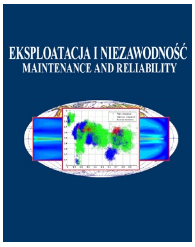

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Analysis of the end-of-life the front suspension beam of a vehicle

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Highlights

- The wear of the front suspension beam.
- Fretting wear is observed in the top layer of the beam.
- Wear products include oxygen, silicon and chlorine atoms.
- Material hardness is observed to decrease, thus causing reduction of abrasion resistance.

Abstract

The aim of the article is focused on assessing the degree of end-of-life for the vehicle front suspension beam. The first stage of the problem taken was represented by a road test of the vehicle at distance expressed by 100.000 km. Following the end of the operation tests, the suspension beam was dismantled and subjected to laboratory tests. The tests demonstrated numerous beam top layer plastic deformations, which came into being as a result of the vehicle driving onto an obstacle on the roadway or onto raised road infrastructure elements. At the point of connection of the stabiliser rod to the beam, surface degradation was noted, which consisted in the considerable change of the surface profile, hardness reduction and the grey and dark brown colour. Corrosion regions and fretting wear traces were noted. Corrosion pits, scratches and material build-ups was observed. The analysis of the chemical composition of wear products demonstrated the presence of elements such as iron, oxygen, chlorine and silicon, as an effect of operational conditions.

Keywords

vehicle suspension system, fretting wear, suspension beam, vehicle.

1. Introduction

In recent years, the dynamic development of road transport is observed, which directly translates into heavy road traffic with vehicles in a diversified technical condition. Visible on the roads are new vehicles with the high reliability indicator as well as used vehicles with considerable mileage. As a rule, the technical condition of the latter vehicle group is poor, and their components become damaged frequently and prematurely.

The road conditions are a significant factor influencing the vehicle technical features, in particular the components of the suspension system. Notwithstanding the fact that the number of motorways and dual carriageways as well as town and city bypass roads grows every year, the technical conditions of the pavement of many roads is still bad. Not infrequently, ruts, cavities of considerable depth in the pavement, humps etc. are encountered, which are the consequence of the heavy traffic of vehicles, mainly trucks [15, 28]. Several roads are being rebuilt without being phased out from traffic, which causes high pavement variability (e.g. asphalt or milled pavements or those with the subgrade made of a compacted building material).

Driver's deeper concentration and better driving skills are required at roads in a bad technical state. The lack of those skills may cause the damage of the suspension system components, such as the front suspension beam.

From engineering point of view, the suspension system is one of the most important structural elements responsible for driving comfort [5] and safety [24]. Engineers of automotive industry components of suspension systems by using, modern engineering materials (…) [27], new components (…) [2, 22-23] or manufacturing technology (…) [3]. They efforts are also focused on of vibrations in the suspension system on the driver's working conditions [7]. In [6], the authors analysed the possibility of using electric motors in vehicle wheels. This type of solution, may cause a deterioration of travel comfort due to the increase in unsprung masses. Therefore the authors have investigated the problem of vertical vibrations of the suspension. Damages to the elements of the suspension system are caused by forces originating from the vehicle weight [4] as a well as road quality, environmental conditions, and driver's skills.

Even though vehicles are subjected to compulsory technical inspections and service following from the operation period, the task of such inspections and service being the prompt detection of damage or wear and tear, unexpected damage to the suspension system elements is still noted, such damage preventing the further operation of the vehicle.

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Such a situation may be due to a failure to recognise microcracks or other defects of the materials, which are not yet visible by means of available service instruments or organoleptically, but those defects may develop with the passage of time, especially when the vehicle is driven in difficult road conditions. Damage which is not detected promptly and which continues to develop will transform into fatigue wear [30], with the element's fracture being the consequence.

The influence of the technical condition of the suspension system on driving comfort and safety, investigations were conducted aiming at the analysis of the wear of the front suspension beam, especially at the region of connection with the stabiliser rod. The authors are of the opinion that in view of the operation conditions of the suspension system, wear may occur at that place, which is impossible to verify during technical inspections at diagnostics garages. As a consequence of damage at the joint mentioned above, the development of fatigue wear may take place, as a result of which the joint may be destroyed. That is why an attempt was made to verify that thesis by firstly conducting operation and then laboratory tests.

Vehicles are used in various climate zones, which are distinguished by vast differences in weather conditions (air temperature, rain and snowfalls), and move on roads built in various technologies and in various technical conditions. The accumulation of all those factors makes the suspension system, in particular the beam, operate in harsh conditions. That is why suspension systems should be distinguished by long life and operational reliability. Structural design engineers strive for the continuous improvement of suspension system components to improve their functional quality. This task is by no means an easy one because, as mentioned previously, suspension systems operate in conditions comprising many factors (Fig. 1). Those factors rarely act on the suspension system at the same time, thus creating a complex operation environment.

The leading factor affecting the technical condition of the front suspension beam is the road pavement condition and therefore the dynamic impact on the vehicle. Road pavement irregularities are random in nature and it is not possible to describe them with one function. The vehicle passage on the irregularities and road pavement cavities causes the deflection of both the sprung and unsprung weight. The size of those displacements depends on the vehicle weight and road pavement condition [10].

When a vehicle drives on roads, dynamic loads are generated on wheel, which are transferred to the vehicle body through the components of the suspension system. The configuration of those elements in the springing movement space changes continuously. Determination of dynamic loading for each possible configuration in the springing movement space is needed for capturing stress state in the sections of the elements of the suspension and steering system [25].

The next material factors influencing the technical condition of the front suspension beam are the environmental factors. Depending on the pavement type, precipitation causes the increase of driving movement resistance and therefore the reduction of the adhesion coefficient. Consequently, the vehicle driver is forced to break and change the driving speed more often, due to which the additional displacements of the mating elements of the suspension system take place. Those displacements occur in the micro space, however, long vehicle operation time in such conditions will be conducive to the development of the wear of the suspension system tribological kinematic pairs. Moreover, water from the road may penetrate into the gaps between the suspension beam and stabiliser mounting thus favouring the faster wear of those elements.

