PROTOTYPE OF TOOL POSITIONER USED FOR MANUALLY RESIDUAL STRESS MEASUREMENT

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SUMMARY
Today's automated, toolless Rapid Prototype systems can directly produce functional parts in small production quantities. Thus, this advantage of RP systems is used for production of more flexible drill positioner that is used for manually residual stress measurement with the "hole-drilling" method using strain gauges. Innovated drill positioner is produced by three dimensional printing process. Functionality of innovated drill positioner is well-proven.

Keywords: 3D printing, RP systems, residual stress measurement

1. INTRODUCTION

Rapid prototyping is a group of techniques used to make complex physical objects according to CAD data from either three-dimensional models or computed tomography data without the tools. Nowadays, commercial RP systems are based on the following technologies: Stereolithography Apparatus (SLA), Solid Ground Curing (SGC), Laminated Object Manufacturing (LOM), Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS) and Three Dimensional Printing (3DP) [1]. The process flow of all technologies is similar and consists of few main phases that are presented in Figure 1.

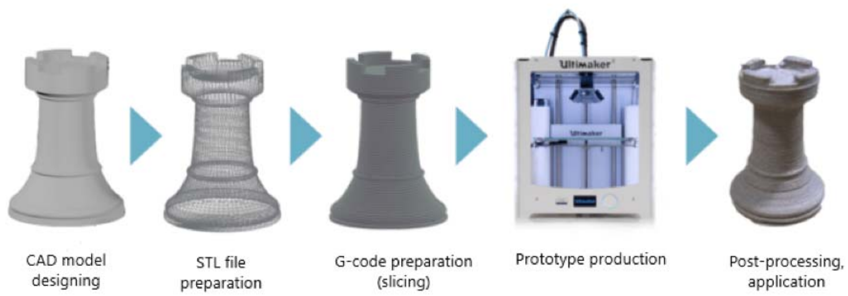

Figure 1. Three dimensional printing process flow [2]

The first step of rapid prototyping is advanced three-dimensional modelling, i.e. generating a solid 3D model using some software package (CATIA, I-DEAS, Solidworks, Ansys, etc.). This step usually takes the most time in the complete process flow. In order to produce a physical model based on computer model file, the computer file is converted into the so-called STL file, in the next step. During the third phase, model is prepared for production. All possible errors on model are removed and model is sliced into cross sections. After production phase, the physical model can be post-processed, as needed [1].
RP processes are also used for quickly solving problems that occur during constructing, designing, measuring or similar processes. In this paper, an example of the use of RP technologies to solve problems that occur during residual stresses measuring is presented. In order to ensure better accuracy and safety of the manual residual stress measurement, a prototype of the drill positioner is produced by 3D printing technology.

2. DEFINING THE PROBLEM

2.1. The residual stress measurement in general

Considering the enormous importance of welded joints in the industry today, it is necessary to correctly conduct its strength testing methods. According to the experts in this field, one of the basic negative effects of welding is the occurrence of residual stresses. The residual stress as a condition in a structure is caused by elastic deformations that are balanced inside the structure. In order to determine and preserve the stability of the structure, numerous residual stresses measuring methods are used. One of the most common method is a hole-drilling method using strain gauges. Above mentioned method can be applied by automatic and manual measuring system.

2.2. Conducted residual stress measurement description

The experimental measurement of residual stress in a welded pipe joint was conducted at Faculty of Mechanical Engineering in Zenica, as an experimental part of master thesis. The hole-drilling method using strain gauges was applied during experiment. Measurement was performed using manual measuring system due to inaccessible geometry of the pipe joint. During manual measurement, the possibility of measurement error is much higher due to the human factor, i.e., operator error. For this reason, a manual measuring system component – tool positioner is used to minimize possibility of human error. This component is a cubical shape, made of a steel material with a built-in magnetic elements for fixing on the measurement sample. The main purpose of the tool positioner is to prevent unwanted displacement of drill tool during measurement.

Due to cylindrical geometry of the pipe and cubical geometry of the tool positioner, it was not possible to accurately fix positioner on the pipe surface. Thus, positioner was glued at the surface using cement adhesive, as it is shown in Figure 2.

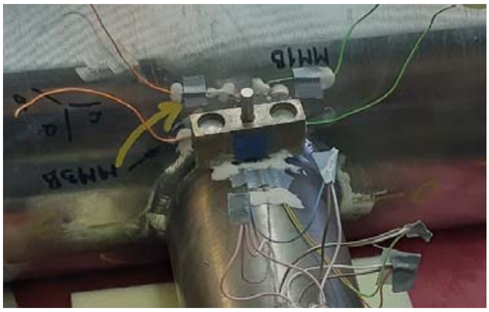

Figure 2. Tool positioner fixed at pipe surface [3]

The measurement for the master thesis was performed at total of six measurement points. Fixing and removing glued positioner activities aggravated and also prolonged duration of experiment.

