MEASURING CUSTOMER COMFORT OF THE SIDE DOOR SELF-EQUIPMENT FOR THE AUTOMOBILE INDUSTRY

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Abstract
The article deals with the assessment of the customer comfort of controlling the side-cars-door and the creation of measuring devices for its objectification. The aim is to describe to the reader different approaches and the creation of a customer assessment methodology in the automotive industry. The collected data helps the automotive industry to innovate existing parts, construct new ones, reduced claim and production costs. The result is satisfaction customer's needs with a focus on a particular customer group.

Key words: *Energy measurement, speed measurement, automotive industry, quality, customer comfort.*

INTRODUCTION

Automobile manufacturers are looking for an opportunity to reach out to the customer, offering him added value. They use process and existing methods such as Customer design for X - DFX (1), Failure Mode and Effects Analysis - FMEA described by H u a n g (1996) , Advanced Product Quality Planning-APQP mentioned by S t a m a t i s (2003),. The automotive industry often used Lautes Denken methods used by Z h a o , B r o w n, K r a m e r , & X u (2011). For repeatability, all processes need to be checked to guarantee product quality. Car manufacturers follow the ISO 9001: 2015 standard, which establishes a link between company management, quality management system, customer requirements, allocation of competences, and more accurate targeting of market expectations. Newly, the introduction of a risk management system. These standards are defined and controlled in the Czech Republic by means of the Czech Accreditation Institute. The Czech Accreditation Institute (ČIA) provides the accreditation of persons, certification of authorities according to ČSN EN ISO/IEC 17021-1: 2016 or the quality management system. Means of law 505/1990 collections. the measurement, measuring equipment and systems are defined. Next it determines gauges, catalogs them, recommends calibration periods, defines the measurement process.

This article focuses on the preparation of technical measuring instruments. These specialized measuring devices evaluate the door closing speed and the total energy needed to close, open or progress the door control. We will explain the analogy of both approaches to evaluation and measurement of customer comfort. In the examples, it demonstrates the weaknesses and strengths of both methods in detecting manufacturing or user defects. The aim is the creation of a measuring device that describes a subjective customer assessment using measurable physical parameters. Another objective is to create a methodology that guarantees the repeatability and comparability of measurements. The obtained data are used by the automotive industry at the stage of development, production control and claims analysis. The priority is to reduce claims and production costs and to meet customer needs with a focus on a specific customer group focusing especially on a particular customer group.

MATERIALS AND METHODS

The principle of measuring the closing speed is the measurement of the time at which the measured object will run between two points on a defined path. By deriving the path by time, then determine the velocity according to the formula (1),

$$v = \frac{ds}{dt} = \dot{s} \qquad (1)$$

Where the path s (m), time t (s), the resulting closing velocity v (m / s). The measuring device Fig. 1 is composed of a detection head and an evaluation unit. The detection head includes two industrial inductive sensors detecting presence of metallic material. Sensors are located exactly 50mm apart on a clearly defined linear path. Inductive sensors have been used, because passenger cars are mostly made of metallic materials. The evaluation unit contains a microprocessor that performs the evaluation of the measured value and the resulting closing speed is displayed on the display. Measuring device for energy measurement of the side door of a passenger car is based on the idea of measuring the total energy needed to close the door. One of the ways to measure energy is represented by equations (2), where m (kg) is the total weight of the door, v (m / s) is the speed of the moving door when closing or opening, Ec (J) is the resulting total energy.

$$E_c = \frac{1}{2} m \times v^2 \tag{2}$$

The measuring device Fig. 5 works on the principle of measuring the force supplied by the operator and accumulated in the spring. This stored energy is used for closing the door of a passengers car. The device also includes a tensometric sensor that measures the force supplied by oparator to the spring. The measurement result is the whole energy needed to close the passenger car door. Equation (3) describes the measurement principle of the instrument.

$$E_c = \frac{1}{c}\left[F_1 \times F_0 - F_0^2 + \frac{1}{2}(F_1 - F_0)^2\right] \tag{3}$$

Constant C (N / mm) the spring stiffness is determined by calibration from repeated measurements on the test standard. Force F_1 (N) is the tension force required to close the side door of the vehicle to overcome the effects listed in the table Tab..The force F_0 (N) is the force of the biased measuring arm. The resulting total energy E_C (Nm) is the energy needed to close the car door.

