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HOW PRODUCTION REGIMES CAN IMPACT THE QUALITY OF GAZELLE NEXT BALL JOINTS

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ABSTRACT

The purpose of this study is to find a solution for one important problem related to the production of steel parts, and namely, using a case study of ball joints designed for the GAZELLE NEXT vehicles, to establish if regimes of the production processes have an effect on simple quality indicators of the product or not. If regimes of the production processes have an effect on simple quality indicators or not was established through tests based on a method that comprised three stages. During Stage 1, measurement tools were defined that would be suitable for measuring simple quality indicators. This is confirmed by MSA (Measurement Systems Analysis) results. During Stage 2, a batch of parts was produced in the current production set-up, and simple quality indicators were determined and their values documented. During Stage 3, changes were implemented to the production regimes and a test batch was produced. The items produced were used to monitor all the simple quality indicators. The obtained value of a simple quality indicator exceeding the tool error would indicate a noticeable effect produced by the regimes of this particular production process on the simple quality indicator evaluated. After the experiment was over, the production regimes would be reset to the original values, and Stage 3 would be repeated for the following process. With the help of the experiments conducted, the authors were able to establish a relationship between production regimes and simple quality indicators with regard to 10 different production processes and 9 simple quality indicators related to the GAZELLE NEXT ball joints. The results obtained in the course of the tests are described in this paper. The method used in this study can also be used to establish a relationship between production regimes and simple quality indictors with regard to other products.

Formation of simple quality indicators with regard to steel products is a complex process influenced by multiple factors. However, the production process and the design of the product [1–15] play a major role. In terms of production process optimization, to improve the quality of the products it could be necessary to adjust production regimes [1, 2]. At the same time altering the regimes of one process may influence multiple simple quality indicators of the overall item. The effect of the implemented changes can be estimated through product quality analysis [3, 4].

Establishing the relationships between production regimes and simple quality indicators will facilitate finding solutions for the following practical tasks: identifying the simple quality indicators of steel products the values of which need to be re-evaluated after adjustment of the production regimes; identifying the production processes that need to be adjusted in order to improve simple quality indicators of the product.

The ball joint used in one of the Russian major light commercial vehicles, GAZELLE NEXT, is taken for a case study to determine how production regimes can impact simple quality indicators of steel products.

So, the purpose of this study is to find a solution for one important problem related to the production of steel parts, and namely, using the case study of ball joints designed for the GAZELLE NEXT vehicles, to establish if regimes of the production processes have an effect on simple quality indicators of the product or not.

General Description

The design of the ball joint used in the GAZELLE NEXT vehicles is shown in **Fig. 1**. The ball race *2* and the spherical surface of the steel ball stud *3* make a conventional friction pair. For durability when dealing with high alternating loads, the ball race is made of high ductility acetal homopolymer. The friction coefficient in the friction pair is lowered due to the application of lubricants. The ball race *2* and the ball stud *3* rest in the steel housing *1* and are safeguarded against loosening by a permanent connection between the steel housing *1* and the thrust washer *4*. The sealing boot *7*, in combination with the snap ring *5*, which ensures a tight connection between the sealing boot and the steel housing, and the O-ring *8*, which ensures a tight connection between the sealing boot and the ball stud, ensures protection of the friction pair from abrasive particles and chemicals. The spacer *6* keeps the sealing boot neck in place.

The above ball joint design used in the GAZELLE NEXT vehicles is patented with Utility Patent of the Russian Federation No. 2475652 [5].

The number of simple quality indicators to be used for the ball joints is specified between the supplier and the customer. The list of simple quality indicators for the ball joints used in the GAZELLE NEXT vehicles was compiled following the GOST R 52433 [6] standard: tilting torque of ball stud; rotating torque of ball stud; no squeaking when the ball stud is tilting or rotating; no jamming when the ball stud is tilting or rotating; total