In terms of its life, the front suspension beam is disadvantageously affected by driving in the winter period, especially when low air temperatures, snowfalls and snow melt periods prevail. Works preventing the occurrence of winter slipperiness as well as its elimination are carried out then. Those works consist in making the road pavement resistant to the formation of an ice or iced snow layer with the use of chemicals lowering the water freezing point. Winter slipperiness elimination, however, consists in the removal of ice and compacted snow by means of chemicals, anti-skid agents or mechanic measures.

Using a vehicle on a road pavement where chemical deicing agents have been used exposes, in particular, the suspension system to chemical reactions with its structural elements [19], which may lead to the initiation of corrosion processes and, consequently, to the development of fretting wear.

Driving skills may be another factor influencing the technical condition of the suspension system. One of the fundamental vehicle driving rules is to obey the prudent and careful driving principle. This principle requires the driver to analyse the road pavement and current traffic environment conditions on an ongoing basis. The driver must also know the loading on the vehicle. Speed selection and the skills related to overcoming the obstacle etc. have the significant influence on the operation of the suspension system [26] and therefore on the damage to the beam or the development of beam wear and tear. The vehicle driver should react to changing road conditions, ruts or cavities in the pavement early enough. The lack of the driver's reaction such as speed reduction, or uncritical driving into the cavities in the road pavement, has considerable influence on the possible damage to the suspension system elements [11-12].

2. Test methodology

2.1. Test object and its work environment

The tested object was represented by a front suspension beam of a vehicle (Fig. 2). The beam is a component of suspension belonging to the group of independent suspension systems, which are distinguished by a separate system of guide elements permitting the independent wheel operation. In the case of that type of suspension, increasing the number of wheel guide elements and the related increase of the number of wheel movement planes enhances the option to ensure the appropriate transfer of forces to the vehicle body.

Front suspension beams of five brand new delivery vehicles at the same distance in comparable conditions were inspected. The vehicles were used at various routes and roads and serviced both urban and rural areas. Fig. 3 shows the results of road pavement evenness tests for the selected road section, at which the vehicles were operated. The tests were conducted in accordance with BN-68/8931-04 with the use of the PD01 Omega planograph. The measurement was conducted at a 400-500 m section, and the planograph was set for the registration of maximum variances greater than 4 mm (the red line in the diagram). The pavement requires comprehensive heavy repairs or even redevelopment. The following defects: ruts, fissures, cracks,

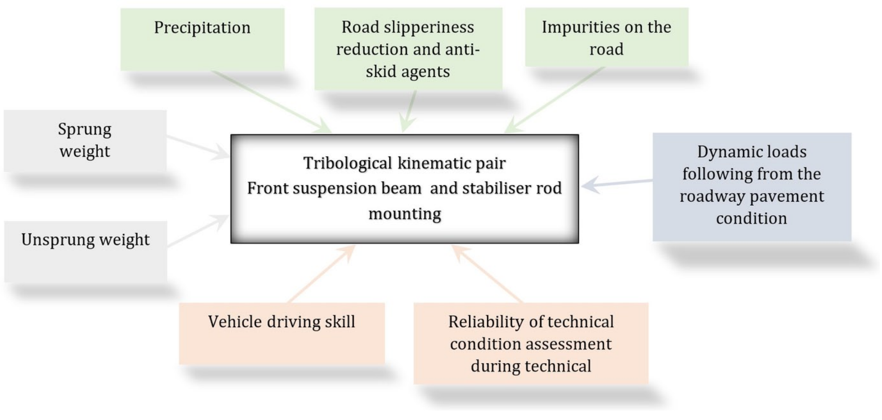


Fig. 1. Components of the operation conditions of the front suspension beam and stabiliser rod mounting tribological kinematic pair

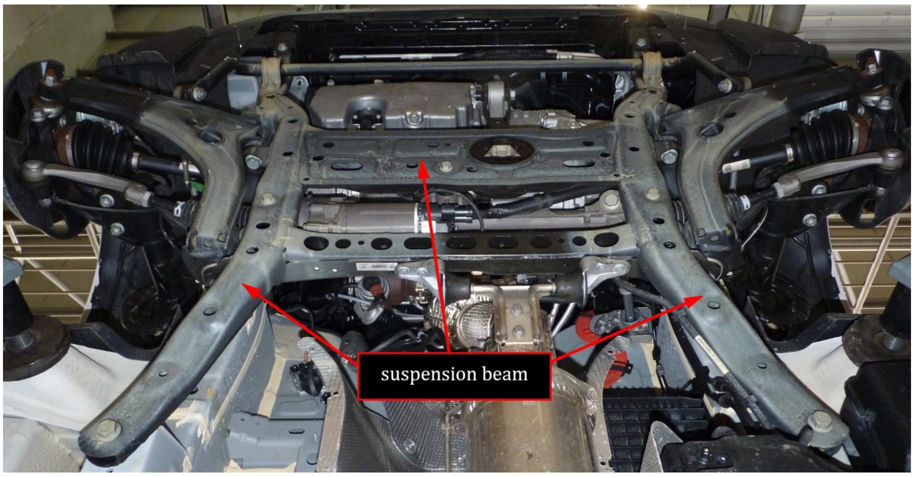


Fig. 2. View of the front suspension beam mounted in a delivery vehicle

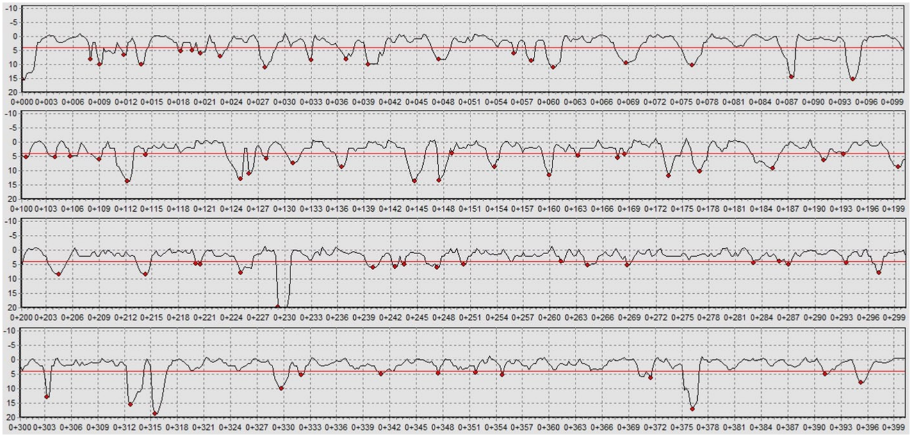


Fig. 3. Unevenness of road pavement in a form of a profile

reflection cracks, pavement chippings, potholes and roughness loss were noted.

