Journal for Technology of Plasticity, Vol. 42 (2017), Number 2

DOI: 10.24867/jtp.2017.42-2.23-22

CONTROL OF HYDROFORMING SYSTEM OF WELDED METAL SHEETS

Karabegović E[1]., Šemić E.[2], Poljak J.[1]

[1]University of Bihać, Faculty of Technical Engineering Bihać,
Dr. IrfanaLjubijankića bb, 77000 Bihać,
[2]University "Džemal Bijedić" Mostar, Faculty of Mechanical Engineering,
Univerzitetski kampus, 88104, Mostar
Bosnia and Herzegovina

ABSTRACT

Control of the machining systems, with the purpose of control of the machines and systems by changing the parameters specified for their work, has already been defined in their design. The application of the mechatronic system in the control of the machining process was analyzed for the conditions of experimental hydroforming of welded steel sheets. Hydroforming is classified in unconventional design technologies and occupies a significant place in scientific research. In relation to the manual mode of control of the hydroforming process in experimental conditions, the application of mechatronic system, designed for the conditions given in this paper, simplifies and stabilizes its performance. After the design of the mechatronic system, a simulation of the designed mechatronic system model was conducted, followed by verification by performing an experiment in the hydroforming process of welded sheets.
Keywords: *Control of the process, Hydroforming, Mechatronic system, Sensors*

1. INTRODUCTION

Rapid development of new technologies and systems for their production is determined by the market demands for new or innovating existing products. For this reason, in order to improve and ensure quality, the automotive industry is applying new technologies of sheet and pipe design. Most of these technologies are based on the application of different types of energy for design. Some of them are high pressure fluid energy, laser energy, plasma energy, electromagnetic energy, etc. Each of the new forms of energy for designing parts requires appropriate research and analysis in order to achieve better quality solutions than previous

[*]Corresponding author's email: edina.karabegovic@unbi.ba

technologies. Research in this paper relates to the management and control of the hydroforming process in experimental conditions. The application of the hydroforming process is becoming more significant in the automotive industry, which requires wider research and analysis of processes and systems. For this purpose, the design of the mechatronic system was made, in order to improve the conditions and quality of the experimental research by introducing automatic control and process control. The design was performed on the work piece of the defined shape and dimensions. An experimental test of fluid working pressure and displacement was conducted for the hydroforming process of welded steel sheets. One of the methods control of the hydroforming process used the mechatronic system, designed to operate under experimental conditions, whereas other method control of the process was manual [1-12].

2. HYDROFORMING OF WELDED SHEETS

The process of hydroforming of welded sheets is performed by high pressure fluids within the work piece, until the forming or deformation according to the form of the tool (die) is completed, **Fig. 1**.

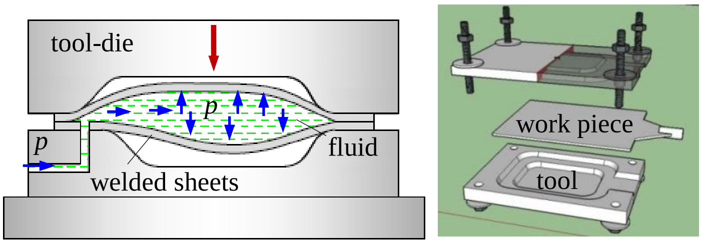


Fig. 1 *- Process scheme (a), tool and work piece (b) for hydroforming of welded sheets*

Hydroforming is conducted in the tool produced of two, three or more parts, depending on the shape and dimensions of the work piece. To prepare the specimen referred to in this paper, we applied the MIG method of welding steel S235JR with 2 mm thickness, whereas the tool consists of two parts (lower and upper die) [1, 8, 9].

2.1. The phases of forming welded sheets

Hydroforming process consists of three phases, **Fig. 2** [1, 8, 9]:

- *preforming*, an initial phase that involves filling the welded work piece with a low-pressure fluid in order to ensure a stable process and even deformation,
- *forming*, characterized by high fluid pressure growth and die of the work piece according to the defined shape of the die,
- *calibration*, characterized by the final shape of the finished piece and the accurate dimensions.

The duration of a particular phase depends on the type of work piece material, the working pressure for the design, the shape and dimensions of the work piece, the tools, the manner of operation and the conditions for conducting the process.

