INCREASING PRODUCTIVITY OF COMPLEX PRODUCT OF MECHANIC ENGINEERING USING MODERN QUALITY MANAGEMENT METHODS

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ABSTRACT

The present study is aimed to review and present modern quality management methods to improve the productivity of complex product of mechanic engineering units. In this regard, the paper aims to study and generalize the design practices for the development of a high-tech product in the theory of sustainable production development in the context of end-to-end integrated quality management. On the example of the Volkswagen /Skoda project in the welding department of OJSC "GAZ", the efficiency of the quality management system of an individual production is assessed; ways to increase the productivity of production. The objectives of the study are achieved through the development of specific activities and actions. In addition, in the process of analyzing the state of the welding department and its equipment, there were identified powerful but unused tools that enable the improvement of work in the department and the coordination with the internal sections of the departments as well as coordination with other departments with other departments.

Keywords: Design Practices, High-Tech Product, Production, Quality Management.

INTRODUCTION

Statement of the Problem or Task in General Terms

Successful competition of Russia with other countries is not possible without a significant improvement in the quality of domestic products. The task of improving quality can be achieved only if all spheres of production and economic activity of enterprises are involved in its solution; and if the company's specialists have the relevant knowledge in the field of quality management. Initially, a strong impulse to acquire knowledge in the field of quality, as well as to create quality management systems at enterprises, was given to domestic enterprises in 1987 by international ISO 9000 series standards, which describe the quality management models for enterprises of any field of activity (Khorasani & Almasifard, 2017). In parallel, the availability of quality systems was required by both customers/consumers and government bodies, which required a guarantee of obtaining high-quality, safe products. The interest in creating quality systems at the manufacturer is also explained by the emerging opportunities to improve production, increase the efficiency of its activities and enter new markets (Kuznetsova, 2017). It is becoming the norm to have certified examination of quality system at the enterprise. Thus, the relevance of the study is due to both external factors associated with the change in the competitive situation in the markets, the requirements of consumers and internal ones, the necessity to meet all the requirements of the international ISO 9000 standard.

METHODOLOGICAL FRAMEWORK

The following specialists (who published their works in different years) are considered to be classics in the field of quality: (Saxon, 2001; Watson, 2005; Juran, 2014; Shewhart, 1939; Taguchi, 1976; Deming, 1993; Ishikawa, 1988; Juran, 1995). ISO specialists who developed the standards of the 9000 series tried to take into account the authors' positions, both in the interpretation of categories and the essence of the quality management system.

The definition of the concept of product quality can be proposed in the following form: product quality is a set of essential properties quantitatively evaluated by the system of technical and economic indicators that distinguish products from another similar purpose that determine the demand for products in market conditions at socially necessary costs and market prices for this production (Kuznetsova, 2015). The purpose of this study is to determine the level of effectiveness of the quality management system at the enterprise on the example of the Volkswagen/Skoda project in the welding department of OJSC "GAZ", as well as to develop measures for its improvement and enhancement. On the basis of the goal set, the tasks for its implementation are as follow:

1. To assess the effectiveness of the processes of the quality management system of the research object;
2. To propose ways to increase production efficiency on the basis of the principle of end-to-end integrated quality management and the requirements of international ISO series standards of TS16949.

RESULTS AND DISCUSSIONS

The study deals with the improvement of the QMS of the enterprise of OJSC GAZ Group on the Volkswagen/Skoda project, the welding department. The department produces welded bodies of Skoda Octavia A7, Skoda Yeti face lift and Volkswagen Jetta assembled with hang-on parts. The Volkswagen/Skoda project operates with a quality management system developed in accordance with the requirements of GOST R ISO 9001. The structural diagram of the Volkswagen/Skoda quality system in the welding department is created on the basis of the structural diagram of the enterprise and gives an opportunity to show the composition and interrelation of all structural units performing functions in the quality system. The quality of the products produced by the welding department is subject to high demands both on the quality of the surface, on the quality of the welded joints and on the vital connections of the vehicle. Quality assurance of the output of the welding department is carried out in stages (Garina, Kuznetsov, Viktor, Lapaev, Dmitry, Romanoskaya, Elena, Yashin & Sergey, 2017):

Determination of QRK Control Points (Qualitats Regel Kreis)