2.3. Disadvantages of conducted measurement

The most important disadvantages of residual stress measurement conducted for master thesis purpose were:

- the need for preparation a big amount of the cement adhesive,
- the possibility of the strain gauges damage during the glue deposition,
- the possibility of the strain gauges damage during the removal of the positioner,
- increased required measurement time,
- lower measurement quality and higher possibility of error.

3. DEFINING THE SOLUTION

In order to eliminate or reduce the above presented disadvantages for measurements on some further cylindrical models, the conceptual design is based on the modified design of the tool positioner. The production of the conceptual solution is performed by the process of rapid prototyping – three dimensional printing. For this purpose, the geometry of the modelled positioner is compatible with the cylindrical geometry of the pipes. The construction of the modified model has a curved surface through which the contact of the positioner and the object of measurement is realized. The radius of the curved surface is adjusted to the measured geometry. Figure 3 shows geometry of the actual and innovated positioner. As it is presented, contact surface of the conventional positioner is flat, as opposed to the innovated one.

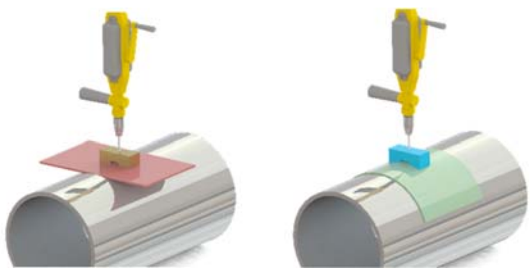

Figure 3. The contact surface of the conventional and innovated positioner

4. PROTOTYPE OF TOOL POSITIONER PRODUCTION

4.1. Designing of CAD model

The overall dimensions of the innovated positioner are similar to the conventional positioner. It is important to create 7 mm diameter drill hole on the innovated positioner to be adjusted to the measuring equipment. In order to avoid contact between strain gauge and positioner, a groove on the curved surface is created.

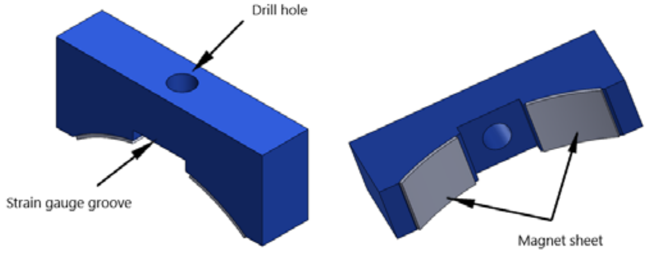

Figure 4. Positioner model

The positioner models for standard pipes DN80 and DN200 were created in according to the above mentioned details. All dimensions of models are presented in Figure 5.

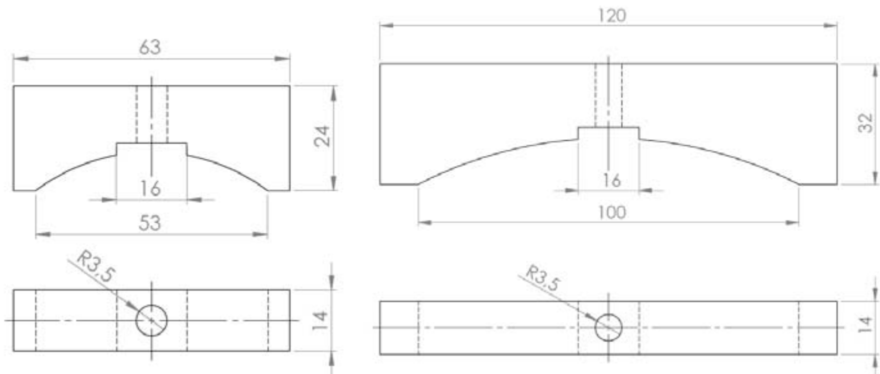

Figure 5. Positioner models dimensions

4.2. Preparation of STL file

According to the standard rapid prototyping procedure, in the next step it was necessary to convert the CAD model into an STL file, so that it can be read into the software of the three-dimensional printer. After the conversion process, the prototype model of the positioner for the DN80 pipe contained 232, and for the DN200 pipe contained 240 triangular planes. The STL file of the drill positioner model for DN80 is presented in Figure 6.

Figure 6. STL file of positioner model

4.3. Three dimensional printing of tool positioner

Three dimensional printing of drill positioners was performed in the IDEA-laboratory of the Faculty of Mechanical Engineering, University of Zenica. Since it is a simple model, the 3D printing process was performed on a Ultimaker 2+ printer. The prepared STL files were uploaded to the Ultimaker Cura software (Figure 7). The models were positioned in that way, the curved surfaces of the positioner were made in the final stage of printing. Thus, the lowest shape and dimension deviation of the curved surface were ensured. After defining the position of the model, the print settings were defined.