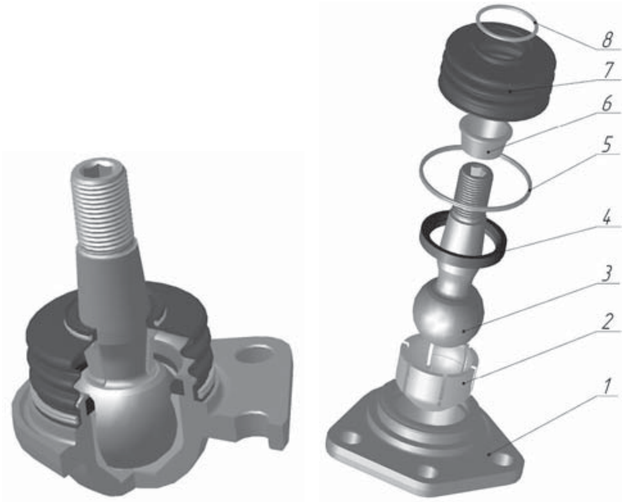

Fig. 1. Design of Ball Joint Used in the GAZel NEXT Vehicles:
1 — steel housing; *2* — ball race; *3* — steel ball stud; 4 — thrust washer; *5* — snap ring; *6* — spacer; *7* — sealing boot; *8* — O-ring

axial movement of the ball stud; ball stud tear-out force; pivot angle; dimensions; mounting dimensions.

The GAZELLE NEXT ball joint production process involves the following steps: make mounting holes in the ball joint housing; machine the inside of the ball joint housing; machine the outside of the ball joint housing; contour machine the ball stud; thread the ball stud; roll the fillet of the ball stud; roll the sphere of the ball stud; assemble the ball race and the ball stud, dose the grease, press the friction pair in the housing, install the thrust washer; form a permanent connection between the steel components of the joint; dose the grease, install the sealing boot, install the O-ring and the snap ring.

Applied Methods

It is reasonable to use experiments when trying to establish relationships between the production regimes and the target simple quality indicators of the item considered. For the problem at hand, a series of experiments need to be conducted that would involve making consistent changes to the production regimes used to produce the parts followed by analysis of the simple quality indicators achieved.

To understand how production regimes could impact simple quality indicators, which were subjected to quantitative analysis, a method was applied that comprised three stages.

Stage 1 serves to define the measurement tools that would be suitable for measuring simple quality indicators. The applicability of the measurement tools should be confirmed by MSA (Measurement Systems Analysis) [7–9] results.

During Stage 2, a batch of parts is produced using the current production process, and the parts are verified based on the specified simple quality indicators. For quantitative simple indicators, arithmetic mean values are determined based on the measurement results, whereas for qualitative indicators the yield indicator is determined, which indicates a percent of conforming parts in a batch.

During Stage 3, consistent adjustments are made to the production regimes, and a test batch is produced after each adjustment. The same simple quality indicators as those in Stage 2 are used to verify the items produced.

In the case of the quantitative simple quality indicators, if the deviation of the obtained arithmetic mean value does not exceed the measurement tool error, the regimes of this particular production process are considered to have no effect whatsoever on the simple quality indicator evaluated. The deviation of the obtained arithmetic mean value exceeding the tool error would, on the contrary, indicate a noticeable effect produced by the production regimes on the simple quality indicator evaluated.

In the case of the qualitative simple quality indicators, if the obtained values of the *yield* indicator for the original and altered production process match, the regimes of this particular production process are believed to have no effect, within the change range, on the simple quality indicator evaluated. A difference in

Table 1. **Measurement tools, error and the type of data obtained as a result of simple quality indicator measurements**

Simple Quality Indicator	Tool	Error	Type of Resultant Data
Tilting torque of ball stud	Tohnichi Torque Wrench DB12N4-S	±3%	quantitative
Rotating torque of ball stud	Tohnichi Torque Wrench DB12N4-S	±3%	quantitative
No squeaking when the ball stud is tilting or rotating	Tohnichi Torque Wrench DB12N4-S	±3%	qualitative
No jamming when the ball stud is tilting or rotating	Tohnichi Torque Wrench DB12N4-S	±3%	quantitative
Total axial movement of the ball stud	TiraTest 2300 Tensile Testing Machine	±1%	quantitative
Ball stud pull-out force	TiraTest 2300 Tensile Testing Machine	±1%	quantitative
Pivot angle	Protractor	±0.1°	quantitative
Dimensions	Caliper ShTsTs-I-150-0.01 GOST166	±0.03	quantitative
Mounting dimensions	Caliper ShTsTs-I-150-0.01 GOST166, Thread gage M16×1.5-6g GO/NO-GO	±0.03	quantitative, qualitative

Table 2. **Values of the tilting torque of ball stud as measured on the parts produced in the current production set-up**