RESULTS AND DISCUSSION

Customer reviews are influenced by a subjective perception that assigns a negative or positive emotional charge to individual actions. Automobile manufacturers seek to gain and transform the customer's view into a measurable physical quantity that will help innovate the product in the PLM lifecycle management process in order to maintain its competitiveness. One example is the control of the car's side door system. Here the customer claims the difficulty of closing the door. To evaluate the subjective customer opinion, the automotive industry uses two methods. One is based on the measurement of the energy needed to control the door, the other method only monitors the closing speed of the door in the last phase of the movement. The measuring method of closing velicity of passengers car is based on an experiment empirically verified by the fact that the closing doors of the personal car need the greatest speed to overcome the door locking mechanism and compression of the door seal that seals the vehicle immediately before closing the door. Therefore, it is not necessary to measure the speed throughout the closing process, but just measure the impact speed of the door immediately before closing them, ie approximate the circular path of the door in the measured section as a straight line.

Fig. 1 Measuring of closing velocity

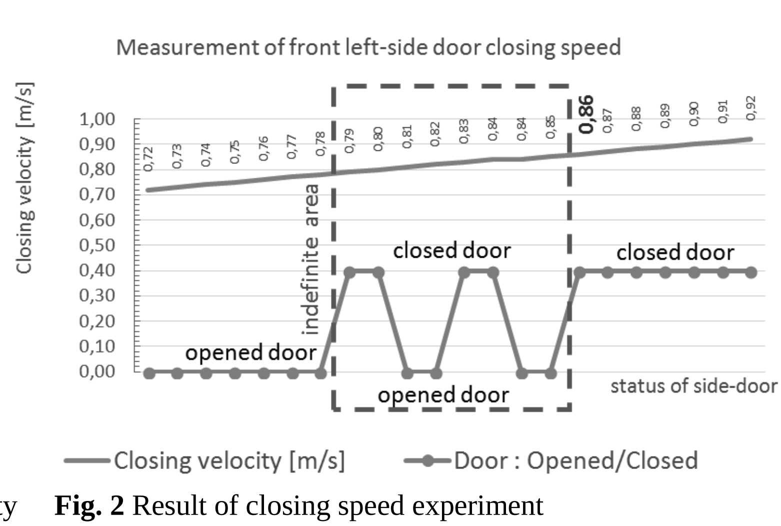

Fig. 2 Result of closing speed experiment

The measurements were made on the front-left door of Škoda Octavia car in the door handle area. The door has been repeatedly closed to find the smallest value of the door closing speed. The measurement was repeated several times to determine the accuracy of the measured value. The results of the measurements were recorded in the graph Fig. 2.The experiment showed an anomaly during the closing speed measurement close to the true closure speed (0.86 m/s). In this "undefined area", the side-car-doors may be during repeated measurement opend or closed randomly in spite of the same value of closing speed. An "undefined area" was defined at a rate of 0.78 m / s and 0.85 m / s. Another measure was found that the closing speed is affected by the delay between the two measurements and is dependent on the relaxation of the main seal Fig. 3.

