Creation of a methodology for predicting the appearance of knocks of shock absorber at the first stages of vehicle design

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Abstract. The phenomenon existing in the automotive industry is considered, namely the valve “knock” associated with noise during the operation of the shock absorber. Road and bench tests of shock absorbers allowed explaining the causes of the valve «knock» - a developed method for predicting the appearance of knocks at the vehicle design is presented.

1. Introduction
In the automotive industry, there is a steady trend to reduce noise affecting the acoustic of the consumer comfort [1]. In this regard, requirements for components aimed at reducing noise in the car are growing or appearing. The shock absorber is one of the sources of noise. Shock absorber noise can be classified by origin into: hydraulic “SAP”, valve "knock" and impact [2]. The most difficult to predict and little-studied is the valve «knock». The prediction difficulty lies in the fact that the same (serviceable) valve system on one model of the car emits an undesirable, clearly audible knock, and on the other model this sound is not heard, which indicates the effect on the sound and design of the shock absorber to the body. Moreover, this knock can occur on the car at different ambient temperatures and the degree of wear of the shock absorber. Thus, it is impossible to be sure that this knock will not appear after the launch of the car into production, even with the use of proven valve systems [3].

Accordingly, there is a need to have a methodology for predicting the appearance of valve knocking before launching the car into production, using objective methods; this leads to the need to solve the following problems:

- Search for a criterion that correlates well with audible knocking,
- Development of a method of measuring this criterion on the car and on the stand,
- Development of a method for optimizing the parameters of the shock absorber and connecting elements to reduce the probability of knocking to a minimum.

This article is devoted to solving the first two problems.

2. The method of research
For the study, a car was selected with a clearly traceable valve knock in the rear suspension at ambient temperatures below minus 5 degrees Celsius, when driving at a speed of 10-20 km/h on irregularities such as ice. The knocking disappeared during the shock absorber warming up. When the ambient
temperature dropped to minus 15 degrees, the knock did not disappear, but only reduced its intensity when the shock absorber was heated. Before the start of the exclusion tests, the knock was clearly localized; its source was definitely the shock absorber. Moreover, rubber mount pads were selected when using the knock was not heard and shock absorbers with other valve systems with which knock became less intensive were picked up [4].

It is known that for the appearance of a sound, a force perturbation is necessary, which in turn is directly proportional to the acceleration. Therefore, for instrumental control, accelerations occurring on the shock absorber rod, on the body in the immediate vicinity of the shock absorber fixing point, as well as on the shock absorber body were measured. To do this, accelerometers connected to the LMS analyzer (figure 2) were installed in these places (figure 1). Information about accelerometers is given in table 1.

![Figure 1. The mounting location of the accelerometers.](image1.png)

![Figure 2. LMS analyzer.](image2.png)

| The installation location of the accelerometer | Model       | Characteristics         |
|-----------------------------------------------|-------------|-------------------------|
| Shock absorber rod                           | PSB 352C33 | Sensitivity: 100 mV/g   |
|                                               |             | Measuring range: ±50 g  |
| Carbody                                       | PSB 352C33 | Sensitivity: 100 mV/g   |
|                                               |             | Measuring range: ±50 g  |
| Shock absorber tank                          | PSB 356A02 | Sensitivity: 10 mV/g    |
|                                               |             | Measuring range: ±500 g |

In addition to the selection of equipment, the preparation for the test also included the selection of roads and driving modes on which a knock definitely occurs. To fix the modes in which there appeared a knock, the recording of signals from the sensors was conducted before the occurrence of knocks, after the sound appeared, the recording stopped. More than 100 temporary stories were received. Further, for
comparative analysis, on the same driving modes and when driving on the same roads, signals from accelerometers were recorded when using "non-knocking" pads and "low-knocking" shock absorbers in the suspension. Analysis of the test results showed that in the vast majority of cases, at the time of knocking, there is a surge of acceleration on the shock absorber rod and this surge is transmitted to the car body [5].

To determine the operating mode of the shock absorber at which the knock is occurs, the difference between the readings of the accelerometer mounted on the rod and the accelerometer mounted on the body of the shock absorber was integrated. Thus, the speed of movement of the rod relative to the tank of the shock absorber was obtained. Three signals: the readings of the accelerometers on the shock absorber rod and the body, as well as the speed of the rod relative to the tank, were synchronized. The synchronization of signals allowed us to conclude that bursts of acceleration occur at the moment the shock absorber switches from rebound to compression and from compression to rebound (figure 3).

![Figure 3. An example of a processed signal. Little knocking shock absorbers.](image)

For comparison, the signals obtained by using "non-knocking" pads and "low-knocking" shock absorbers were processed by the same principle figures 4, 5.

![Figure 4. Example of a processed signal. Non-cushion pillows.](image)

![Figure 5. Example of a processed signal. Little knocking shock absorbers.](image)
Due to the graphs, a dependence on the perception of hearing and acceleration on the body is traced. If the surge is alternating, then it is clearly heard, if not, then the knock is not heard. What is more, visible correlation between the amplitude (difference between maximum and minimum acceleration on the same wave) surge and volume of the sound, the larger the scale the more bugged knock. Low-knocking shock absorber has the acceleration range 6 m/s², knocking one has about 13 m/s². Further study of the received signals shows an unambiguous relationship between the magnitudes of the acceleration spike on the rod with the magnitude of the acceleration spike on the body. Knocking shock absorber has splash span about 120 m/S², low-knocking one has about 50 m / S².

Thus, objective signs were found that correlate well with knocking. In the future, these features can be used when assessing the knock on the first prototypes of new vehicle models. Auditory perception is often impossible when using prototypes, because the internal noise in them is much higher than the valve knock. The second problem is to create a methodology for measuring the magnitude of the acceleration surge on the rod in bench conditions, in order to be able to assess the level of the existing product, as well as to optimize the design of the damper valve system of the shock absorber without the involvement of the car. To obtain the bench modes of testing the shock absorber for a tendency to knock, it is obtained temporary history of the piston stroke of the shock absorber piston relative to the reservoir were obtained by integrating the speed signal obtained in the previous paragraph. The analysis of the received signals showed that the mode in which the knock is heard is close to the sine wave figures 6. The parameters of sinusoids describing each of the time histories with great accuracy are shown in table 2.

![Figure 6. Time histories of piston stroke and averaging sine wave.](image)

| № Tests | Amplitude mm | Frequency, Hz |
|---------|--------------|---------------|
| 1       | 10           | 11,4          |
| 2       | 13           | 11,1          |
| 3       | 6,5          | 12,2          |
| 4       | 5,2          | 11,1          |
| 5       | 7            | 11,8          |
| 6       | 7            | 13,3          |
| 7       | 5            | 10,5          |
| 8       | 7            | 11,6          |
| 9       | 8            | 12,2          |
| 10      | 7            | 11,5          |
| 11      | 6            | 12,2          |
| 12      | 14           | 11,8          |
| average | 8,0          | 11,7          |
The received signals were compared to the signals received on the road [8]. The analysis showed that the selected mode is adequate, as during the test there are accelerations having similar phases on the rod (figure 8). The burst of acceleration circled by an orange ellipse was due to the activation of the compression buffer on the car.

![Figure 7. Schematic diagram of bench tests for knocking.](image)

![Figure 8. Signals received at the stand and on the car. Above - rod acceleration, below - shock absorber piston speed relative to the tank.](image)

### 3. Conclusion

The results of this work made it possible to create in the first approximation a technique for predicting the shock absorber knock on the car and a technique for assessing the tendency to shock absorber knock on the stand.
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