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Supporting Welding Work in the Aspect of Increasing Production Process Efficiency

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ABSTRACT

The publications increasingly describe the support of production processes in both manufacturing and assembly areas. The support in industry is due, among other things, to the insufficient manpower, the need to improve productivity or to increase reliability of production in terms of errors. This article presents an example of an industrial implementation in the welding area. The main objective of the application of the presented example was to replace a commercial product and to speed up the manufacturing process of an axisymmetric workpiece of the sleeve type. The presented proposal was implemented in a company where welding is the main manufacturing technology.

Keywords: production optimisation, welding equipment, welding.

INTRODUCTION

The technological tooling is the subject of many scientific publications, and its application is described in various areas of mechanical engineering.

The article [1] focuses on the issue of proper selection of technological tooling for adaptation of 120 mm mortar rounds during laboratory tests on a vibration exciter. The authors' aim was to determine the effect of modified technological tooling on the course of vibration tests in relation to the initial tooling the design of which, together with its fabrication to accommodate mounting on the vibration exciter and its fit to the specimen under test, was changed based on the tests conducted. The aspects related to the improvement of the process fixture as an intermediate element between the vibration device and the test specimen had a significant impact on the vibration tests which, for comparison, were carried out on the exciter head and sliding table.

In the publication [2], the author presented the design of a device for magnet bonding on the external surface of a rotor for SPM motors. The aim of the study was to design a fixture that ensures high accuracy of magnet positioning during bonding and high repeatability of bonding parameters. According to the design guidelines, the fixture must protect the magnet from damage due to uncontrolled impact caused by magnetic forces between the magnets being bonded or between the magnet and the fixture components.

In the article [3], the author presented a way of calculating the manufacturing costs when the tooling is applied for specific operations. The author highlighted the tooling cost as a factor determining the cost of manufacturing the parts for which the tooling is intended.

In the publication [4], the authors presented the benefits (both quantifiable and non-quantifiable) of the use of process tooling in welding processes. They presented examples of standard and specialist tooling.

In the article [5], the authors presented the objectives and needs for the modernisation and automation of welding processes in terms of achieving high and stable quality indicators of welded joints. According to them, the automation and modernisation of welding processes primarily aims at obtaining products that meet global standards not only in the automotive industry, but also in all developing mechanical industries, including the manufacture of industrial equipment.

In the article [6], the author described the characteristics of high-performance MAG welding process, paying particular attention to the occurrence of different types of arcs in this process: conventional, spray and high-performance arcs: short-circuit, spray and rotary. He pointed out their technological advantages and disadvantages such as fusion, spattering and weld defects. The LINFAST concept was discussed, which is based mainly on the selection of shielding mixture composition ensuring the achievement of a given type of arc, as well as narrowing the ranges of wire feed rates with unstable arc glows.

In the article [7], the authors described the development and implementation of technology for automated and mechanised welding of T-joints with butt welds of cargo tank structures made of duplex steel occurring in chemical tanker ships built at Stocznia Szczecińska Nowa Sp. z o.o., at the stage of hull construction on a slipway. Automating and mechanising the welding of T-joints had an impact on increasing the quality of joints and reducing the ship production costs. The article presents the most important aspects of implementation.

In the publication [8], the authors presented the design and software of a robotic deburring station for car wheel rims using vision systems in the manufacturing process. In MATLAB, the authors developed an algorithm to determine the position and orientation of the workpiece, and communication of both MATLAB and RobotStudio environments is via the TCP/IP protocol. The paper also presents the verification of operation and simulation of the constructed workstation.

In the article [9], the authors described the application of nanoelastic photoelectric devices to the welding tooling the use of which will positively influence the reduction of defects arising in welding processes. As part of the research work, the authors used a dynamic matrix predictive control model to predict and control the welding parameters.

The solution presented in this publication shows how simple it is to make changes in the production process in terms of its significant simplification.

Model tests of a sleeve-type component

The support of welding work in the company workshops is required for the following purposes:

- to eliminate mistakes in the assembly process,
- to eliminate the need to read technical drawings at the workstations,
- to enable the employment of low-skilled workforce,
- to reduce the time needed to perform particular welding operations.