The monitored vehicles constituted the fleet of a courier company and transported shipments of varied weight, as shown in Table 1.

Table 1. The mass of vehicle and kilometers

Laden vehicle mass [kg]	Number of kilometres covered [km '000]
2100	16
2450	20
2800	29
3150	23
3500	12

Each of the vehicles covered a comparable route with the total length of approximately 100,000 km. It was assumed that the vehicles' drivers are professionals and the have similar driving skills. Only few cases of accidental driving into a rut which might pose a risk to the suspension beam were noted. The vehicles were driven throughout the year, therefore temperature conditions varied within the range from –15 to 30°C.

After each day of vehicle operation, the technical condition of the suspension beam and other elements of the suspension system was monitored, and the data base was created with the type of damage and the number of kilometres at which damage occurred. The place of connection of the beam with the stabiliser rod was an exception. For technical reasons, that place was not observed during vehicle operation.

The suspension beam was made in the form of pressure-welded steel drawpieces whose chemical composition is given in Table 2. The drawpieces were joined with each other by means of pressure welding. The beam shape and the manufacturing process ensure a suitably strong spatial profile bolted to the vehicle body and integrating the suspension components together.

Table 2. Chemical composition of suspension beam steel [% by weight]

C	Fe	Si	Mn	P	S	Cr	Mo	Ni	Cu	Al
0.074	98.65	0.095	0.744	< 0.005	< 0.005	0.014	< 0.001	0.024	< 0.005	0.042

2.2. Test procedure and laboratory equipment

The test programme was divided into two stages. The first part pertained to vehicle operation tests and to the recording of damage to the suspension system with special emphasis on the suspension beam. The duration of those tests was approximately equal to two years. The second part of the investigations, however, consisted in laboratory tests permitting the beam technical condition and degree of wear to be determined.

The operation test methodology has been discussed in the previous item. Laboratory tests were performed following the preparation of test specimens. The preparation of the test material for laboratory tests consisted in the performance of the following activities:

- dismantling of the suspension system from the vehicle,
- determining evaluation of the technical condition of the front suspension beam,
- protecting damaged or worn-out places,
- decomposition of the suspension beam from the suspension system,
- cleaning with the use of the sand blasting technology at damage zones protection,
- cutting out of samples and performing laboratory observations on the samples.

As part of laboratory tests, macroscopic and microscopic observations with the EDS analysis of the chemical composition were performed and the beam surface profile and hardness were measured.

The macro-photographic observations of the damage regions were conduced by means of use of the NIKON COOLPIX P900 camera with 83x magnification.

The places with noted damage were subjected to microscopic observation with the use of the JEOL JSM-5510LV scanning electron microscope. The investigations by means of scanning electron microscopy were performed in the backscattered electron composition (BEC), backscattered electron shadow (BES) and secondary electron image (SEI) modes with the electron beam acceleration voltage equal to 20 kV.

The quantitative and qualitative microanalysis of the chemical composition at damaged surfaces was conducted by means of the electron microscope equipped with the EDS INCA x-act Energy 350.v spectrometer.

The topography of the suspension beam surface was measured by means of the Form Talysurf Intra device by Taylor Hobson. The obtained data was used for the determination of roughness parameters and for their graphic presentation with the use of TalyMap Platinum 5.1 software. Each measurement was conducted three times, and the averaging results are presented in this work. Test specimens were selected of the beam in such a way as to ensure the measurement within the area both affected and not affected by wear.

Beam hardness was measured by means of the Vickers method in accordance with PN-EN ISO 6507-1:2018 standard. The loading force equal to 19.6 N (HV2) was applied. The test plan assumed three measurement tests. As part of each test, assumed was the hardness measurement at nine survey points (three in the area affected by wear and six in the area not affected by wear).

3. Test results

Front suspension beams of five delivery vehicles were examined. The results of the tests and observations demonstrated top layer plastic deformations of various sizes. After all the elements connected with the beam had been dismantled, considerable deformation of the beam top layer at the point of connection of the stabiliser rod was found. In the authors' opinion, that part of the beam required detailed laboratory tests because, in addition to the change of the top layer profile, that place was distinguished by the grey and dark brown colour, which may suggest fretting wear.

The macrographic observations of the beam plating demonstrated wear in the form of plastic deformations of a peculiar arched shape (Fig. 4). The range of those deformations was insignificant and had no influence on the change of the original beam shape. Linear scratches of the plating as well as hairline cracks of the minimum depth in the beam plating were also noted. The cause of that kind of damage is sought in the contact of that element of the chassis with items making the road dirty, such as sand particles, stones etc., which may have fallen down from aggregate-carrying vehicles. Such items may have also been brought onto the road by vehicles joining the traffic from a construction area or aggregate collection points. Damage described above was located at the lower beam plating, where friction or impact contact with obstacles present on the road may take place.

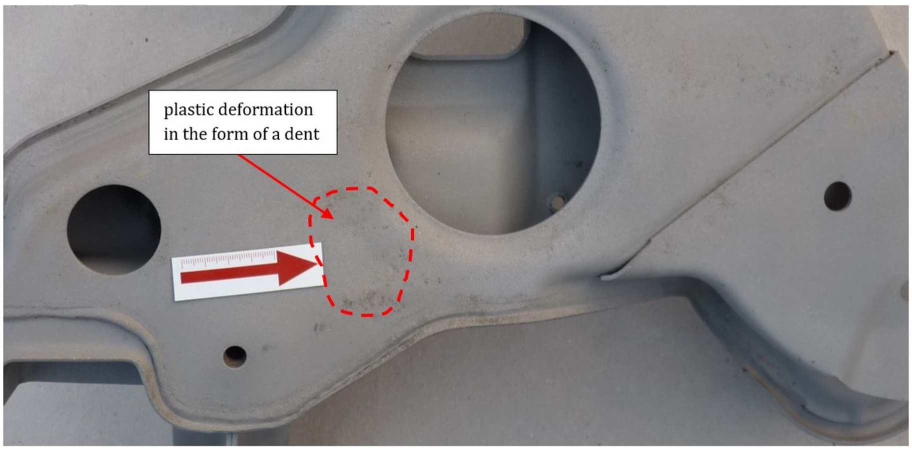


Fig. 4. Beam damage in the form of plastic deformation

That damage, consisting in plastic deformations, did not affect driving safety and was easy to locate during technical inspections, that is why a detailed analysis of that damage is omitted in the further part of this article. The main focus was on the wear following from the natural operation process, which cannot be verified and removed during diagnostic tests.

