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INVESTIGATION ON FORCES IN FRICTIONAL KINEMATIC PAIRS TO ASSESS THEIR INFLUENCE ON SHOCK ABSORBER CHARACTERISTICS

Summary. In telescopic shock absorbers there are two kinematic pairs where dry, semi-dry or fluid friction is most likely to occur. Higher values of friction forces are noted in piston rod-slideway pair due to its sealing function and consequently worse lubricating conditions. The aim of the tests was to assess the influence of forces occurring in frictional kinematic pairs on damping characteristics of shock absorbers. The tests were performed on new and fluid-free shock absorbers for various working strokes and various extortion frequencies.

BADANIA SIŁ W WĘZŁACH TARCIA AMORTYZATORA SAMOCHODOWEGO I ICH WPŁYWU NA CHARAKTERYSTYKĘ TŁUMIENIA

Streszczenie. W amortyzatorze teleskopowym można wyróżnić dwie pary kinematyczne, w których możliwe jest występowanie tarcie suchego, półsuchego lub mokrego. Wyższe wartości sił tarcia, ze względu na pełnioną funkcję uszczelniającą i co za tym idzie gorsze warunki smarowania, występują w złożeniu tłoczysko-prowadnica. Celem badań była ocena wpływu sił w węzłach tarcia na charakterystykę tłumienia amortyzatora. W ramach pracy przeprowadzone zostały badania amortyzatorów w stanie nominalnym i pozbawionych płynu dla różnych: skoków roboczych i częstości wymuszenia.

1. INTRODUCTION

Dynamic properties of a car suspension are largely dependent on what type of shock absorbers is used. Their characteristics are to a great degree responsible for comfort and safety of travel. The most popular types are nowadays fluid telescopic shock absorbers.

The function of shock absorbers is to restrict relative movements in both car suspension and car body through changing mechanical vibrations into heat. As observed on the basis of shock absorber design and operation principle, the main cause of damping the vibration is viscotic resistance in non-return valves and passages [3,4,7,9]. Value of damping force F_t is usually shown as:

$$F_t = k_1 \left(\frac{dx}{dt} \right) + k_2 \left(\frac{dx}{dt} \right)^i \quad [N] \tag{1}$$

where: $k_{1,2}$ - coefficients to define linear and nonlinear parts of damping, dx/dt - relative velocity of shock absorber piston movement against cylinder [m/s], i - exponent to define damping force nonlinearity.

Damping characteristic curves for modern shock absorbers are unsymmetrical and different for reflecting and deflecting movements. Damping forces in squeezing movement are smaller than those in stretching movement due to different valve designs.

Moreover, each shock absorber contains two kinematic pairs in which dry, semi-dry or fluid friction can occur in accordance with lubricating conditions. Those two kinematic pairs are: piston-cylinder, piston rod-slideway. Friction forces in piston rod-slideway pair are greater due to sealing function and consequent worse lubricating conditions. Results of tests related to influence of lubrication intensity on friction force value in such movable pair are presented in paper [8].

