IMPROVING THE QUALITY OF FRICTION WELDING BY SELECTED METHODS

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Abstract

The study is aimed to identify the causes of piston incompatibilities in the friction welding area, as well as to reduce or eliminate the occurrence of non-compliance using quality management tools (Pareto-Lorenz diagram, 5W2H and 5Why method). Diagnostic tests were carried out with visual tests and quality control results were analyzed. The subject of the research was a steel piston for diesel trucks. The studies identified the most serious non-compliance - burnout of the combustion chamber and clarified its cause - the incorrect execution of the upper fork in the area of the combustion chamber due to the lack of supervision of workers. So far, the company has not analyzed quality problems using a sequential quality management methodology, so that the corrective actions implemented have not fully achieved the quality objectives. The sequential method used in the development, including diagnostic and control tests and quality management tools, is a universal way to monitor the quality level of products and quickly correct non-conformities. There are no implications for this methodology. It can be implemented in companies producing products that ensure an adequate level of quality.

Keywords: Mechanical engineering, quality engineering, friction welding, quality management methods

1. INTRODUCTION

Technological developments and changes in the industrial economy require products of high quality and with increasingly better properties. These trends also apply to internal combustion engines which generate energy for the propulsion of motor vehicles [1,2]. Among all the components of the internal combustion engine, the part that is most vulnerable to thermal damage is the piston. Since this element is a mobile part of the combustion chamber, it must be resistant to high temperatures and pressures and free from any kind of non-compliance [3,4]. An important role in the manufacture of such products is played by the technology of their. An example of a method of joining steel components, which has become increasingly popular and important in recent years, is the friction welding method. This technology is one of the few methods of using frictional heat in the technique [5-7]. The joining of metal elements and their alloys takes place in a constant state, which makes it possible to make a constant combination of materials that until now were considered difficult to weld or even untouchable. As a result of the pressure acting in the contact area of the combined products during their relative movement, friction occurs, as a result of which the mechanical energy of friction changes to thermal energy. For traditional metal joining techniques, the friction welding method is versatile, energy-efficient and environmentally friendly [8-10]. The attractiveness of this method is due to the following technical and economic benefits, such as the considerable stability of the welding process affecting its repeatability, high process efficiency, the possibility of process automation and the combination of materials with different properties, as well as better health and safety conditions than those of traditional bonding methods [11-14]. However, the frictional heating connection has limitations related to the difficulty of combining elements with complicated shapes or defects related to the deformation of the contact line [15]. Due to the high strength of friction-welded joints, this method can compete with traditional joining methods. Using this method instead of riveting or welding is important due to the reduction of production costs and product weight. For these reasons, friction welding is included in the key technologies used in automotive [16-18]. In order to improve products and ensure their high quality, comprehensive methods for detecting non-conformities are constantly sought, but also seek to prevent them by detecting their sources or even by looking for the causes that cause problems within them [19,20]. The methods of quality management that enable the activities indicated to be carried out are those which skillfully apply to increase the level of quality of the products offered [21]. Qualitative analyses supported by the use of individual quality management tools [22-25], or the use of these tools to optimize production processes [26, 27] are often presented in quality management literature papers. It is, therefore, appropriate to develop a sequential method for analyzing and improving friction-welded connections.

2. ANALYSIS

2.1. Purpose, subject and scope of research

The purpose of the tests was to examine the connection status of the upper and lower parts of the steel piston after the friction welding process. The diagnosis was made using a method of visual examination. The semi-finished products of the friction welding process were die-forged steel forgings. An additional objective is also to reduce the number of non-compliant products or to eliminate them completely by using quality management tools (Pareto-Lorenza diagram, 5W2H and 5Why method) to determine the sources of non-compliance in the area of connection of forgings after the friction welding process. Due to the increase in identified non-compliant products during interoperable inspections (2% for the previous quarter) and the number of complaints, the subject of the tests was a steel piston for Diesel Man trucks (**Figure 1**). The study concerned a batch of products made in the 4th quarter of 2019 in one of the automotive companies involved in the production of steel and aluminum pistons for trucks and passenger vehicles. The company is located in the southern part of Polish.