In contrast, mistakes in the welding process are due to:

- production speed,
- measurement inaccuracies.

The objective was to develop the tooling for the manufacture of a bearing sleeve to eliminate the purchase of a commercial product, as shown in Figure 1.

The use of such a solution allows to obtain the following benefits [9]:

- reduction in the amount of waste sent to metal waste disposal institutions;
- increasing the production range of the company;
- increasing the range of machines offered on the market;
- lower unit price of the produced retail in relation to the purchase price.

In order to meet these requirements, a three-dimensional model of the sleeve (hub) was developed, which is a combination of a cover element (1) and a bearing sleeve (2) – refer to Figure 2.

To verify the developed hub model for its correct operation, numerical simulations were

Fig. 1. Commercial design of cutting disc attachment used in disc harrows [9, 11]

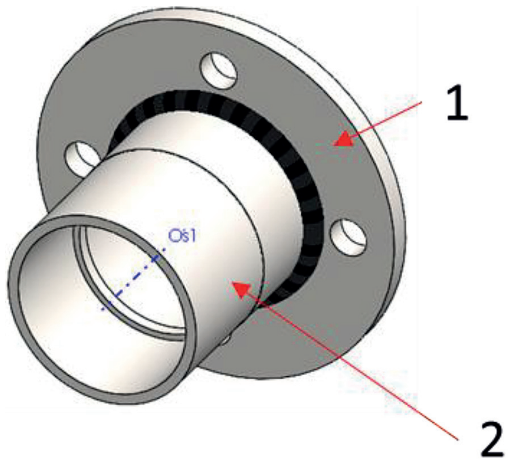

Fig. 2. Numerical model of the bearing sleeve [own study]

performed using the finite element method in the SolidWORKS software. A bending moment was applied (Figure 3), loading the sleeve flange and also the weld connecting the cover to the sleeve.

The load on the hub model was simulated in the form of a remote load, the ties of which were fixed to the cover. The hub model was fixed on the surfaces where the rolling bearings will be placed (green markers). The value of the load was determined based on data obtained from the company financing the presented implementation and was 2,300 N. Figure 4 shows the discrete model of the hub with the FEM mesh superimposed.

The hub model discretisation was carried out with a high-quality solid mesh of 3 mm element size with a tolerance of 0.15 mm, with Jacobian points placed at the nodes [9]. For the numerical simulation, it was assumed that the sleeve would be made of a material grade S235, for which the values of the strength parameters are summarised in Table 1.

The hub strain was simulated in the linear-elastic range of the material adopted. The sleeve was

Table 1. Summary of mechanical properties of material S235

Name	Symbol	Value	Unit
Young's modulus	E	210000	N/mm^2
Poisson's ratio	v	0.28	-
specific weight	ρ	7800	kg/m^3
tensile strength	R_m	355	MPa
yield point	R_e	275	MPa

