thus, it is possible to construct suspensions with the prescribed characteristics as well as integrated elements of suspensions which work as springy and leading elements. Due to the above it has been possible to simplify the construction of vehicle suspension and to lower considerably its weight and costs of production. Moreover, a greater capacity of composite materials to accumulate springy energy may allow the use of smaller and simpler dampers. Numerous researchers prove that springy elements constructed from composites materials in comparison with steel springs are characterized by higher fatigue durability, they are resistant to corrosion and they are many times lighter. A great advantage of composite materials is the way they get damaged under fatigue loading. Elements made of these materials, as opposed to steel elements, do not break or get damaged rapidly. This in turn increases considerably the safety of vehicle operation. The above mentioned properties of composite materials will decide about their wider application in the construction of vehicles, including also the construction of springy elements of suspensions.

2. General idea

The aim of this research is to study the ability of composite spring leafs to suppress vibrations. The composite spring was designed in such a way that it could replace steel springs in a delivery van. A comparison of the properties of the steel and composite spring was made.

In order to carry out the research it was necessary to produce composite springs of the same properties as the steel ones. Many technical problems had to be overcome in order to obtain repeatability of properties. This problems was described in [2]. The composite springs were of the same dimensions as the steel springs and were installed in the same way as the steel springs. Figure 1 presents the diagram of the composite leaf spring. The springs have a constant width and a changing thickness. The shape of the leaf spring is parabolic and it has three layers. The central layer (3 in Fig.1) of the width equal to that of the spring is of the thickness which changes along the length. The external layers (2 in Fig.1) called covers are of a constant thickness. Every layer was made of an epoxy composite which was strengthened with continuous glass fibre. Such a structure of the leaf spring resulted from the necessity to assure sufficient shear strength of the central layers and the required flexibility. At the two ends the leaf spring has specially profiled nests which co-operate with steel – rubber funnels. A detailed description of constructing such a spring is presented in [2].

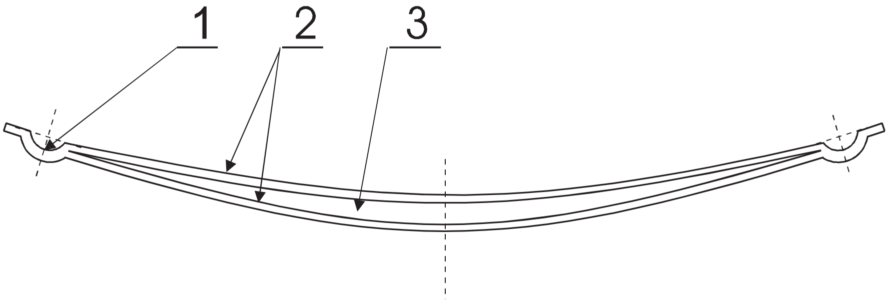

Fig. 1. Diagram of composite leaf spring: 1 - nests to fixing of funnel, 2 - covers, 3 - core.
Rys. 1. Schemat resoru kompozytowego: 1 - gniazda mocowania tulei, 2 - okładziny, 3 - rdzeń.

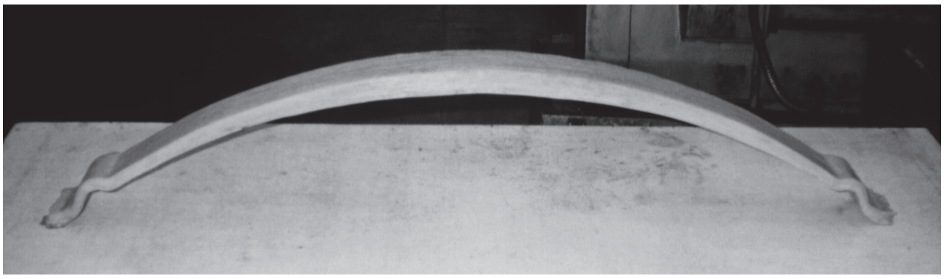

Fig. 2. Composite leaf spring.
Rys. 2. Resor kompozytowy.

Table1. Basic dimensions of leaf spring.
Tabela 1. Podstawowe wymiary resoru kompozytowego.

Parameter	leaf spring	
	composite	steel
Spring width [mm]	80	80
Spring length [mm]	1305	1305
Spring mass [kg]	12	50

3. Experimental research

The device on which the research was carried out is shown in Fig. 3. It includes two principle components: the loading component and the measurement- registering component. The loading unit comprises a striking part – 6 (Fig. 3) and the steering component – 8 (Fig.3). The measurement and registering component includes the sensor of force - 2, sensor of perpendicular dislocations of the centre of the spring –3, sensor of horizontal dislocations of the ends of the spring – 3. The device made possible both the static and dynamic loading of the leaf spring. Loading has been carried out by free lowering of the striking part of 350 kg, which was hung on a rope and placed in runners. The strength of props was measured by the sensor of force, whereas perpendicular and horizontal dislocations of the central part of the spring as well as those of its movable end were measured by the sensors of dislocations. Signals from the sensors were transmitted to a PC where they were recorded in textual files. Steel and composite leaf springs were investigated.