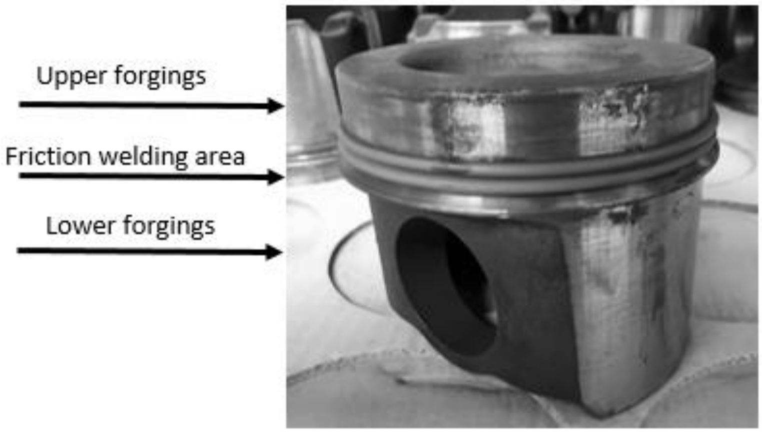

Figure 1 Test subject – piston after friction welding process

The scope of visual testing mainly covered the surfaces of the connection of forgings after the friction welding process.

2.2. Characteristics of the alloy

38MnVS6 steel (38MnSiVS5) is high strength steel based on Mn-V. It is high-quality low alloy steel with good machinability for controlled cooling from working heat (BY treatment, condition + P according to DIN EN 10267) [28]. 38MnVS6 steel is found in a group of dispersion hardened ferritic-pearlitic steels following DINEN 10267 [29]. The chemical composition of the alloy and its mechanical properties are shown in **Table 1**. The alloy is applicable to automotive parts such as gear shafts, pushers, rotary bearings, axle pivots, hubs and piston heads [2,30].

Table 1 Chemical composition and mechanical properties of 38MnVS6 steel [18]

Chemical composition									
Pierwiastek	C	Si	Mn	P	S	Cr	Mo	V	N
Min, [%]	0,34	0,15	1,20	<0,025	0,020	<0,30	<0,08	0,08	0,01
Max, [%]	0,41	0,80	1,60		0,060			0,20	0,02

Mechanical properties			
0,2% proof stress Rp0,2 [N/mm2]	Tensile strength Rm [N/mm2]	Fracture elongation A5 [%]	Reduction of area Z [%]
Min 520	800-950	Min 15	Min 25

2.3. The course of research

To date, the company has not carried out in-depth analyses of the causes of non-compliance in the area of forging connection after the friction welding process, but due to an increase in complaints about steel pistons and negative quality control results, it was decided to take pro-quality measures. To this end, a team of experts was set up, including a quality manager, a technologist, a builder and a complaint specialist. In order to carry out qualitative analysis of products, visual control with quality management tools is set up integrally. The next steps in the proceedings of the appointed team of experts included: visual examination, analysis of the results of the checks for the preparation of the Pareto-Lorenz diagram, the 5W2H method for characterizing in a short and legible manner the most important information about the most important non-compliance and the 5Why method? identified and characterized non-compliance in order to indicate its source of.

3. RESULTS OF ANALYSIS

The instrument proposed by the working party to carry out the non-compliance analysis in the area of forging connection after the friction welding process was the Pareto-Lorenz diagram. The actions taken aimed to identify the most significant non-compliances in terms of frequency and effects (**Figure 2**). The types of non-compliance are indicated in turn: N1 – blows combustion chamber, N2 – no connection continuity, N3 – inadequate piston geometry after the friction welding process, N4 - no piston symmetry after the friction welding process, N5 - determination of the welding line of the recooling, N6 - excessive roughness of the weld surface, N7 - fluctuations in the width of the weld surface, N8 - not even connection of the upper and lower recoating, N9 - damage to the surface of the piston jacket, N10 - scratches of the lower recoat, N11 - deformation of the re-weld after welding, N12 - damage to the lower reticulate. According to the Pareto-Lorenza diagram, 82% of the incompatibilities identified during the visual inspection correspond to three types of non-compliance: burnt combustion chamber, lack of connection continuity, inadequate piston geometry after friction welding process. The most serious non-compliance, however, is the burnout of the combustion chamber – this non-compliance accounts for almost 50% of all the defects specified in the analysis. In the subsequent stages of the improvement measures, the occurrence of the most serious non-compliance with the. An example of the visual test results obtained for the most serious and common incompatibility of the frictional connection area is given in **Figure 3**. Identified fork connection misconnection disqualifies piston. In the next step, a working team set up a Gemba walk and then conducted a 5W2H analysis to accurately characterize the problem (**Table 2**). As part of further analysis of the qualitative problem, the 5WHY method was developed (**Figure 4**). Based on the analysis carried out (**Figure 4**) it was concluded that the source of the problem of scorching the combustion chamber in steel pistons was the lack of proper supervision and qualification of the evaporator – errors during operation and inaccuracy of the worker (human area/ management) which contributed to the implementation of the wrong upper forging in the area of the combustion chamber - incorrect depth of the combustion chamber (material area, method).