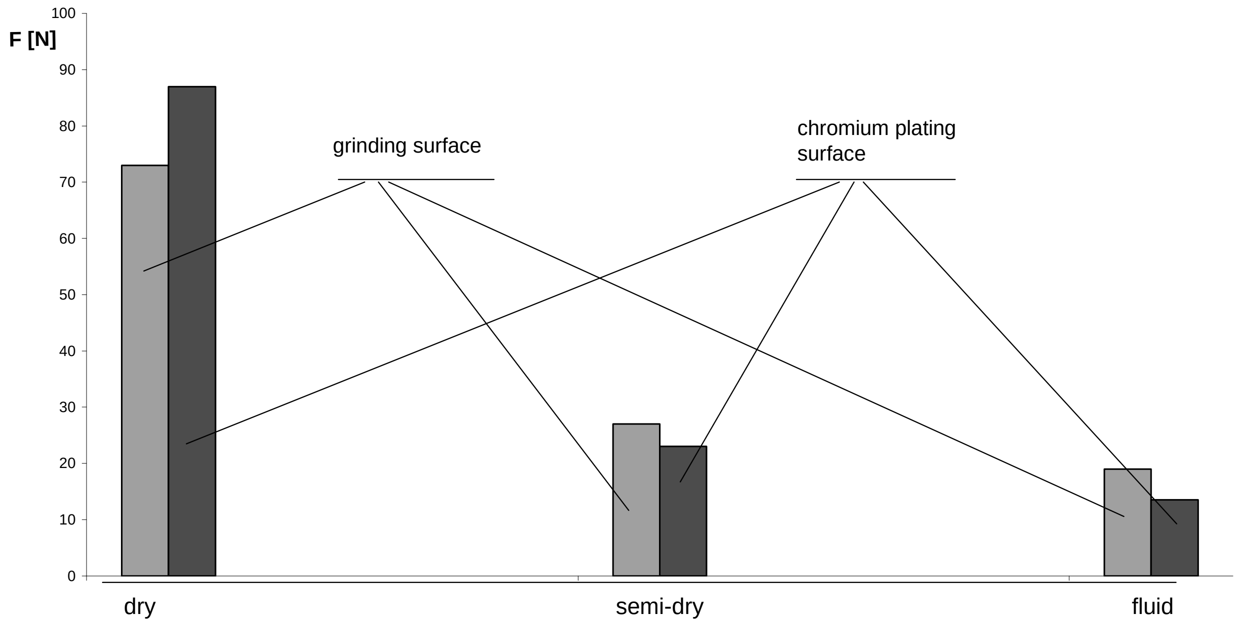

Fig. 1. The influence intensity of lubrication on friction force value in pair: the coulisse - the piston rod [8]
Rys. 1. Wpływ intensywności smarowania na wartość siły tarcia w złożeniu prowadnica - tłoczysko [8]

In result, the work of friction forces occurring in telescopic shock absorber kinematic pairs can reach several dozen per cent of energy transformed into heat during one working cycle.

2. AIM AND SCOPE OF TESTING

The aim of testing was to assess the influence of friction forces occurring in piston-cylinder-seal and piston rod-slideway-seal pairs on damping characteristics of shock absorbers. The tests were performed on new shock absorbers and deprived of hydraulic fluid. The scope of testing required that rolled-in end of the absorber should be replaced by threaded bush. Damping characteristic curves were determined on an indicator test rig where sinusoidal extortion system was employed. The tests were performed for various working strokes and four extortion frequencies.

3. OBJECT AND METHOD OF TESTING

The object of testing consisted of front shock absorbers as used in McPherson car suspensions. Internal design of a shock absorber with kinematic pairs clearly visible is shown in fig. 2.