In the body welding department, quality control (the QRK points) in the production process was introduced. Welding controllers work at the control points of welding. Work on control points is carried out according to the documentation. There are 2 control points QRK in the welding department at the moment: QRK1-floor quality control station 2060 and QRK2-quality control of the base station 6400. At the QRK quality control station 1st. 2060, the underbody is inspected for defects, tracing so-called "TOP" defects, the correction of which is guaranteed. Also, the defect statistics form is maintained. Operators conduct feedback with the leaders and masters of the site concerning the emergence of mass defectiveness. Correction and prompt feedback by operators at the QRK station of detected defects on site allows improving the quality of products (Schiffauerova & Thomson, 2006). At the QRK quality control station 2st. 6400, the bodies are inspected for defects, tracing TOP defects, the correction of which is guaranteed. Also, the defect statistics form is being maintained. Operators conduct feedback with the leaders and masters of the site concerning the emergence of mass defectiveness. Correction and prompt feedback by operators at the QRK station of detected defects on site allows improving the quality of the products.

Quality Control: R-110, R-140, R-150 Check, R-150 Confirmation

Work is carried out by welding controllers according to the following documentation located at the station: the process book that includes working standards and jesses visualization sheets and problem sheets. In addition, the security calendar "Green Cross" is kept on the control points: days without injuries are marked with green; days with injuries of low severity are marked with yellow and the days with traumas of medium and higher severity-with red. Each station has a feedback sheet describing the sequence of actions when a critical defect or a frequently occurring defect is detected. In addition to work with the body, its instrumental, visual and tactile inspection, the work with the check list of the car is performed. At each station a seal is put on the passage of a station with a certain status-OK or NOK. In addition, information about the defects of the body is recorded to the check list and production seals are put concerning the performance of a certain operation.

Forming Feedback on Quality

In case of detection of a critical or frequently recurring defect, the QO employee informs the supervisor about it, who in turn informs the production-responsible person. The responsible person from the production takes the necessary action/measures as soon as possible to eliminate and prevent future mismatch and transfers the information to the defects registration sheet. The defects registration sheet is made by the QO employee at each control station at the beginning of the shift. During the shift the supervisor checks the correctness of filling in the data in the defects registration sheet and at the end of the shift, transfers it to the archive for further storage for a period of 3 years.

When a critical mismatch is detected (A-error), the supervisor/leader issues a check sheet of the conveyor/site and passes it to the production master/leader. The production master/leader checks all available units/bodies/cars as soon as possible for the absence of this discrepancy, checks the accuracy of the technological process at the site of the problem, designs a plan of measures to prevent such defects in the future. In the conveyor/site check sheet the production master/leader places the body numbers or chassis numbers of cars with the status OK/NOK, indicating the cause of the defect occurrence and the actions taken. After all the performed operations, the conveyor/site check sheet is handed over to the supervisor/leader to verify the correctness of the filled in data. At the end of the shift the conveyor/site checklist is transferred to the archive for further storage for a period of 3 years.

Body Audit in the Welding Department

In addition to the control within the line, off-line monitoring is carried out: body audit in the welding department, destructive testing, research in the metallography laboratory and audit of the black body. Audit of the body in the welding department is a special organizational form of control of the products. The audit is conducted daily by auditors in accordance with the requirements of the procedure DP-VW/Skoda-005 "Body audit in the welding department". The body for audit is selected arbitrarily, after a standard quality control process, based on the volume of current production. Manufacture of bodies: <100 pcs of 1 model per shift=1 body for audit; >100 pcs 1 model per shift=2 bodies for audit. The definition of defects types also depends on the specific zone. The body is divided into 3 sectors. Sector 1 includes all surfaces on which the defect leads to special inconveniences and is very noticeable (the outer and inner surfaces of the body); Sector 2 includes all surfaces on which the defect is not very noticeable (exterior and interior surface of the body); Sector 3 includes all concealed surfaces that are rarely or briefly visible during operation (exterior and interior surfaces of the body). Designation of sectors that are hidden by body components. If the surface is not hidden by the components of the body, the adjoining sector is considered to be the main one. The body is assessed according to the standard. And if there are discrepancies, the error classes A, B or C is assigned. After the audit the body assessment is calculated.

$$\text{Evaluation-QC (quality class)}=\sum(A_1)+\sum(A)+\sum(B_1)+\sum(B)+\sum(C_1)+\sum(C) \quad (1)$$

"Pain boundary", the minimum quality index + 0.4 QC

Here is the example (Kuznetsova, 2017): targeted indicator=1.5 QC; the minimum indicator is 1.5+0.4=1.9 QC; if QC=1.9 it hurts. If QC=2.0 is the blocking of the fleet of the released bodies to the consumer; checking the entire fleet to identify errors that caused the exceeding of the target (or a sample from the fleet of 10% to identify errors that caused the exceeding of the goal)/determines the quality director/head of the quality management. An unscheduled check of the process of operations that issued critical errors A/A1, re-audit of the body. Based on the results of the audit a meeting is held to identify those responsible for the elimination of the defect. The audit report is sent to all interested parties.