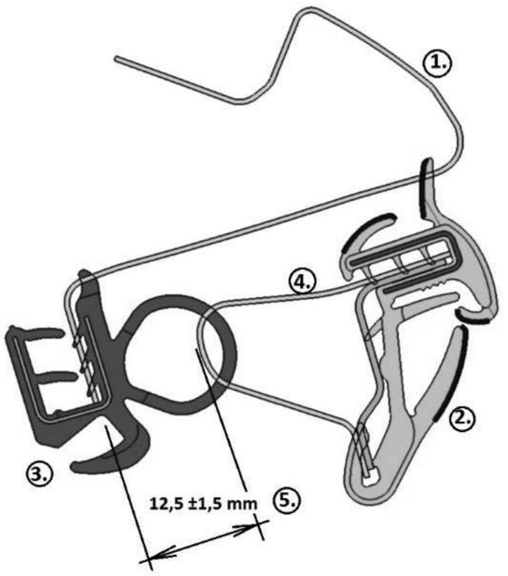

Fig. 3 Cur through the side door

Fig. 4 Detail of the main sealing of the door

The side doors, position 4. at Fig. 3. are adjacent to the side of the car (position 1.) and are sealed at the point of contact by the main sealing (position 3.), which has cut off venting hole in regular intervals. Relaxing the seal means the fully inflated seal time Fig. 4 to a state where it does not exhibit deformation. Based on this experiment, a method of measuring the closing speed was set up and a pause between iterations was set, resulting in a "undefined area" reduction and higher measurement accuracy. The following measurements determined the side effects on the closing velocity Tab. 1.

Tab. 1 Effect on the door closing speed

Influencing effect	Vehicle part	Parameter / unit
Position of the door latch and lock	Lock of the lock	position at Y and Z axis / (mm)
Facing the door to the side of the car	Door hinges	position at Z axis / (mm)
The gap between the door and the side	Door, sidebars	position at Y axis / (mm)
Flexible of main seal	Main door seal	hardness / (N/mm)

The measuring of closing energy method is based on the measurement of the total energy needed to close the door. The measuring device Fig. 5. consists of a spring (which accumulates the force required to close the door). Then the strain gauge (measures the force). The measuring device measures the total energy required to close the door when the spring is released.

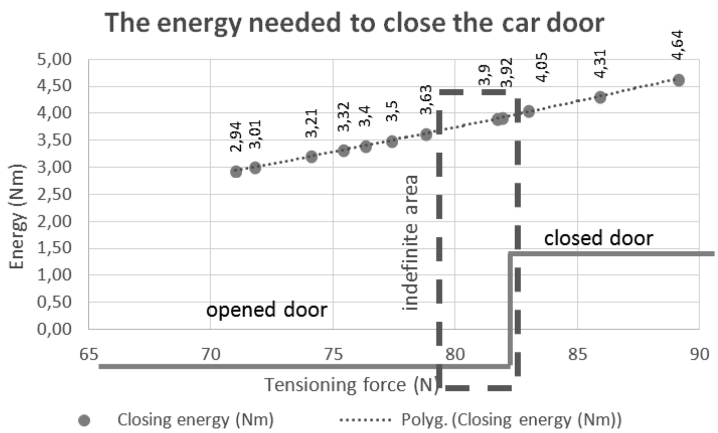

Fig. 5 Measurement of closing energy **Fig. 6** Result of closing energy experiment

The experiment showed that there is also a "undefined region" (Fig. 6), in which one door is open and one closed at one closing energy value. Its size is influenced by other phenomena in addition to the phenomena mentioned Tab. 1. (see Tab. 2)

Tab. 2 Side effect on the door closing energy

Influencing effect	Parameter / Unit
Setting the measuring arm in the car	distance in X axis / (mm)
Preload of the spring before the measurement begins	force / (N)
The accuracy of meas.depends on the quality of the operator	Repeatability of measurement

CONCLUSION

The results of the experiments were used to make a comparison between the two measuring methods, ie the side-door-closing speed and the closing energy needed to close the passenger side door Fig. 7. The measurement did not show a linear dependence between the closing energy measurement and the closing speed.