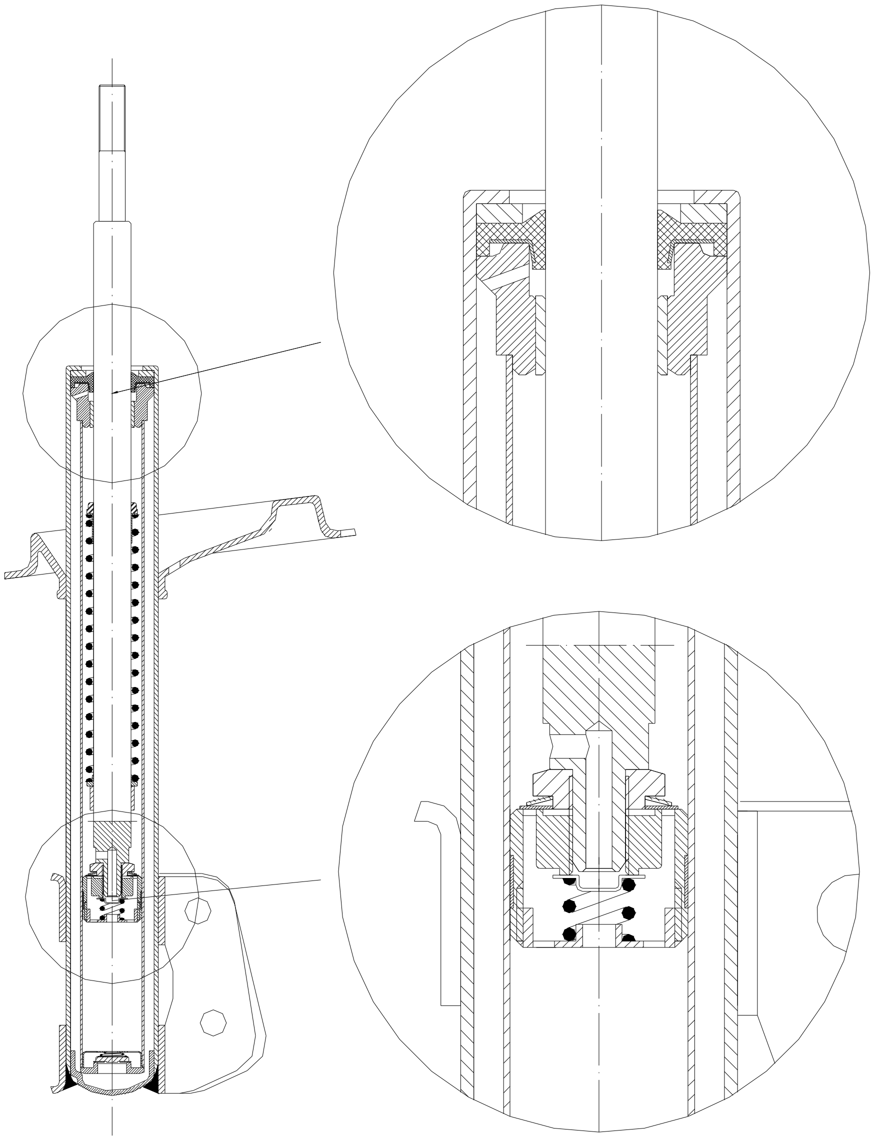

Fig. 2. Construction of hydraulic twin tubes shock absorber
Rys. 2. Budowa wewnętrzna hydraulicznego amortyzatora dwururowego stosowanego w kolumnie McPherson

Damping forces were measured in both new and fluid-free shock absorbers. Indicator test rig was provided with a power transmission system to enable extortion in sinusoidal form for various frequencies ω and crankweb length R. The tests were performed for combinations of four extortion frequencies with three working stroke lengths.

Testing telescopic shock absorbers on an indicator test rig enables to obtain force-displacement diagrams illustrating damping forces in function of shock absorber piston displacements against its casing. The diagram is a closed loop which becomes elliptic with axes incompatible with coordinate axes if the shock absorber damping characteristics are symmetrical. The line crossing the origin of coordinates and tangency point between the diagram and the lines parallel to X-axis for extortion stroke extreme values makes β angle with Y-axis [5].

Shock absorber damping constant k is equal to the ratio of force F_t (shown by the point of intersection between the diagram and X-axis) to product of extortion angle frequency ω and arm length R.

$$k = \frac{kR\omega}{R\omega} = \frac{F_t}{R\omega} \tag{2}$$

Tangent of β angle is the value of apparent elasticity c_u [5].

$$c_u = tg\beta \tag{3}$$

In case of shock absorbers used in modern cars where damping characteristics are unsymmetric due to overflow valves, the force-displacement diagrams are hardly or not at all elliptic [4,5,6]. Therefore it seems reasonable to claim that fluid telescopic shock absorbers are nonlinear viscoelastic elements.