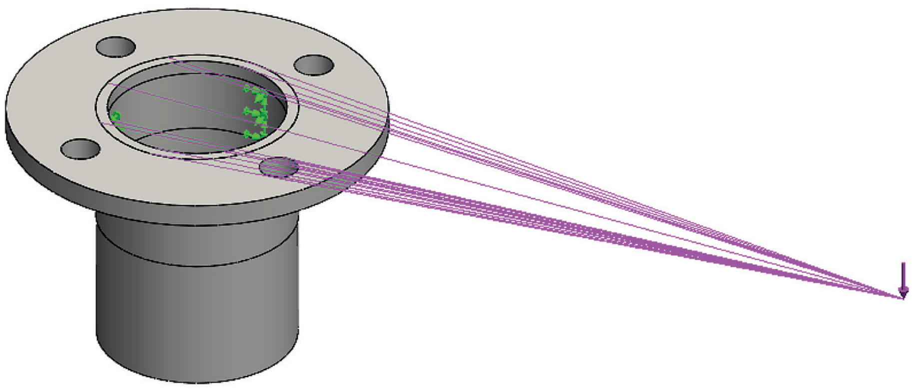

Fig. 3. Diagram of hub bending moment loading

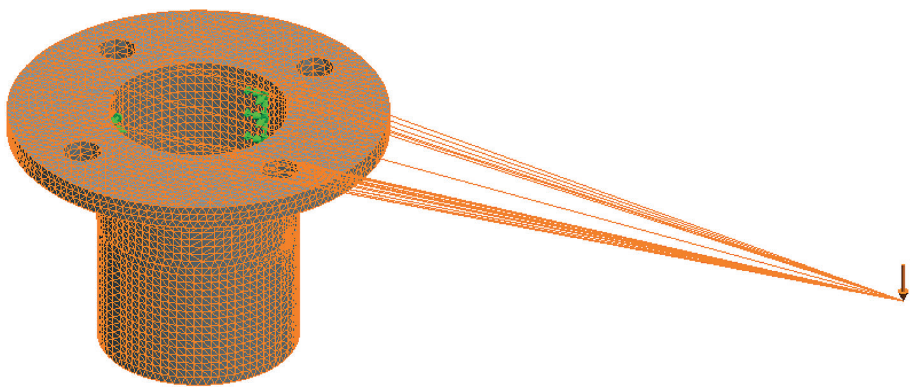

Fig. 4. Model of hub with FEM mesh applied

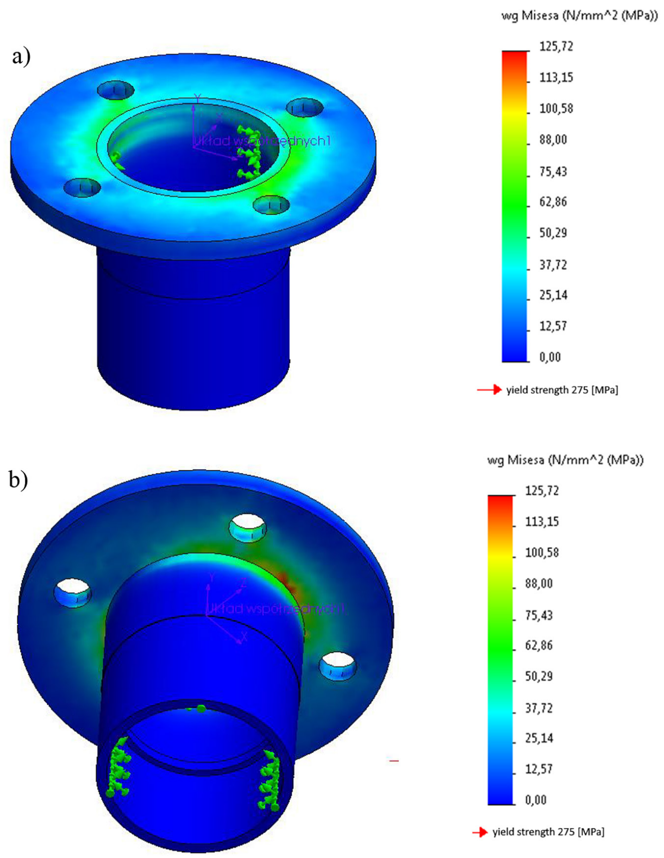

Fig. 5. Sleeve strain under the loading of 2300 N: a) isometric view, b) isometric view from underneath the sleeve