The detailed macrographic observations of the beam surface demonstrated peculiar changes of the surface profile at the point of connection of the stabiliser rod (Fig. 5). Visible wear traces occupy a square area of 16 cm^2. The wear-affected area is distinguished by high waviness and a change of the top layer structure.

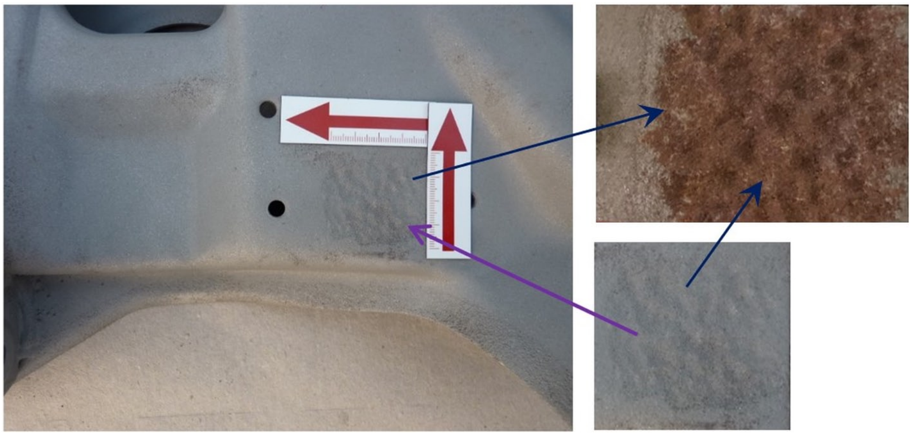


Fig. 5. Front suspension beam fragment with visible wear traces

It is appropriate to think that fretting is highly likely to be noticeable at the point of connection of the stabiliser with the front suspension beam. To confirm that theory, however, further tests and analyses are necessary. The required condition for the development of fretting wear in the case of the front suspension beam and stabiliser rod tribological kinematic pair was fulfilled.

As it can be noticed in other articles [8, 9, 16, 20], the following conditions are realted to fretting:

- contact between two surfaces of the bodies – that condition is fulfilled as the beam mates with the stabiliser rod through bolted mounting, that is at the place where damage mentioned previously was noted;
- small-amplitude oscillatory tangential displacements of body surfaces as a result of the activity of a variable normal force or the tangential force to the contact surface. This condition occured, at the vehicle moving along the road with various and significantly pavement profiles.

In order to recognise features of the wear zones, microscopic observations were conducted. Fig. 6 presents SEM images of wear traces.

The microscopic observations confirmed the macroscopic observations suggesting that the main damage of the beam at the point of mounting the stabilisers rod is constituted by corrosion or fretting wear. The following features were observed: fatigue crack, corrosion pits, hairline cracks and material build-ups, which become plasticised and crumbled.

To identify wear products, conducted was the analysis of the chemical composition of the beam area containing peculiar traces indicating fretting wear. Surface and spot analysis at three selected places was performed. The results of those investigations are shown in Figures 7 and 8.

The surface analysis of the chemical composition of wear products demonstrated the presence of iron, oxygen, silicon, chlorine and manganese atoms. The spot analysis of the chemical composition at another place also demonstrated the presence of the same elements. Iron and oxygen atoms prevail in the chemical composition of wear products. Such a result is the evidence of the penetration of oxygen in between the mating surfaces, which leads to surface oxidation and to the initiation of a phenomenon similar to corrosion. In the case of fretting wear, iron and oxygen atoms are the prevailing components of the wear products, too [1, 21, 29]. Thus, the thesis that the suspension system elements may be exposed to fretting confirmed in this case as well.

The analysis of the chemical composition of wear products demonstrated the presence of silicon and chlorine atoms. Silicon is the evidence of the presence of sand or other impurities from the road in the space between the beam and stabiliser rod mounting. This also proves the fact that the vehicles were moving on sand or unpaved roads. During vehicle operation, sand grains trapped in the space between the mating elements move in various directions thus causing, with the passage of time, the development of friction wear and surface scratches on the micro scale, which may also initiate the development of fatigue cracks. The presence of chlorine atoms confirms that the vehicles were moving on roads at which slipperiness was reduced by means of road salt. During suspension system deflection, salt present on the road would penetrate into the space between the beam and stabiliser rod mounting. Road salt which will not be removed from that space, will accelerate wear processes.

The examined beam surface at the place of wear showed considerable changes in geometry in relation to the remaining part of the beam, that is why surface roughness and hardness were also measured.

The wear of the elements of the tribological kinematic pair results in the changes of surface geometry and in the top layer structure, which arise as a result of the mutual influence of the mating surfaces. The degree of wear depends, first of all, on the work environment of that tribological kinematic pair. One of the ways of measuring the changes in surface geometry is the evaluation of profile of the surfaces [17-18].

The configuration of the surface structure, including the degree of surface isotropy, influences wear intensity. In view of contact between the mating surfaces, which are influenced by the degree of isotropy, wear may be intermittent or continuous [14]. Given a small degree of isotropy, the ridges of the irregularities move on one another, and given a high degree of isotropy, the ridges of microirregularities rest on one another or find their way into the cavities, ridge the opposite surface or become shorn [13]. In the latter case, there will be more wear products and the surfaces may demonstrate lower wear resistance. The lay of the surface structure has significant influence on friction wear intensity, and the mating angle between the structures will influence the wear mechanism [14]. Greater surface roughness reduces corrosion resistance due to the increase of the actual contact surface area of the corroding element. For that reason, the biggest influence on corrosion wear intensity is exerted by high surface roughness parameters and the radius of curvature of microirregularity pits.