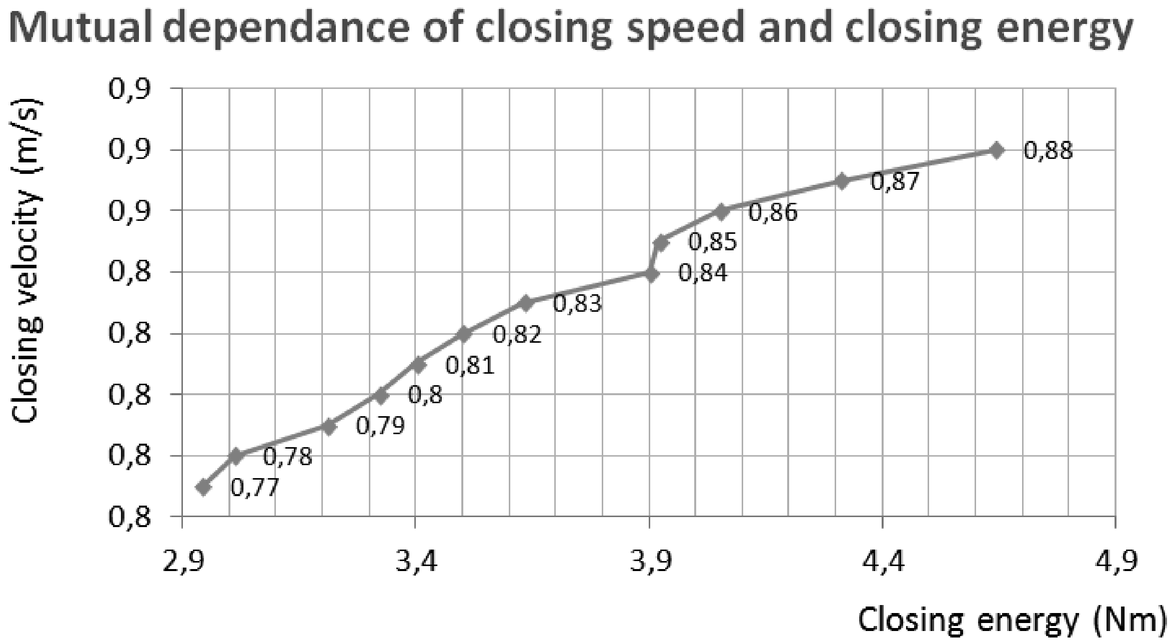

Fig. 7 Result the comparison of closing speed and closing energy

The energy measurement method has proven to be disadvantageous for several reasons:

- Higher dependence on the operator precision, setting of the measuring arm and continuous and gradual increase of the tensioning force F_1 (N).
- The wider indefinite area represents approximately 10.4% of the measured value. Repeated measurements have failed to reduce the measurement and thus improve the measurement.
- The repeatability of measurement due to non-linearity Fig.7 is worse when measuring the closing energy compared to the closing speed measurement.
- Because the telescopic arm is rubbing, the measurement inaccuracy increases.
- The total measurement time of the car is including installation for about 1.5 hours, which puts great demands on the operator's concentration.
- The measuring range depends on the spring tension F_0 (N) of the measuring arm, ie the measurement in the range of 10-25 cm opening the side door.

The closing speed measurements showed the following benefits over the closing energy measurements:

- Greater sensitivity and scalability of measurement allows for faster analysis.
- Repeatability of measurement result approx. ± 0.03 m/s
- Closer indefinite area, here is 0.07 m/s, which is about 8% of the measured value, but empirical experience can achieve another narrowing of an "indeterminate area" to about 4% of the measured value.
- Lower operator requirements
- Easier installation of measuring equipment, complete car can be measured in about 1/4 hours
- Measuring range, 5cm.

The purpose of this article was to make a comparison between closing energy and closing speeds, methods that evaluate customer comfort in the automotive industry. Exploration has shown that snap rate measurement is better suited for quick fault detection, which is quick, easy on the operator and allows faster analysis. Measurement of the closing energy is an elegant way of measuring the otherwise subjective feeling of the customer because it evaluates the energy input in a larger open-door-range (about 5 times greater) than when measuring the closing speed.

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