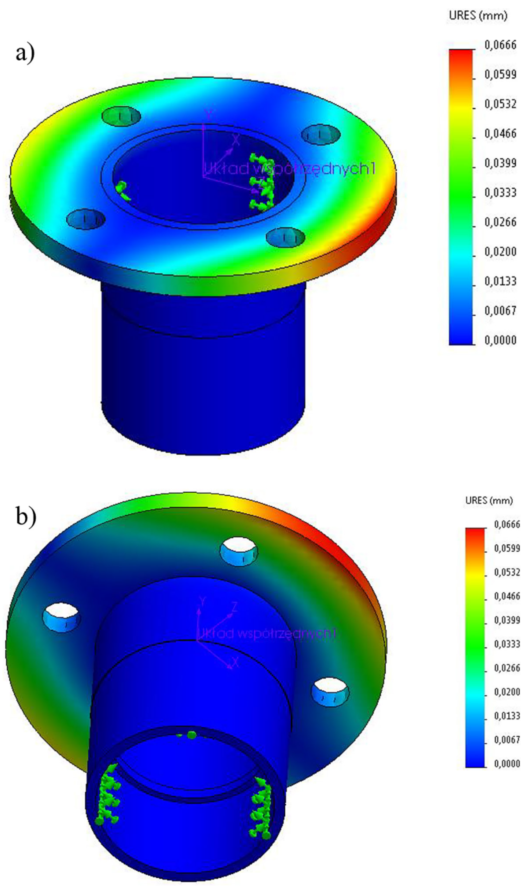

Fig. 6. Displacement of sleeve components: a) isometric view, b) isometric view from underneath the sleeve

fixed to the inner surface of the hub, in which the bearings will be placed in the actual product, which allowed 3 translational degrees of freedom *Ux* = *Uy* = *Uz* = 0 and two rotational degrees of freedom Rx = Ry = 0 to be received. The results of numerical simulation of stresses are shown in Figure 5, while Figure 6 shows the results of displacements.

The presented numerical simulation made it possible to perform a fatigue simulation of the prepared hub model, the results of which are presented in Figure 7. Showing the places with the lowest durability coefficient was possible thanks to the adopted number of cycles of 1100 with the load increased to 23000 N in a peel-and-stick arrangement. Such a pattern mimicked the appearance of momentary increases in load, which illustrated, for example, a stone in the plowed soil that the harrow disc had run into. From the numerical simulations of the strain, two main areas can be observed. The first area of extrusion shown in Figure 6a contained on the upper surface of the lid, where s_g stresses of 75 MPa occur. Another area shown in Figure 6b includes its lower surface, where the maximum zd stresses of 125 MPa accumulate. The stress value of the lid from below is the result of bending the lid relative to the sleeve, thereby inducing pressure with the edge of the lid on the sleeve surfaces. The loading condition is illustrated by the displacement of the cover with a maximum value of U_y = 0.06 mm, which is consistent with the assumed loading direction. Stress at s_g = 125 MPa with respect to the yield strength of the adopted material allows for a safety factor of 2.2. Computer simulations have shown that the stress values in the entire area of the bushing are below the permissible yield strength. Thus, it can be concluded that the proposed solution meets the set sentences and can be tested under working conditions.

Figure 7 presents the fatigue simulation results. Figure 7a shows the fatigue life distribution of the sleeve analysed. The map shows that with reference to 1 million cycles, after 6080 cycles, micro-cracks may appear in the areas marked in red, which reduce the sleeve durability. Figure 7b illustrates the damage location with the probability of 18%. This means that after reaching the maximum number of cycles, damage may occur first in the lower surface of the cover in contact with the cylindrical surface of the sleeve.

Design of special tooling for welding sleeves

In order to introduce a special welding fixture into the production practice that would meet