The results of the three-dimensional surface profile measurement are shown in Figures 9 and 10, and the obtained parameters of the surface

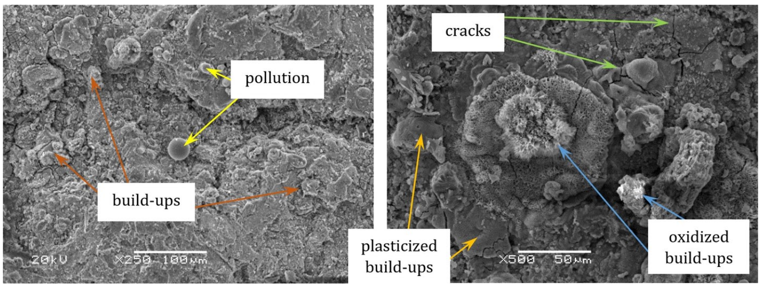


Fig. 6. Sample SEM images of the wear products on the front suspension beam surface

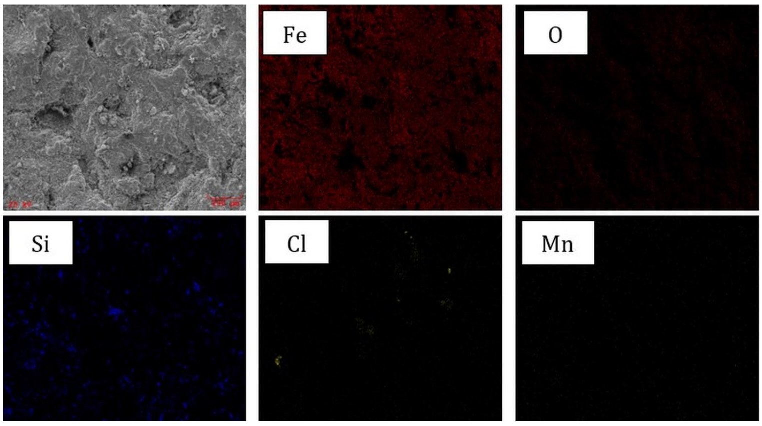


Fig. 7. Surface analysis of the chemical composition of the front suspension beam wear products

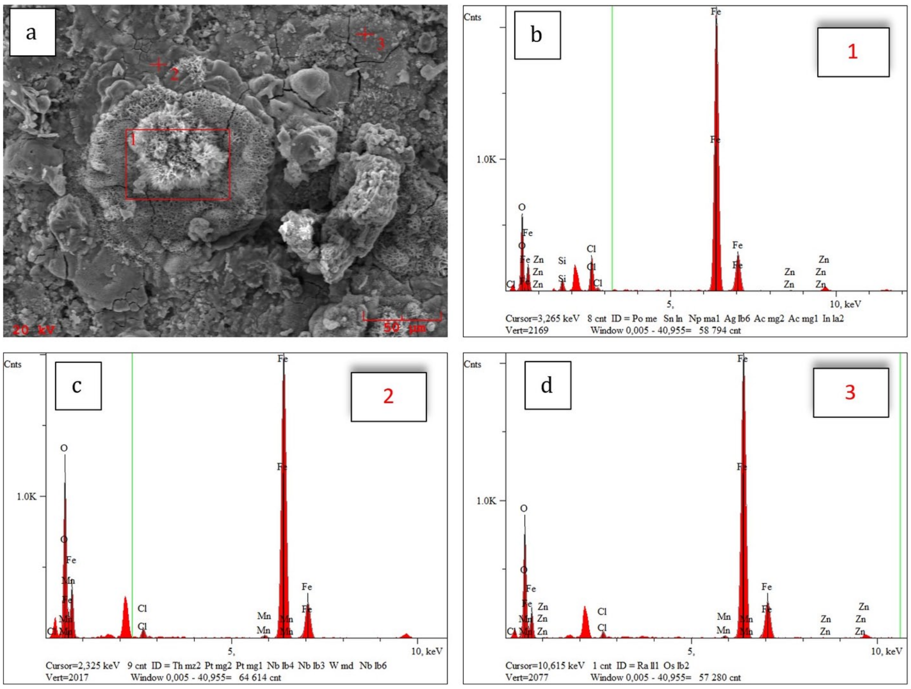


Fig. 8. Spot analysis of the chemical composition: a) SEM image, b) radiation spectrum peculiar for point 1, c) radiation spectrum peculiar for point 2, d) radiation spectrum peculiar for point 3

		Chemical composition of wear products			
Chemical element	Line	Area 1	Point 2	Point 3	Unit
Fe	Ka	62,582	77,679	60,096	wt.%
O	Ka	30,688	47,519	38,245	wt.%
Cl	Ka	4,086	0,993	0,768	wt.%
Si	Ka	2,166	–	–	wt.%
Zn	Ka	0,478	–	0,446	wt.%
Mn	Ka	–	0,434	0,603	wt.%