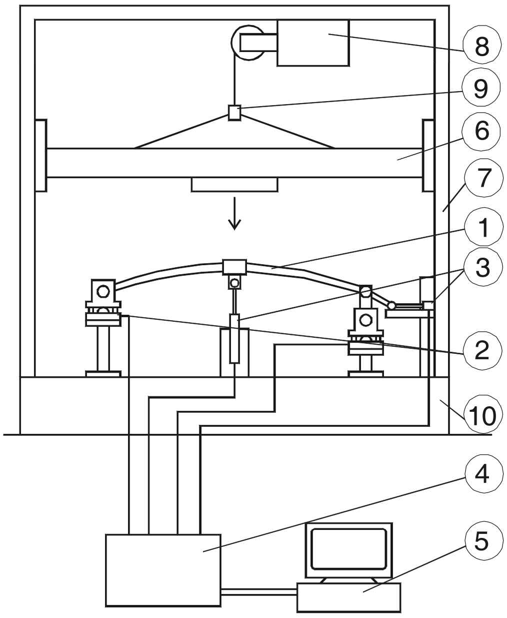

Fig. 3. Diagram of the research device: leaf spring; 2 - sensor of force; 3 - sensor of dislocations; 4 - amplifier; 5- PC computer; 6 - striking part; 7 - runners; 8, 9 - steering component.
Rys. 3. Schemat stanowiska badawczego: 1 - resor; 2- przetwornik siły; 3 - przetworniki przemieszczeń; 4 - wzmacniacz; 5 - komputer PC; 6 - bijak; 7 - prowadnice; 8, 9 - mechanizm sterujący.

Data from the sensors were recorded in textual files in a PC. Using these data, for each test graphs were made which showed the radial diffraction and the sum of perpendicular reactions of props as a function of time. Also, for each test the coefficient of vibration suppression was calculated. Table 2 and Fig. 4 present measurement data for the composite leaf spring, whereas Fig. 5 and Table 3 show the data for the steel leaf spring.

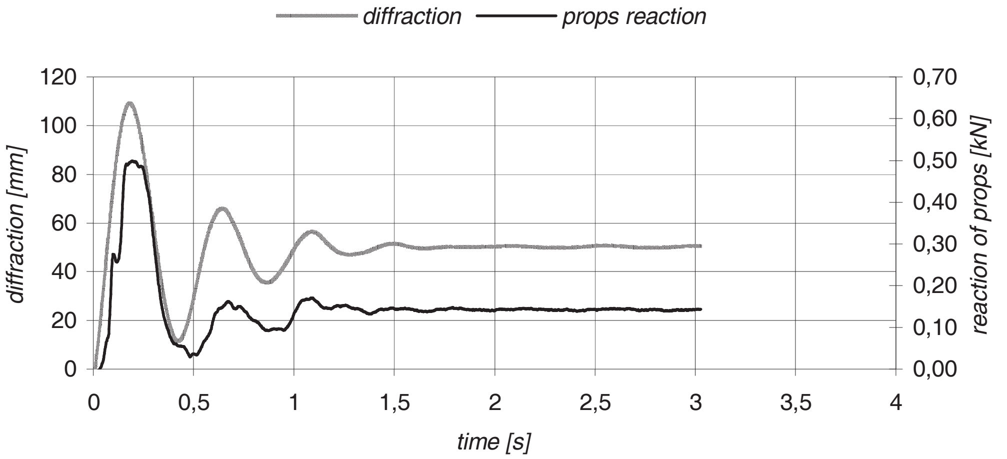

Fig. 4. Diffraction and total perpendicular reaction of props in function of time composite leaf spring.
Rys. 4. Ugięcie i suma pionowych reakcji podpór w funkcji czasu resoru kompozytowego.

Table 2. Coefficients of suppression of vibrations for composite leaf spring.
Tabela 2. Współczynniki tłumienia drgań resoru kompozytowego.