Measured Values, N×m								Arithmetic Mean Value, N×m
5.2	5.0	4.8	4.8	5.2	4.4	4.2	5.8	5.02
4.6	5.6	4.2	4.2	6.0	5.4	4.6	4.0	
5.4	5.6	5.8	5.6	4.8	5.8	4.2	5.0	
5.8	4.8	6.0	4.2	5.6	4.0	4.2	5.8	

Table 3. **Values of the tilting torque of ball stud as measured on the parts produced in the altered production set-up**

Measured Values, N×m								Arithmetic Mean Value, N×m	Deviation
5.8	5.0	4.6	5.8	4.4	5.6	6.2	5.8	5.14	+2.4%
6.2	4.8	5.2	5.6	5.4	6.2	5.4	4.2		
4.6	5.2	4.2	4.0	4.6	4.2	4.2	4.8		
5.4	4.4	6.0	5.2	5.8	6.4	5.6	3.8		

the obtained values of the *yield* indicator between the two processes would indicate a noticeable effect produced by the production regimes on the simple quality indicator evaluated.

Once the measurements have been taken, the altered regimes of the production process in view are reset to the original values and adjustments are implemented to the regimes of the successive production process.

Materials and Methods of Analysis

The measurement tools applied, the error and the type of data obtained as a result of simple quality indicator measurements are given in **Table 1** [12–14].

The applicability of the measurement tools given in Table 1 is confirmed by MSA results. These measurement tools are applied to monitor simple quality indicators during production.

A total of 32 measurements were taken for each of the simple quality indicators, which number had been defined based on the random error of 0.3 and the measurement system reliability factor equal to 0.9. The latter values were assigned on the basis of the measurement tool data given in Table 1. The above mentioned measurement tools were used to measure the simple quality indicators as specified in the guidelines [15]. As the destructive method will be used to measure the ball stud pull-out force, the batch size does not require adjustment. So, each batch comprises 32 pieces.

Measurement Results

In accordance with the proposed method for establishing a relationship between the production regimes and the simple quality indicators of the product considered, a batch of 32 pieces was produced using the existing production set-up. **Table 2** contains the values of the tilting torque of ball stud as measured on the parts produced in the current production set-up. A similar approach was implemented when measuring the other simple quality indicators.

To illustrate how a production process can impact simple quality indicators, a process of making mounting holes in the ball joint steel housing can be considered. The process was adjusted and the quality of the final product was analyzed. To realize it, the RPMs and the motion of the cutting tool were changed and no lubricoolant was fed. A fresh batch was produced in the new production mode. **Table 3** shows the measurement results for this batch.

The data given in Table 3 indicate that for the quality indicator '*Tilting torque of ball stud*' the deviation between the arithmetic mean values obtained before and after changing the production regimes does not exceed the measurement error. Thus, one may conclude that the production process considered has no effect on the simple quality indicators.

A similar approach was implemented when measuring the other simple quality indicators.

Table 4. **Impact of the production regimes on the simple quality indicators of the GAZELLE NEXT ball joints**

Simple Quality Indicators	Regimes of Production Processes									
	Machining of Ball Joint Housing			Machining of Ball Stud				Assembly of Ball Joint		
	Make mounting holes	Machine the inside	Machine the outside	Contour machine	Cut threads	Roll the fillet	Roll the sphere	Assemble	Form a permanent joint	Seal the friction pair
Tilting torque of ball stud		+		+			+	+	+	+
Rotating torque of ball stud		+		+			+	+	+	+
No squeaking when the ball stud is tilting or rotating							+	+		+
No jamming when the ball stud is tilting or rotating		+					+	+		+
Total axial movement of the ball stud		+		+			+	+	+	
Ball stud pull-out force		+	+	+			+		+	
Pivot angle		+		+		+		+	+	+
Dimensions			+							+
Mounting dimensions	+			+	+					

Table 4 shows how production regimes can impact the simple quality indicators of the GAZELLE NEXT ball joints. The '+' symbol at the intersection between a line and a column indicates that the production regimes do indeed have an effect on the corresponding simple quality indicator.

Conclusion

The purpose of this study, which is to establish a relationship between the regimes of the production processes and the simple quality indicators of the GAZELLE NEXT ball joints, has been accomplished. The task was fulfilled with the help of experiments, which involved making consistent changes to the production regimes followed by the production of a control batch and quality analysis.

The method used in this study can also be used to establish a relationship between production regimes and simple quality indicators with regard to other products.

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