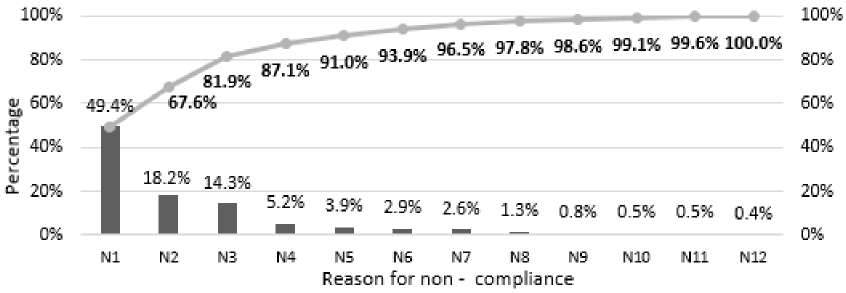

Figure 2 Diagram Pareto – Lorenz for non-conformities arising from the friction welding process

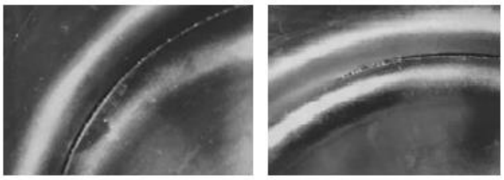

Figure 3 Results of visual tests from the frictional connection area - burnout of the combustion chamber

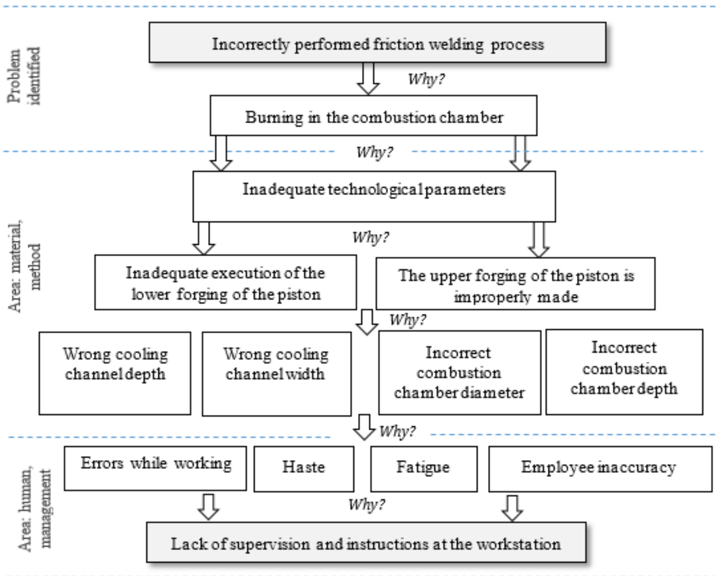

Figure 4 5Why method for the problem of burning the combustion chamber in the friction welding process

Table 2 5W2H method for combustion chamber burnout problem

Question		Answer
Who?	Who has detected the problem?	Employee who performed visual inspection
What?	What is the problem?	Blow steel piston combustion chamber
Why?	Why is this a problem?	Non-compliance with customer standards and requirements – disqualification of the product
Where?	Where was the problem detected?	In the area of the piston combustion chamber – friction heating area of forgings
When?	When was the problem detected?	During visual inspection carried out immediately after the technological operation – friction welding
How?	How was the problem detected?	Non-compliance was detected during visual inspection with an unarmed eye with normal visual acuity
How much?	How big is the problem?	2% of products manufactured in the fourth quarter of 2019.

4. CONCLUSION

The proposal in the study for a detailed analysis of non-compliance concerning the identification of the most serious non-compliance and the examination of the causes of defects in steel pistons, combined with the configured integration of quality management tools, contributed to their elimination and subsequent implementation of effective measures to prevent non-compliance. The purpose of the tests was to identify non-compliant devices and to check the suitability of the control and diagnostic test in the production area. Through a (visual) check, inconsistencies were detected in the frictional heating area, while the Pareto-Lorenz diagram predicted the most significant burnout of the combustion chamber in terms of quantity and effects of wade. The presence of such non-compliance disqualifies the product. To define the problem, a Gemba walk and a 5W2H analysis were performed. To identify the causes of non-compliance, was the 5Why analysis performed according to which it was found that the root cause of the problem was the lack of proper supervision and qualification of the evaporator, which contributed to the wrong execution of the upper forging - the wrong depth of the combustion chamber. The proposed analysis of non-compliance may form part of methods supporting quality management processes [31]. Further studies will be related to the implications of the proposed sequence of non-compliance analysis, which is an effective way of solving the quality problems of the products, within the production of the remaining products offered by the company. The obtained results may also be interesting for the development of welding methods [32,33].

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