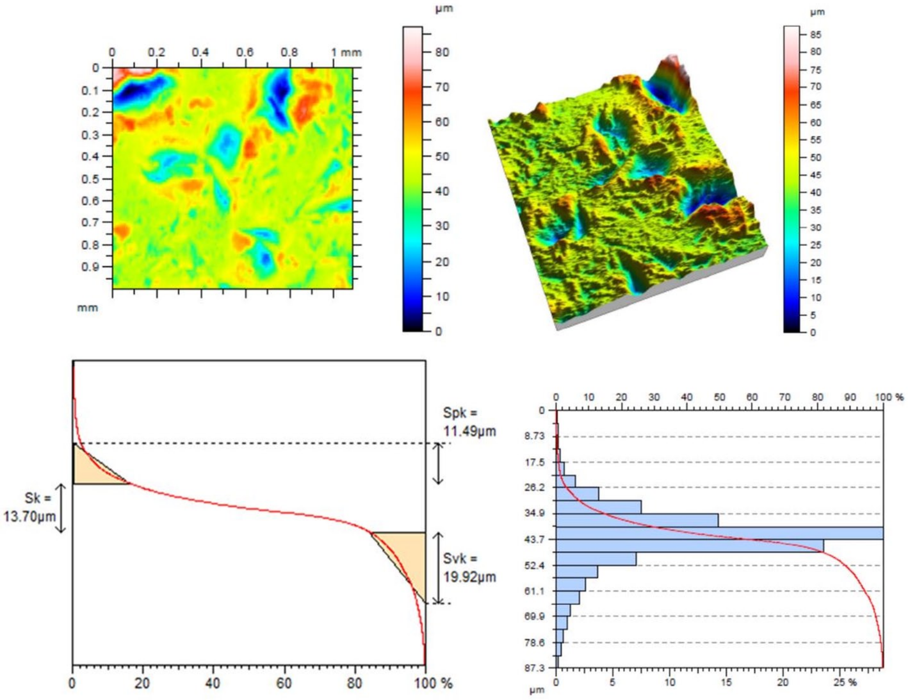


Fig. 9. The area without wear traces in profilometrical analysis

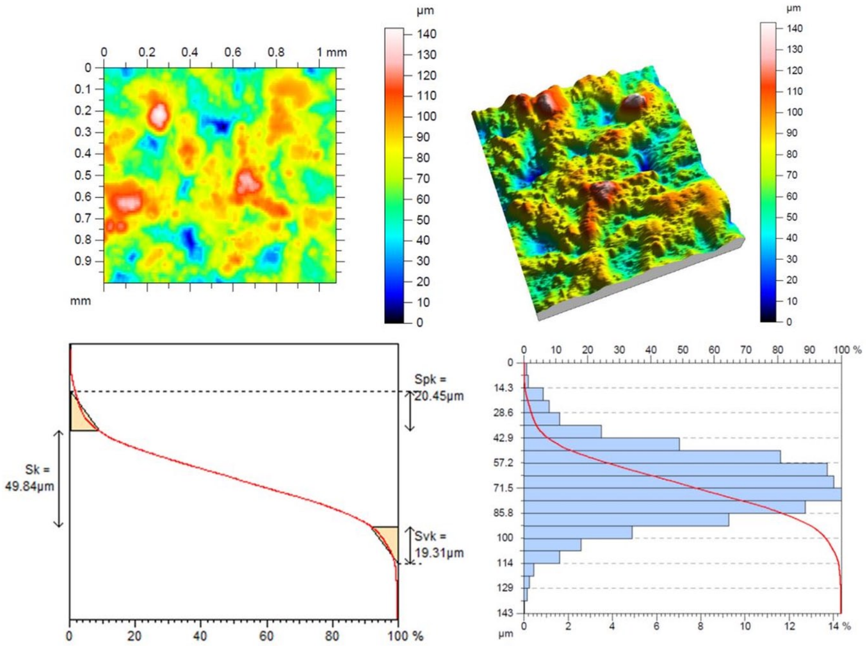


Fig. 10. The area affected by wear in profilometrical analysis

Table 3. Parameters of the surface geometry structure – the area without wear traces

Height	Spatial	Hybrid	Functional	Sk
Sa = 6.496 µm	Str = 0.7015	Sdq = 0.4660	Sbi = 0.3539	Sk = 13. 7 µm
Sq = 9.709 µm	Std = 112.2	Sds = 1088 1/mm^2	Sci = 1.330	Spk = 11.49 µm
Sp = 41.98 µm	Sal = 0.060481 mm	Ssc = 83.72 1/mm	Svi = 0.1968	Svk = 19.92 µm
Sv = 43.63 µm		Sdr = 10.16 %		
Ssk = −0.7271		Sfd = 2.481		
Sku = 6.022				
Sz = 85.60 µm				

geometry structure are presented in Tables 3 and 4.

When analysing the obtained values of the parameters for the area not affected by wear, it may be noticed that the maximum surface height Sz is 85.60 µm, the arithmetic mean surface height Sa=6.496 µm, the maximum peak height Sp=41.98 µm, the maximum valley depth Sv=43.63 µm and the root mean square height Sq=9.709 µm. Quite quick fading of the ACF function (the Sal parameter) is the evidence of the dominant share of the random component in the surface geometry structure. The distribution of the data for the local summits is the normal distribution with high kurtosis Sku=6.022 and insignificant negative skewness Ssk=–0.7271, which points out to the surface with a plateau shape.

The uniform structure of the top layer was evidenced in the regions without damages. This was confirmed by the value of the texture aspect ratio which takes Str=0.7015 (the isotropy level 70.15%).

When analysing hybrid parameters, attention should be paid to the high local summit density (Sds= 1088 1/mm^2) and the large fractal dimension (Sfd=2.481). The surface has the smallest core fluid retention index (Sci = 1.33) and the highest valley fluid retention index (Svi=0.197) given the bearing index Sbi=0.3539 compared to the surfaces affected by corrosion.

In the case the area affected by wear, it may be noticed that the maximum surface height Sz is 143.2 µm, the arithmetic mean surface height Sa=15.04 µm, the maximum peak height Sp=69.68 µm, the maximum valley depth Sv=73.52 µm and the root mean square height Sq=18.93 µm.

All the height parameters even doubled in comparison with the surface not affected by corrosion. The quickly diminishing autocorrelation function (Sal=0.10691 mm) is peculiar to random structures.

The distribution of the data for the local summits is also the normal distribution with high kurtosis Sku=3.275 and with insignificant positive skewness Ssk=0.07224, which indicates the surface with a pointed shape.

The surface affected by corrosion has a random isotropic structure, as evidenced by the value of the texture aspect ratio Str=0.8574 (the isotropy level 85.74%).

The local summit density decreased by the factor of two compared to the surface not affected by corrosion (Sds= 531.13 1/mm^2). A large fractal dimension (Sfd=2.382) was also obtained. The root mean square gradient was equal to Sdq=0.664, the arithmetic mean summit curvature reached Ssc=93.03 1/mm and the developed interfacial area ratio obtained Sdr=20.20% doubled, confirming greater surface roughness.