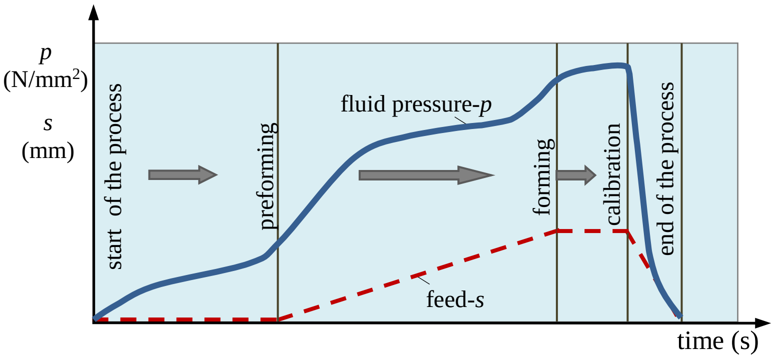


***Fig. 2** - Phases of hydroforming of welded sheets [1]*

The analysis of the hydroforming process given in the paper, refers to the phase changes in the value of the fluid working pressure, taking into account the method control of the process during the design of the defined work piece.

3. THE DESIGN OF THE MECHATRONIC SYSTEM

In order to perform automatic process control, a mechatronic system model with the components was designed, **Fig. 3** [3, 4, 5].

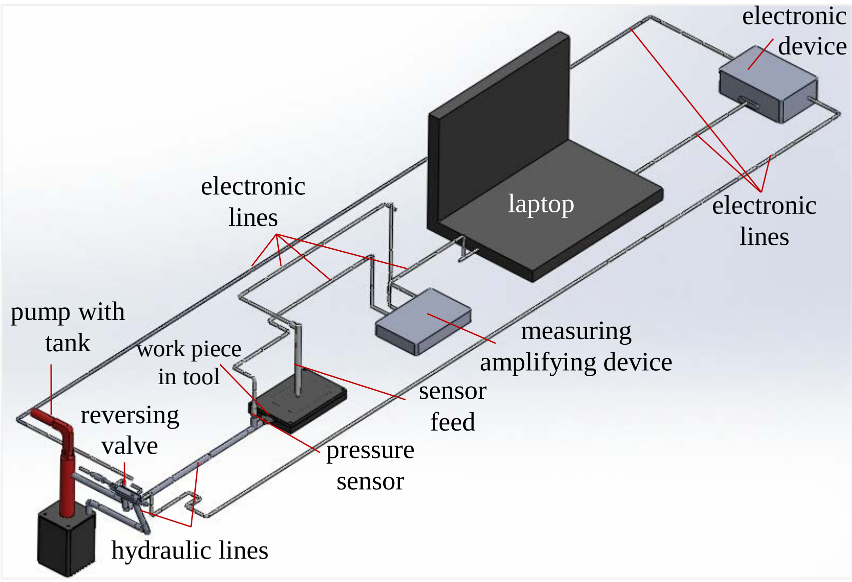


***Fig. 3** - Model of mechatronic system for hydroforming of welded sheets [8]*

In relation to the manual control system, the designed mechatronic system model has an electronic device for automatic process of control, which is connected to other components of the hydroforming system of welded sheets. The functionality of the designed model is enabled by the software formed according to the flow diagram of the hydroforming process, **Fig. 4**.