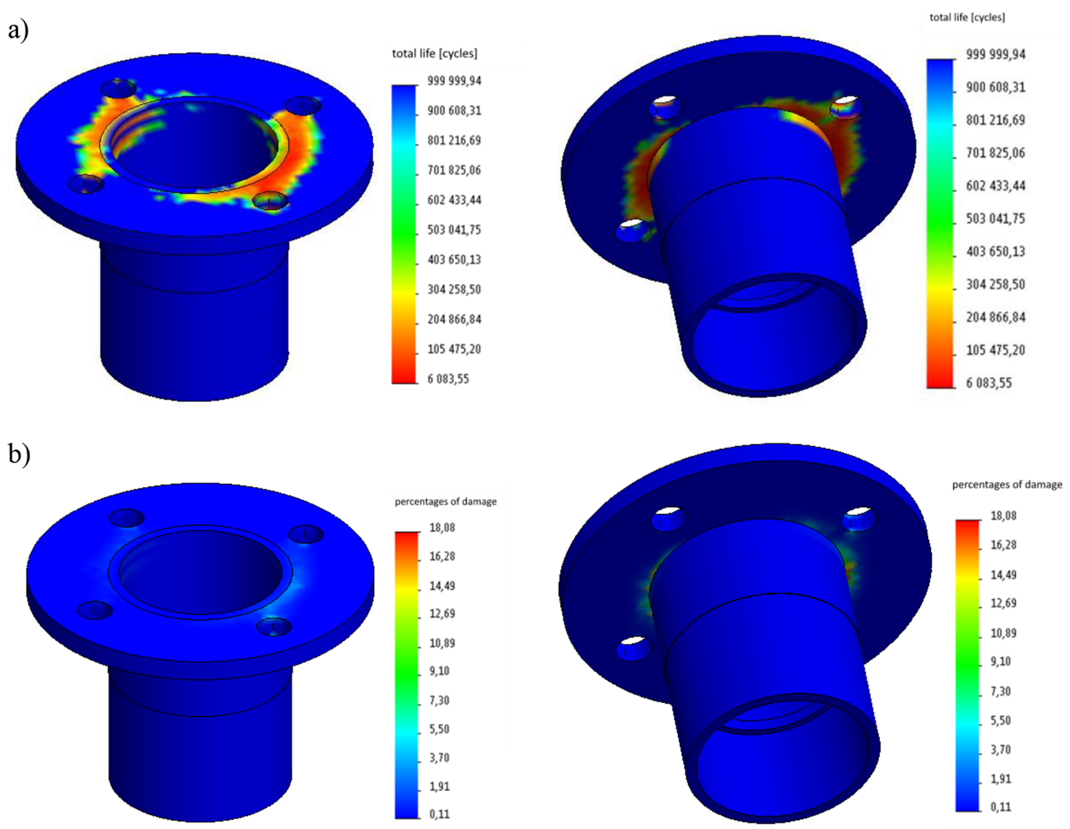

Fig. 7. Fatigue simulation results: (a) durability, (b) probability of failure location

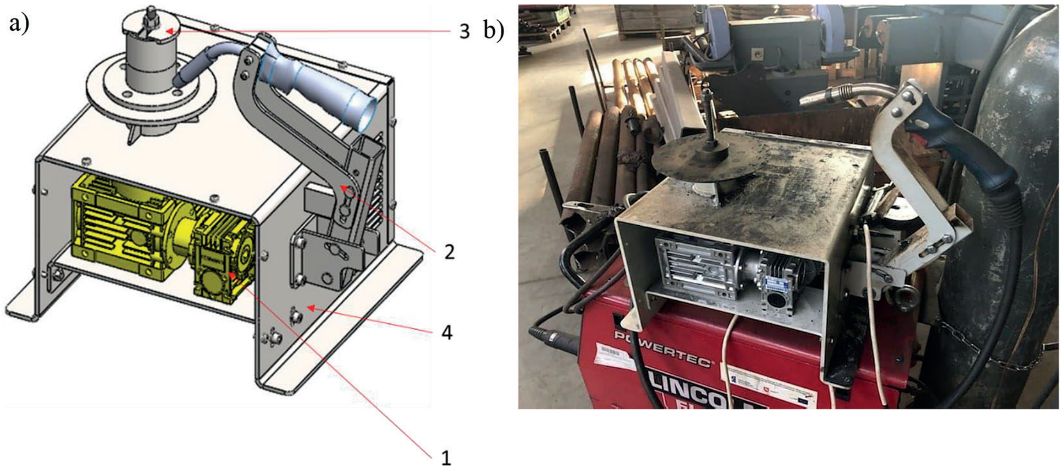

Fig. 8. Special welding turntable for welding of disc harrow sleeves using MIG/MAG method: a) - design, b) - accomplished project

the requirements, a concept was developed for a welding turntable designed for the welding of the hub shown in Figure 2. The turntable model is shown in Figure 8a and consists of: housing 4 in which reducer 1 is mounted whose operating parameters allowed its speed to be correlated with the welding speed, and a tilting welding fixture 2.

The idea was that the welder assembles the collar together with the sleeve on the mandrel and presses them together with the washer 3. When the welding gun 2 is tilted to the working position, the arc is self-ignited and the workpieces are set in motion.