Test	a_n [mm]	a_{n+1} [mm]	t_n [s]	t_{n+1} [s]	T [s]	Logarithmic decrement of suppression D	Coefficients of suppression q
1	27,6	0,74	0,420	0,890	0,470	1,3	2,77
2	25,4	0,54	0,225	0,692	0,467	1,54	3,30
3	15,9	0,34	0,223	0,725	0,502	1,54	3,07
4	47,1	15,3	0,160	0,603	0,443	1,12	2,53
5	36,7	7,5	0,202	0,652	0,450	1,59	3,53
6	49,7	11,3	0,187	0,627	0,440	1,48	3,63
7	59,0	15,8	0,180	0,634	0,454	1,32	2,91
8	61,8	27,4	0,176	0,663	0,502	0,81	1,95
9	60,6	23,8	0,186	0,665	0,490	0,93	1,84

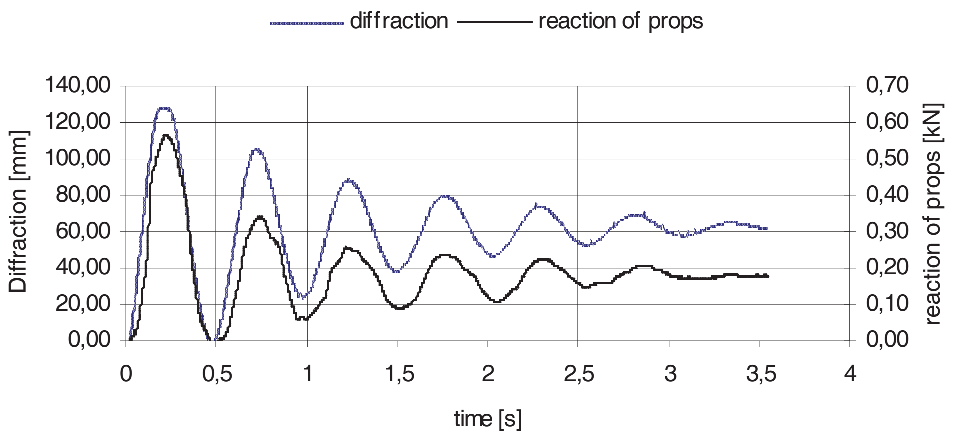

Fig. 5. Diffraction and total perpendicular reaction of props in function of time steel leaf spring.
Rys. 5. Ugięcie i suma pionowych reakcji podpór w funkcji czasu resoru stalowego.

Table 3. Coefficients of suppression of vibrations for steel leaf spring.
Tabela 3. Współczynniki tłumienia drgań resoru salowego.

Test	a_n [mm]	a_{n+1} [mm]	t_n [s]	t_{n+1} [s]	T [s]	Logarithmic decrement of suppression	Coefficients of suppression
1	43,9	24,4	0,262	0,785	0,523	0,59	1,12
2	45,3	24,3	0,259	0,788	0,529	0,62	1,18
3	45,2	24,5	0,258	0,776	0,518	0,61	1,18
4	49,4	28,2	0,223	0,745	0,522	0,56	1,08
5	50,8	33,1	0,222	0,757	0,535	0,43	0,80
6	51,0	30,2	0,218	0,728	0,51	0,53	1,03
7	62,7	36,6	0,212	0,723	0,511	0,54	1,05
8	65,4	38,0	0,20	0,714	0,512	0,54	1,06
9	65,8	38,6	0,199	0,732	0,533	0,53	1,00
10	66,2	43,5	0,2	0,706	0,506	0,42	0,83
11	66,0	46,4	0,194	0,711	0,517	0,35	0,68
12	66,4	43,8	0,21	0,723	0,513	0,41	0,81

4. Recapitulation

Data from the sensors were recorded in textual files in a PC. Using these data, for each test graphs were made which showed the radial diffraction and the sum of perpendicular reactions of props as a function of time. Also, for each test the coefficient of vibration suppression was calculated.

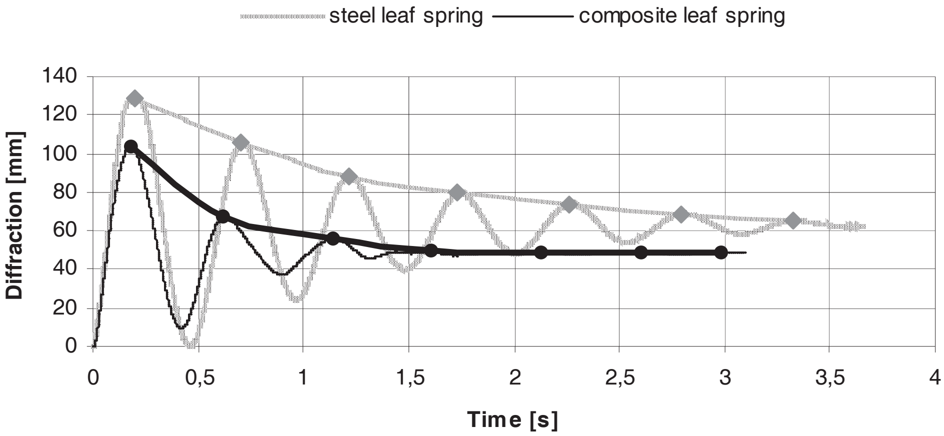

Fig. 6. Tremblings course of chosen steel and composite leaf spring.
Rys. 6. Przebieg drgań wybranego resoru stalowego i kompozytowego.