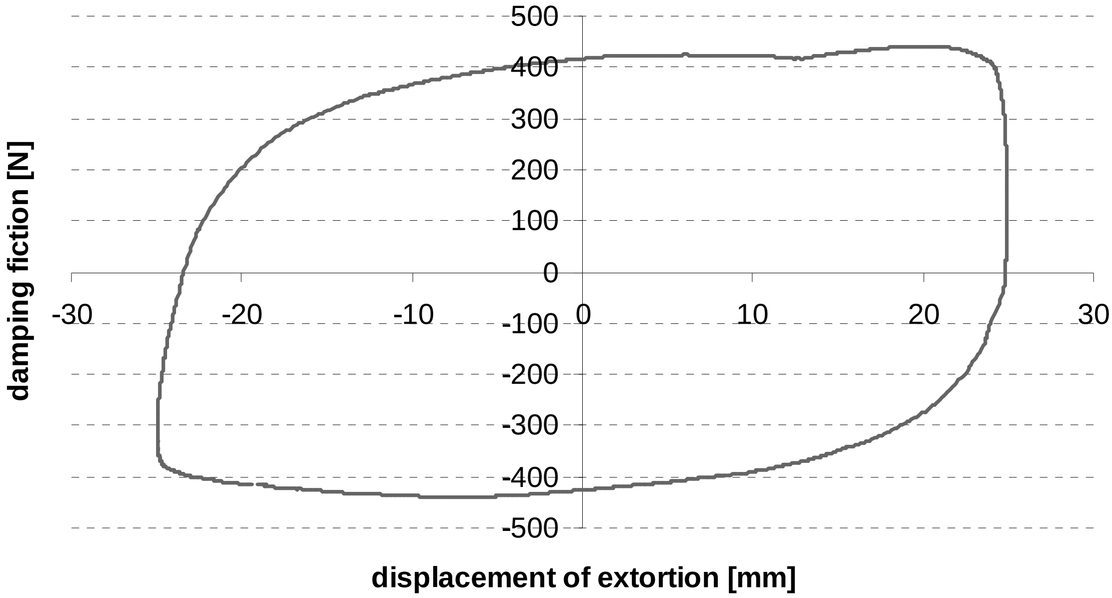

Fig. 3. Graph of shock absorber work - own investigations
Rys. 3. Przykładowy wykres pracy amortyzatora – badania własne

According to shock absorber manufacturers, the basic criterion for assessing the absorber quality is its force-displacement diagram showing the damping forces in respect of specific extortion parameters. Reference force-displacement diagrams, used as basis for the absorber verification, are traced for one frequency of extortion and specific route of the absorber piston against cylinder. Shape of the absorber diagram and maximal values of damping forces with deflection and reflection are the basis for assessing its technical state. Such approach ignores the nonlinear form of the absorber characteristics which is additionally a function of many variables. Nonlinear system response depends on extortion parameters [6]. In paper [2] we assumed that the value of damping force depends both on relative velocity of piston and cylinder movements and frequency of the absorber working stroke frequency.

The shock absorber force-displacement diagrams were used to trace damping characteristics *F(v)*. The values of damping force (as occurring for maximal velocity of the absorber piston and casing relative movement), with changes in extortion frequency, were used to identify damping characteristics for specific length of working stroke.

4. RESULTS OF TESTING

Shock absorber damping characteristics as obtained in result of the tests for various working stroke lengths are presented in fig.3 (new shock absorber) and in fig.4 (fluid-free shock absorber).