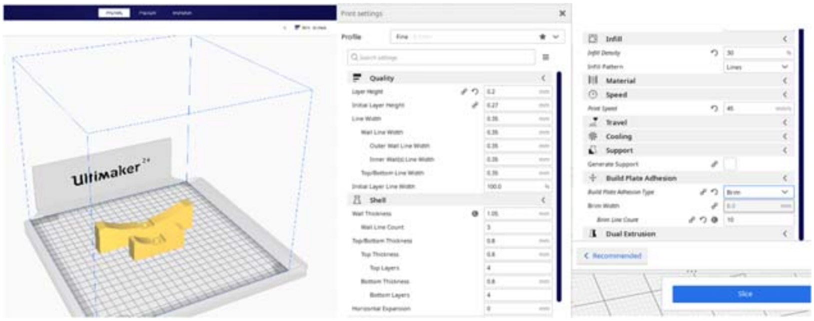

Figure 7. Ultimaker Cura interface and print settings

The supports were printed at the beginning of process, followed by the first layers of the prototypes. Printing was performed continuously, without interference and completed within a defined period. The prototypes during and in the end of printing process are shown in Figure 8.

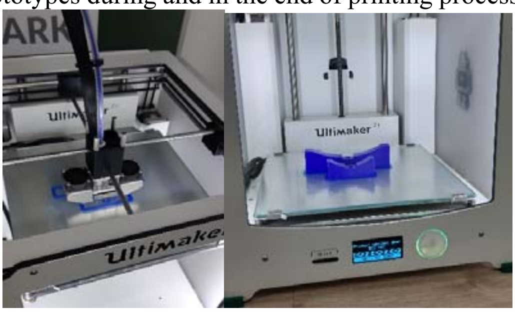

Figure 8. Three dimensional printing process

5. TOOL POSITIONER PROTOTYPE APPLICATION

The printed samples of the drill positioner were carefully removed from the base of the printer. Additional processing of the prototypes was performed to remove the support material that was glued to the prototype material. After finishing, the magnetic sheets were glued using silicone glue. After all preparation activities, prototypes of tool positioners were ready for test use. In the first phase of testing, the prototype for the DN80 pipe was mounted on a smaller pipe of the welded joint on which the measurement was performed using the original positioner, for the purposes of the master's thesis (Figure 9 left). Residual stress measuring was successfully performed.

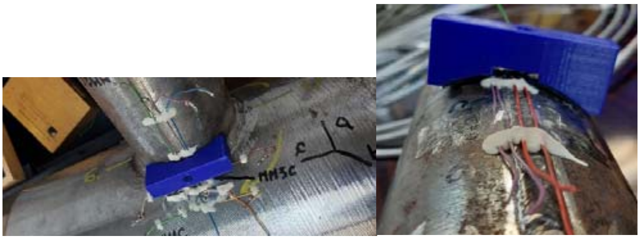

Figure 9. Prototype positioner mounted on the pipes

In the next phase, prototype positioner for DN80 pipe was mounted on longitudinally welded DN80 pipe (Figure 9 right). Measuring experiment also performed without any interferences. An analogous procedure was performed on a DN200 pipe with a longitudinal butt weld. In this case, the drill positioner is also properly fixed without the need for use of glue.

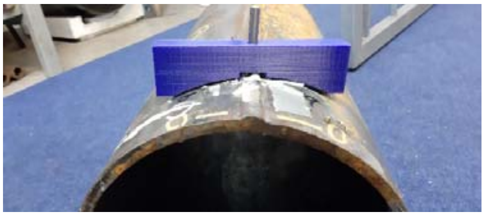

Figure 10. Prototype positioner mounted on the pipe DN200

6. CONCLUSIONS

Prototypes of tool positioners have been successfully used for measurements on DN80 and DN200 pipes with longitudinal welds. Using these positioners, the measurement was performed both on the weld material and on the HAZ. The fixing of the positioner was done using the magnetic sheets and there was no need for additional fastenings. The average consumption of magnetic sheet metal per positioner is very low: 0.001 m^2. The rapid prototyping has proven to be a very efficient and simple way to solve the shortcomings in the manual measurement of residual stresses. One of the advantages of the prototype drill positioner is its very simple geometry. The initial CAD models that were made for measuring on pipes DN200 and DN80 with longitudinal welds can be very easily and quickly adapted for measuring on pipes of different diameters. Quick and easy production as well as low cost are also an advantage of innovated positioner.

7. REFERENCES

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