Before the implementation of the presented solution, the hubs were welded on a traditional welding table. The welding process was carried out in three stages, due to the fact that the welder had to pause to make a pass around the sleeve. Thus, while welding, the sleeve had three characteristic starting and finishing points. These spots, which were a kind of technological notch, meant that they were the first point of failure during unfavourable working conditions.

The implementation of the presented solution in the production area resulted in time savings, the component values of which are shown in Figure 9.

The solution presented not only streamlined the production process, but also improved the mechanical properties of the joint, which in turn reduced the number of complaints. In addition, the use of a fixture for this operation relieved the welder's workload, which had a positive impact on his working conditions. Another important aspect of the implementation was the number of hubs produced per unit time. The recorded times of individual operations made it possible to obtain within 15 minutes of work: 11 pieces without the fixture and 20 pieces with the fixture. In this way the production increased almost twice within the same unit of time. It is worth noting that the

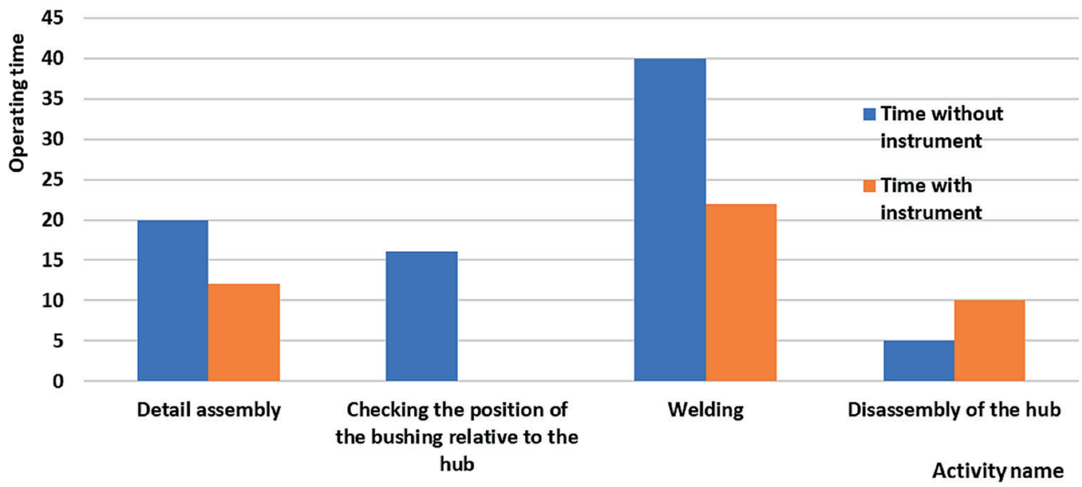

Fig. 9. Comparison of operating times during hub manufacturing: without fixture and with fixture

developed method of fixing the sleeves in relation to the hub disc made it possible to completely eliminate the operation of checking them for correct position in relation to each other.

CONCLUSIONS

The conclusions that emerged from the implementation of the fixture and the hub to the company can be described as follows. The conceptual and implementation work carried out made it possible to almost double the production. The fixture concept presented in the article has not only allowed an increase in the number of parts produced, but also an improvement in their mechanical properties. Thanks to the strength analyses carried out, the company was able to eliminate the commercial product shown in Figure 1, which had a positive impact on savings. The advantage of the introduced hub solution is the saving of material (sheets and tubes), which can be used practically until the end. The use of scrap material considered to be usable results in a reduction in the amount of scrap steel being given away. The implementation of solutions for specific operations makes it possible to eliminate errors caused by the human factor. The obtained results of measuring times showed quantitative compliance with expectations. The obtained welding times using the proposed solution were significantly reduced, which translated into an increase in the number of manufactured parts per shift. The use of tooling also made it possible to achieve better weld quality by obtaining a continuous weld around the perimeter of the parts to be joined, which was in contrast to welding in the previous way. The quality of the weld is crucial not only from the point of view of the strength of the joint, but also provides important information regarding the quality of production at the plant.

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