Table 4 shows the coefficient of vibration suppression in steel and composite leaf springs. The coefficients of vibration suppression were calculated using the research results and the following equation:

$$\rho = \frac{\ln\left(\frac{a_n}{a_{n+1}}\right)}{T} \tag{1}$$

$$D = \ln\left(\frac{a_n}{a_{n+1}}\right) \tag{2}$$

where:

D – logarithmic decrement of suppression; T – period of vibrations [s];

a_n – first (larger) inclination; a_{n+1} – next inclination.

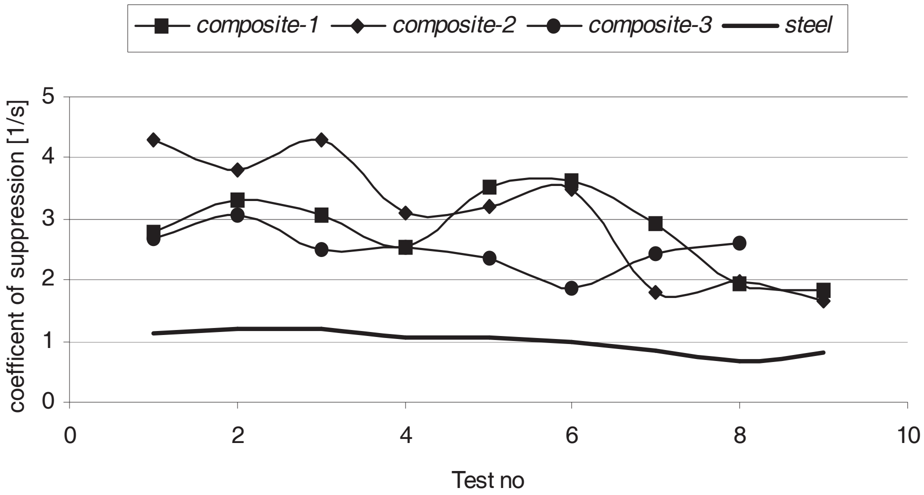

Fig. 7. Suppression coefficients of vibrations composite and steel leaf springs.
Rys. 7. Współczynniki tłumienia drgań resorów kompozytowych i stalowych.

Table 4. Suppression coefficients of vibrations composite and steel leaf springs.
Tabela 4. Współczynniki tłumienia drgań resorów kompozytowych i stalowych.

Test no	Energy of hitting	Leaf spring coefficients of vibrations	
		composite	steel
1	Static load; Q= 3500N	2,77	1,12
2	Static load; Q= 3500N	3,30	1,18
3	Static load; Q= 3500N	3,07	1,18
4	1400 J	2,53	1,05
5	1400 J	3,53	1,06
6	1400 J	3,63	1,00
7	1750 J	2,91	0,83
8	1750 J	1,95	0,68
9	1750 J	1,84	0,81

Coefficients of vibration suppression of leaf springs are very different. In the case of composite springs this value ranges from 1,65 to 3,63. The coefficients for steel springs do not reach such different values. The values are from 0,68 to 1,18 (Tab. 4).

Coefficients of vibration suppression of steel leaf springs are in the range of 1, they are about three times smaller than the coefficients for composite springs. A comparison of the property of vibration suppression of some composite leaf springs and steel leaf springs is shown in Fig. 7.

Not only the value of vibration suppression coefficients of steel leaf spring is smaller, but also their sensibility to a change of loading. The coefficients of composite leaf springs clearly decrease when load is increased. At the same dynamic load, reactions of steel springs are larger than the reactions of composite springs. The difference is about 20%.

Conclusions:

- Leaf springs made of a glass-epoxy composite have a greater ability to suppress vibrations than steel springs,
- Composite materials offer a possibility of forming any shape of vehicle suspension components. Therefore, it is possible to obtain the desired stiffness, elasticity and vibration suppression in components made of these materials,
- Vehicle components made of glass-epoxy composites are about 5 times lighter than made of steel,
- The use of composite materials for the construction of vehicle components is a good way to reduce emissions of greenhouse gases.

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Parametry dynamiczne resorów kompozytowych

Streszczenie

W artykule przedstawiono wyniki badań podstawowych parametrów dynamicznych resorów kompozytowych. Przeprowadzono badania statyczne i dynamiczne. Badania prowadzono na resorze kompozytowym który jest współzamienny z resorem stalowym stosowanym w zawieszeniu samochodu dostawczego Lublin. Obliczono współczynniki tłumienia drgań resorów stalowych i kompozytowych. Wyniki zestawiono w tabelach oraz przedstawiono za pomocą wykresów.