Out-of-line Monitoring

The control carried out in the welding department by the production personnel of the VW/Skoda project is divided into:

1. Control of welding points by ultrasonic testing device with statistical tracking of the result and providing feedback to research the causes and eliminate deviations. If a bad connection is detected, the protocol is immediately transferred to the leader of the site group where the component part is made to fix the defects. On the component parts after the repair, a second inspection is carried out. A record is made in the protocol on the correction of the defect with a mark about the elimination.

2. Check of welding points not to destruction with return to work. The control of welding points is not destructive with the return to work with statistical tracking of the result and providing feedback is conducted to research the causes and eliminate deviations. Welding points are checked by cutting-in method-using a hammer, the chisel is slammed next to the welding points till the moment of deformation, preventing the destruction of the component part and then correcting the deformation with a hammer.
3. Check of welding points by destruction. Strength test is a form of control of welding and adhesive bond according to a destructive method. (Instrumental method of influencing the joint (welding or adhesive) is used till the moment of complete destruction.) To evaluate strength characteristics, adhesion properties, fillability and penetration of the material.). The work is carried out according to JES (step-by-step execution of the operation), control of welding points and flaring by CJ destruction with a statistical tracking of the result and providing feedback to research the causes and eliminate deviations. The test of strength of welding and glue is carried out according to the requirements of the procedure DP-VW/Skoda-013 "destructive testing, welding strength and glue test". Periodicity of the test is maintained according to the plan: 1 body every 3 months of each model (minimum 1 serial body per quarter).

Based on the reports in the case of out-of-specification results, corrective measures are taken. After the introduction of corrective measures laboratory tests are repeated. From the welding department the body is transferred to the paint department with all the mounted component parts. Mounted component parts must be installed with a nutrunner with a specified tightening torque. That is why vital connections are established by the ES nutrunner. The quality of the JVS is carried out with the help of ES nutrunners, which ensure the necessary tightening torque of the joints. The vital connections are tightened by the ATLAS COPCO electronic nutrunner. A quick and lightweight battery nutrunner with a sensor is ideal for performing tasks in which the quality of the tightening is the first priority. It is ideal for work in a confined space where ease of access and high mobility are required. No other battery tool is a match for the unique tightening speed and advanced process control capabilities. The Industrial Radio communication System (IRC) developed by the company allows to use nutrunner combined with a controller to accurately monitor the tightening torque and fully monitor the quality of the joints. At a standard workplace one tool is used to perform several tasks with the same torque range.

In addition to the activities a visualization sheet is created that shows the acceptable (OK) and unacceptable (NOK) state so that the operator pay attention to the defects and avoid them. Acquaintance of operators/controllers with visualization is performed under signed receipt.

Defect Statistics

Data acquisition for statistics is conducted at control points and it is put down in the defect statistics sheet. The vehicle check list contains information about the passing a particular station. Operators put personal seals on passing their station, the controllers put down the information about the presence of defects on the body. The description of the defect is recorded on the card in writing and the location of the defect is indicated on the body with a special pencil. Information on the number of defects and bodies is put down in the defect statistics sheet, which includes the name of the defect itself and the location where the defect was detected. In addition, the body is assigned the status as defect-free, the body without entering the repair area, the body with unsolved defects. Defect statistics include such indicators as DRL and DRR.

DRR (Direct run rate) is the percentage of direct descent. Measuring the percentage of direct descent provides a system of built-in quality and effectively delivers the first quality results for sequential tracking and continuous improvement. DRR=Total number of cars accepted without entering the repair area/total number of cars presented for the first time at a particular station (Hackman & Wageman, 1995).

DRL (Direct run loss) is an indicator of the average number of defects per vehicle. The DRL process serves as a means of measuring the number of defects per vehicle during the entire process. Each defect detected at the control stations is taken into account when calculating the DRL. DRL=Total number of defects detected at a particular station/total number of cars presented for the first time at a particular station (Schatz, 2006).

CONCLUSIONS

The conducted research showed that the DRR does not reflect the actual situation about the criticality and number of defects. While calculating statistics it was suggested to change this indicator to FTC (First time capability)-indicator of the percentage of cars taken at a quality control station without defects. FTC, as well as the achievement of quality operations on workstations, prevention of problems, their detection and permanent detection.