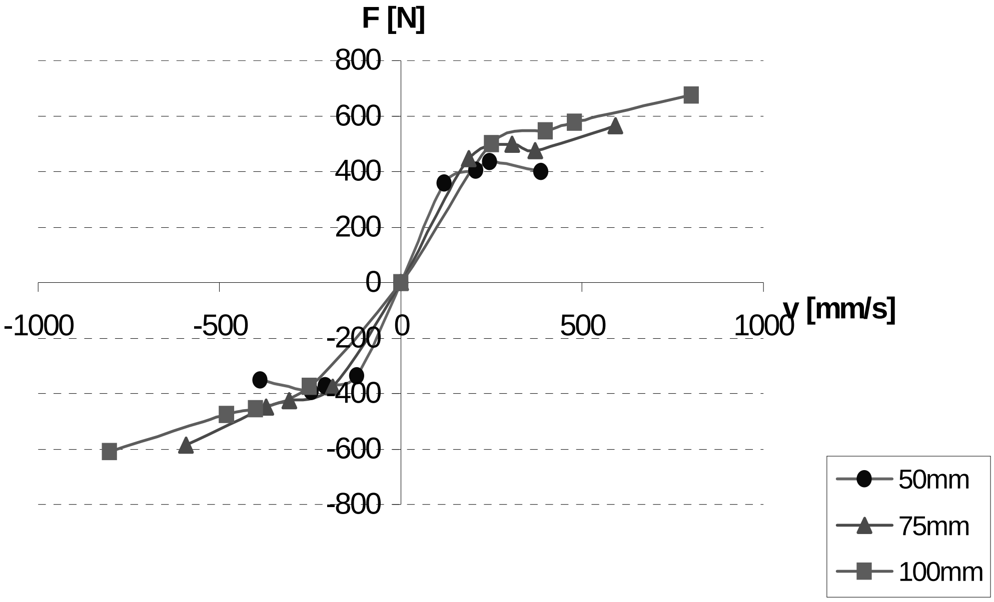

Fig. 4. Characteristics of new shock absorber
Rys. 4. Zbiór charakterystyk tłumienia amortyzatora nowego

Changes in damping characteristics shape confirm that there is a close relationship between instantaneous values of damping forces and frequency of extortions plus working stroke travel length. Identification procedure for shock absorber damping characteristics should take two extortion parameters into account.

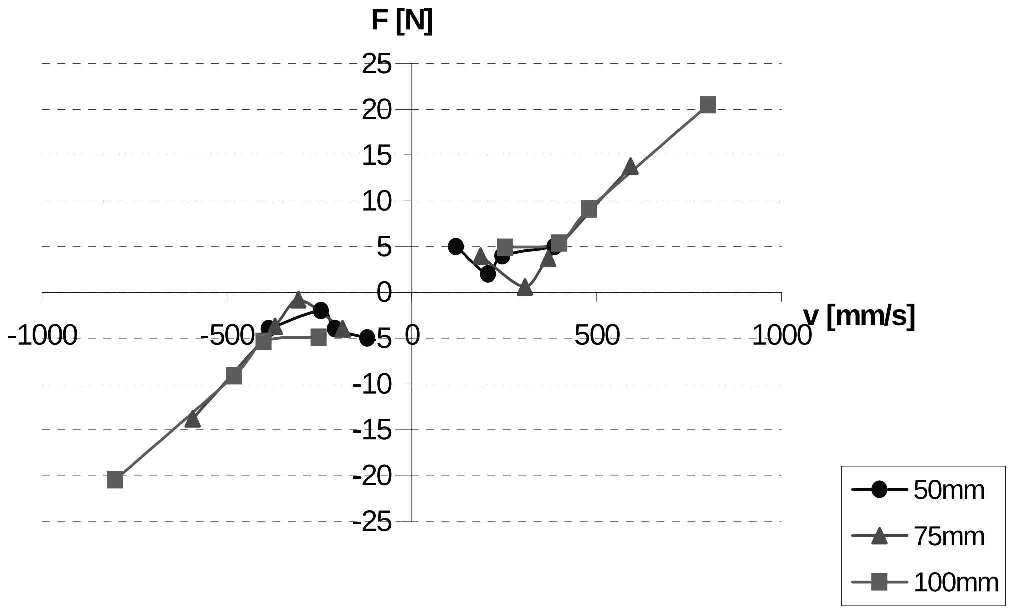

Fig. 5. For without fluid shock absorber measured values of damping frictions
Rys. 5. Wartości sił tłumienia wyznaczone dla amortyzatora pozbawionego płynu roboczego

Damping force diagrams obtained during tests on a fluid-free shock absorber (fig. 5) are similar in shape to frictional pair when considered as combination of linear viscotic damping process and sticking effect upon changes of movement direction. It is noteworthy that the shock absorber was not dried throughout the tests.

Within low velocities, the extorted friction forces are small and do not exceed 6 [N]. If higher velocities are used, the diagram of damping forces is roughly a straight line whereas maximal values do not exceed 3% of damping forces in a new shock absorber, no matter how long the extortion stroke would be. The influence of forces generated totally by two kinematic pairs on the shape of damping characteristics is hardly significant.

5. CONCLUSION

Constructors of car suspensions have an aspiration to improve their vibroinsulating properties through reduction of forces in frictional pairs. The shock absorbers we tested did not show high relationship between movable kinematic pairs and the value of damping forces. Identification process for nonlinear damping characteristics requires that all extortion parameters should be given careful consideration.

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