In comparison to the surface not affected by corrosion, the area affected by wear is distinguished by a greater core fluid retention index

Table 4. Parameters of the surface geometry structure – the area affected by wear

Height	Spatial	Hybrid	Functional indices	Functional parameters
Sa = 15.04 µm	Str = 0.8574	Sdq = 0.6640	Sbi = 0.4821	Sk = 49.84 µm
Sq = 18.93 µm	Std = 57.75	Sds = 531.13 1/mm^2	Sci = 1.526	Spk = 20.45 µm
Sp = 69.68 µm	Sal = 0.1069 mm	Ssc = 93.03 1/mm	Svi = 0.1092	Svk = 19.31 µm
Sv = 73.52 µm		Sdr = 20.20 %		
Ssk =0.07224		Sfd = 2.382		
Sku = 3.275				
Sz = 143.2 µm				

Where:

Sa – Arithmetic mean height
Sq – Root mean square height
Sp – Maximum peak height
Sv – Maximum pit height
Ssk – Skewness
Sku – Kurtosis
Sz – Maximum height

Str – Texture aspect ratio
Std – Texture direction
Sal – Auto-correlation length
Sdr – Developed interfacial area ratio
Sfd – Fractal dimension of the surface

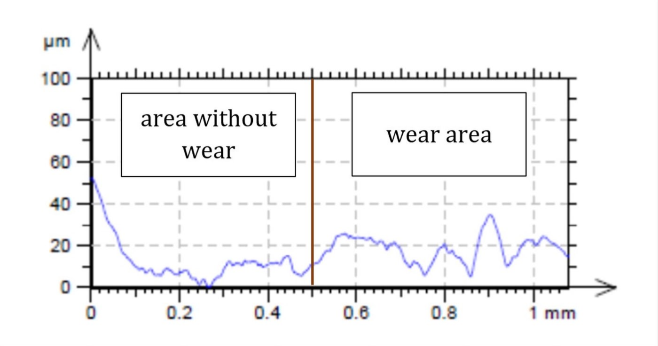
Sdq – Root mean square gradient
Sds – Summit density
Ssc – Mean summit curvature

Sbi – Surface bearing index
Sci – Core fluid retention index
Svi – Valley fluid retention index

Sk – Core roughness depth
Spk – Reduced peak height
Svk – Reduced valley depth

(Sci = 1.526) and diminishing valley fluid retention index (Svi=0.1092) with the growing bearing index Sbi=0,4821.

The 2D course of the profile of the beam surface comprising the area with and without wear (Fig. 11) confirms the loss of the material as a result of cyclical loading, the continuous generation of wear products in the tribological kinematic pair (the joint between the suspension beam and the stabiliser rod mounting), which products, during vehicle operation, move over the entire joint length thus causing surface scratches or the formation of micropits and microabrasion. Those phenomena are conducive to fretting wear development.



Ra	Rz	Rp	Rv	Rc	Rt	Rq
2,59	13,2	4,97	8,21	9,82	26,6	3,19

Fig. 11. 2D roughness parameters of the surface comprising the area with and without wear

Fig. 12 shows the results of the spot measurement of the beam surface hardness. As part of one investigation, the measurement was conducted at nine points comprising both the area unaffected and affected by wear.

The measured beam surface hardness varies from 179 to 186 HV2. Following the analysis of the beam hardness results, the decrease of surface hardness in the area affected by wear can be noticed. In that area, surface hardness was equal to 179-181 HV2. Steel hardness reduction may be the cause of the reduced resistance of the element to friction wear and plastic deformations, which are conducive to adhesion processes. Those factors create a suitable environment for the development of fretting wear, whose consequence is the development of fatigue wear and the cracking of the element.

4. Development mechanism of tribological kinematic pair

Based on the analysis of vehicle operation conditions and test results, a development mechanism for the wear of the front suspension beam and stabiliser rod mounting tribological kinematic pair may be proposed (Fig. 13).

Factors related to the loading from the vehicle weight as well as dynamic factors connected with road conditions act on the beam and on the remaining elements of the suspension system of a moving vehicle. Due to the cyclical activity of those factors, the microdeflection of the mating elements and, at the same time, their static microdisplacement, takes place. This situation is conducive to a change of the profile of the elements' surface and, as a result of friction, surface micropullouts, microholes and micropits will come into being at the beam surface.

During vehicle operation, impurities on the road, for example dust particles, sand grains etc., will penetrate into the space between the beam and stabiliser rod mounting through a gap created as a result of the deflection of those elements. Water drops, the molecules of an anti-skid agent and road salt will also penetrate along the same way.

Trapped impurities will move along the joint and cause the degradation of the elements of the tribological kinematic pair as a result of abrasion. As a result of that activity, microholes and micropits become deeper and abrasion traces appear. In the deeper microholes, more impurities and surface abrasion products will accumulate thus leading to the plastic deformation of the top layer of the elements.

Further vehicle operation will result in the rise of microcracks, which will expand in the direction of the interior of the element's top layer thus causing the development of fatigue wear and, as a consequence, the cracking of the element. Road salt and water present in the space between the elements will be conducive to the formation of corrosion centres, which are an additional burden for the tribological kinematic pair.

5. Summery and conclusion

The evaluation of the technical condition of the front suspension beam as one of the elements of the suspension system is a crucial issue in terms of driving safety and comfort. Delivery vehicles cover many thousands of kilometres a year, often in harsh conditions, which