FTC calculation: FTC=Total number of cars accepted from the first presentation/total number of cars presented for the first time at a particular station

The FTC indicator allows determining the level of production defectiveness and the number of bodies without defects. Taking into account this indicator, it is possible to reduce the number of defects in cars, to regulate the welding process of bodies.

A report “Metric” is daily generated from SQS on the basis of the received data on the detected discrepancies from the quality control stations, which contains the following information for each department:

1. TOP-5 problems for the previous month;
2. TOP-5 problems on a cumulative total for the current month;
3. TOP-5 problems for the current day;
4. Quality indicators.

Also, in the welding department statistics from the paint department, the station control and station of taking-over of welded bodies is taken into account. The color quality control station L_{110} inspects the body for defects in welding.

The defect statistics not only formulates the main defects, but also constructs a graph of the current level of defectiveness in relation to the target figure on the graph. In addition, the people responsible for the elimination of a specific defect are indicated under the graph in the column with the list of TOP defects. According to the graphs at the quality control stations R_{110} and L_{110}, the average number of defects is greater than the target number, but at L_{110} the number of bodies accepted from the first presentation was bigger than the target indicator.

Each month based on the received data on identified discrepancies from quality control stations, graphs are generated that contain the following information for each work department:

1. DRR-The percentage of cars accepted without entering the repair site. The calculation of DRR is carried out both separately for each monitoring station and a common one for three points AxBxC;
2. DRL-The average number of defects per vehicle. Calculation of DRL is carried out both separately for each monitoring station and common for each quality control station;
3. FTC-The percentage of cars accepted from the first presentation. The FTC calculation is carried out separately for each quality control station.

In addition, the company has a Skoda quality system (SQS). However, this system is not used. At quality control stations the defect statistics are fixed in manual form. And the general statistics is calculated by a specialist in the collection and processing of information.

The reasons for not using SQS are as follows:

1. The system of collecting information is not completed and does not always work adequately;
2. It takes more than one takt to enter the data into the program and the operator does not have enough time to process data from all computers;
3. The system is incorrectly translated into Russian that causes difficulties in the processing of information.

However, the development of this system is advantageous in terms of quality and time saving. If necessary, the interested person will have an access to information about the body of the car, the number of defects, the tightening status of the LIV, etc. At the moment, to obtain this information one needs to look for a body check list in the archive. Search of the check list takes a lot of time and the card cannot be taken out of the archive for carrying out the work. A computer system SQS can be used with access to the portal of teamwork.

In addition, there is a problem with acquaintance with the statistics of defects in the welding department. Not all department floor foremen are acquainted with the defect statistics sheet. The department floor foremen are loaded down with work and do not have time to bypass the control station. The introduction of SQS will allow automatically sending the information and receiving read receipt.

The introduction of the system will reduce the costs of calculating and synchronizing statistics, as the checkpoint will not be obliged to keep statistics in manual form. This is an opportunity to reduce the number of workers, to optimize the work of controllers, to ensure that everybody is recorded in statistics.

To implement the program the following costs are required (Mizikovsky, 2016):

1. Optimization of check lists. This program works by scanning a check list of a certain type. Therefore, each defect and the location of its detection must be described separately in order that, when scanning, the program may accurately recognize a certain defect;
2. Attachments to the adequate translation of the SQS program into Russian;
3. Automatic acquaintance of interested persons with statistics of defects.

The proposed improvements make it possible to achieve a number of cost advantages (Table 1).

Table 1
INDICATORS OF THE COST ADVANTAGES (Garina, 2014)

Name	Before	After
Annual output, units	66000	88000
Number of defects claim of A category, units	28	17
Number of quality claims from customers, units per year	191	122
Required number of employees	600	550
Takt time for a unit of production	200	130
The number of throw-outs per year (pcs)	70	35

In addition to the effect given in the table, the introduction of the proposed improvements will facilitate access to information about body defects; the calculation of statistics will be performed in electronic form, not in a manual one. It will be not necessary to fill in the defect statistics sheets manually; it will be possible to take into consideration each body.

The objectives of the study were to identify shortcomings of the current QMS based on analysis and development of measures for its improvement and enhancement. These goals were achieved through the development of specific activities and actions based on the study materials.

In addition, analyzing the state of the welding department and its equipment, there were identified strong unused tools that enable the improvement of work in the department and the inter-coordination with other departments and departments.

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