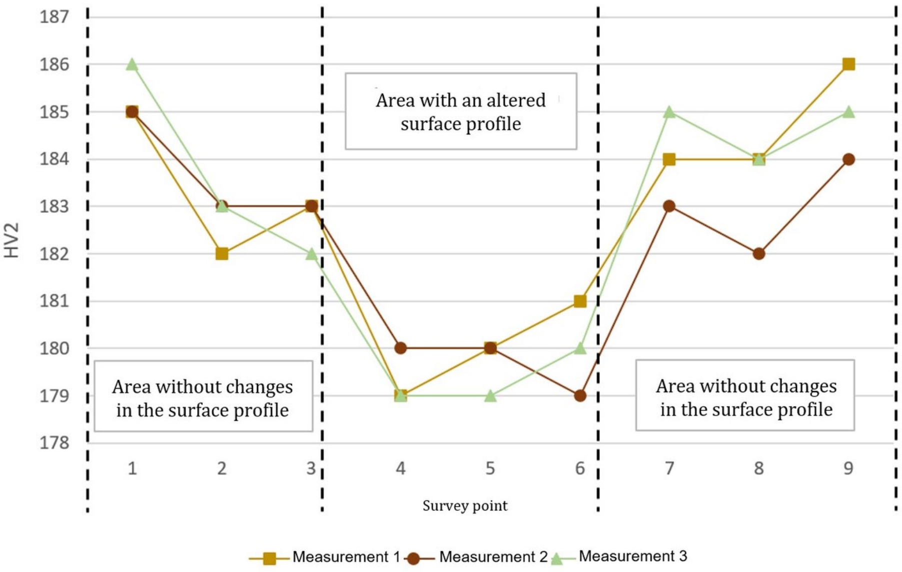


Fig. 12. Suspension beam hardness measurement results

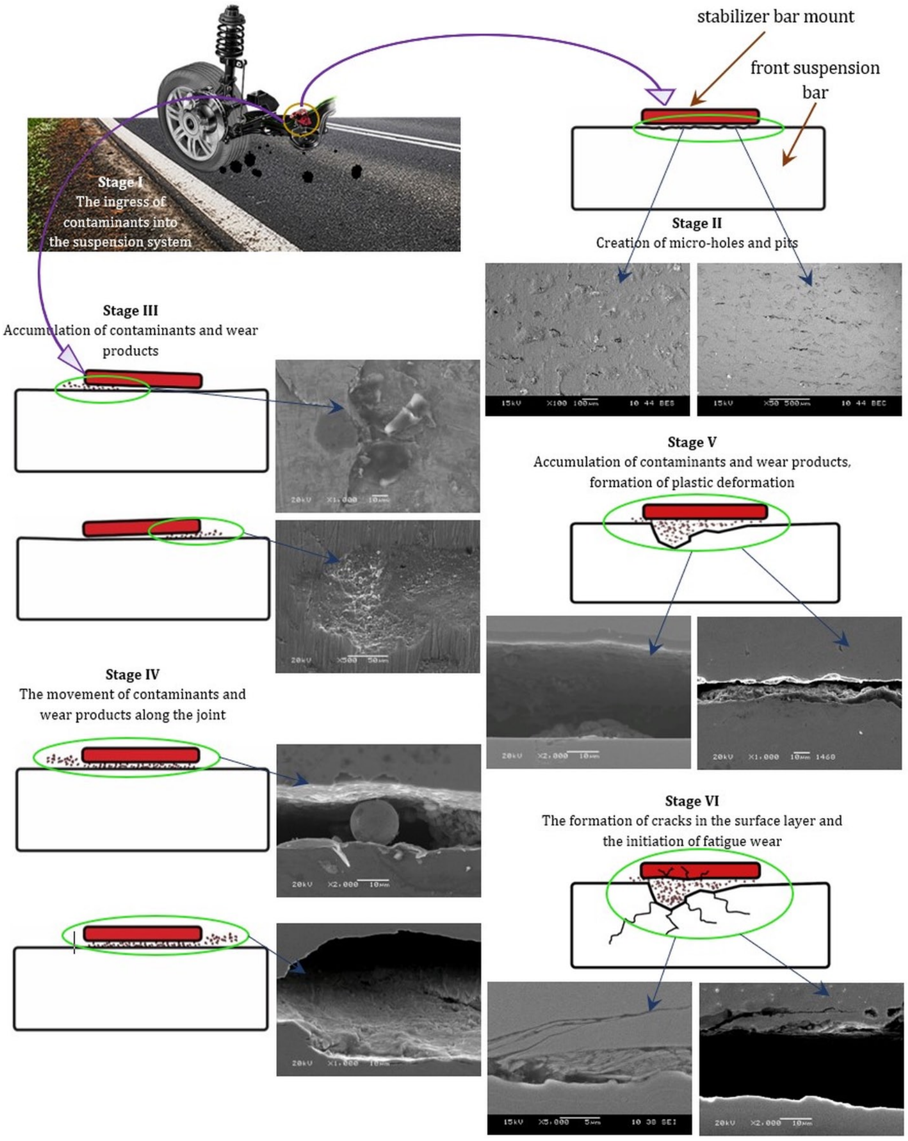


Fig. 13. Development mechanism of the tribological wear in the suspension beam and stabiliser tribological kinematic pair

translates into the deterioration of the technical condition the elements of the suspension system.

Failure to promptly recognise damage or any wear, even minimal, will frequently lead to the problem becoming more serious, which will result in the development of fatigue wear, which may cause a road incident.

The purposes of the investigations presented in this article has been to evaluate the wear of the delivery vehicle's front suspension beam, particularly in places which are not subject to standard inspections during diagnostic tests.

The operation conditions of the object, which is a delivery vehicle in this case, significantly influence the rate and degree of the wear of its elements.

Based on the test results, the following conclusions may be drawn:

- The place of the maximum exposure to wear is the point of connection of the stabiliser rod to the suspension beam. In that zone, a change of the surface structure and the grey and dark brown colour of the surface were noted.
- Other places on the beam featured insignificant plastic deformations as a result of the vehicle driving onto an obstacle, or due to a stone impact.
- On the suspension beam, fretting wear located at the point of connection with the stabiliser rod is visible. That wear causes a change of the surface profile thus increasing roughness parameters, which adversely affects the technical condition of the element.
- The surface with the changed roughness profile retains the features ensuring fluid retention between the stabiliser rod mounting and the beam, which is disadvantageous as that phenomenon supports the development of corrosion and fretting wear. Based on the noted changes of the Spk values, it may be stated that intensive removal of the highest profile peaks takes place, and the load-bearing ratio of the surface increases. The Spk parameter doubled for the surface affected by corrosion.
- The analysis of the chemical composition of the wear products demonstrated the presence of elements such as oxygen, chlorine and silicon in the joint. The presence of those elements proves the contact of the surface with atmospheric air, roadway anti-skid agents and sand, that is with factors conducive to fretting wear development.

The test results presented in this article have demonstrated the significant influence of the operation conditions of a given object on the wear of its components. The point of connection of the stabiliser rod turns out to be the weak part of the vehicle front suspension beam. During vehicle design, structural engineers should take that place into account and propose a new structural or engineering solution to prevent future dangerous road incidents due to the fatigue wear of the suspension beam.

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