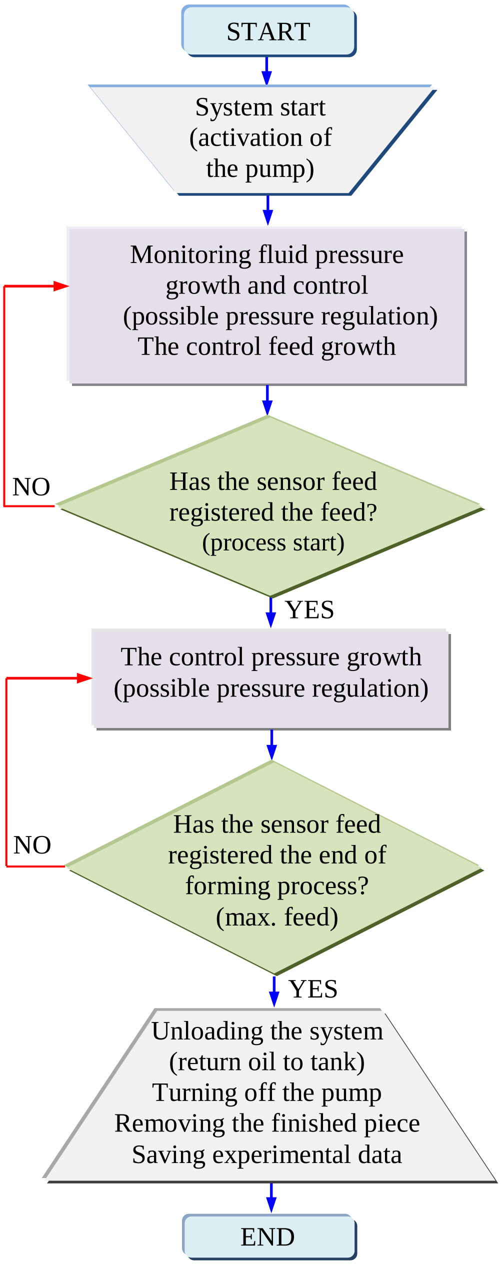
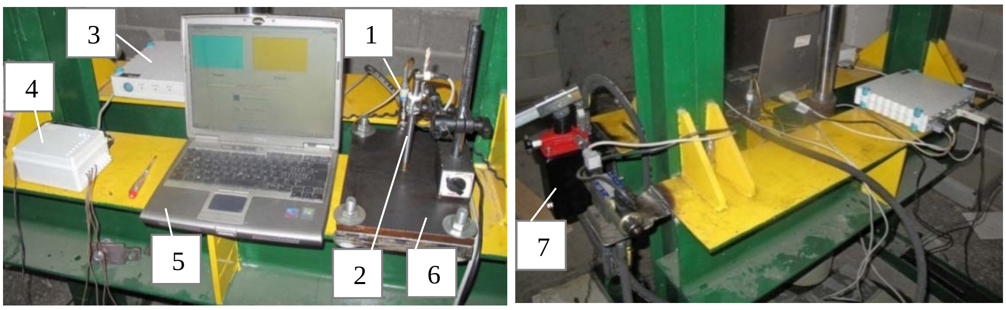


***Fig. 4** - Experiment flow chart [8]*

4. EQUIPMENT FOR CONDUCTING THE EXPERIMENT

Fig. 5 depicts the equipment for the experimental hydroforming of welded sheets using mechatronic components for process control.



1 – pressure sensor, 2 –sensor feed, 3 – measuring-amplifying device,
4 – electronic device, 5 – laptop, 6 – tool and work piece, 7 – pump

Fig. 5 *- Equipment for experimental hydroforming [8]*

Measuring-amplifying device ″Spider 8″, produced by HBM (Hottinger Baldwin Messtechnick) from Germany, has been matched to work with the computer and has eight independent measurement channels for connecting to sensors. Pressure sensor-P8AP, produced by HBM, is a tensometric sensor. The nominal sensitivity of the sensor is $2mV/5 \cdot 10^7$ Pa, and its measuring range is from $0\text{-}5 \cdot 10^7$ Pa. The sensor feed-WA20, produced by HBM from Germany, operates on an inductive principle, with a sensor nominal sensitivity of 80 mV/20 mm. The electronic control unit for the components of the hydraulic system (electric pump and the reversible hydraulic valve) has 8 independent relays and can independently control up to 8 devices. The hydraulic pump achieves the working pressure of the fluid (oil) to $p_{max}=3 \cdot 10^7$ Pa. To regulate fluid flow in the system, a reversible hydraulic valve "Poclain KV-4-3-5K0-6-2" was used. The forming fluid is the "Inol Hidrol-X 46" oil.

4.1. The results of experimental measurement and discussion

In order to verify the designed mechatronic system, the experiment was conducted on 4 samples. Manual control also created 4 samples. The analysis of the results according to the forming phases, Figure 2, included the mean values of the fluid working pressure-p_{sr} and the mean value of the duration of the individual phases of the process-t_{sr}. The experimental values of the fluid pressure and phase-effect time, achieved by manual control (MC-p_{sr} and MC-t_{sr}), in relation to the values obtained by automatic control (AC-p_{sr} and AC-t_{sr}), are the following [8, 9]:

- in the *preforming* phase, the value of the working pressure of the fluid is less by $7{,}8 \cdot 10^5$ Pa or about 40%, and the duration is longer by 32,3 s or about 66%
- in the *forming* phase, the value of the working pressure of the fluid is higher by $7{,}1 \cdot 10^5$ Pa or about 8% and the duration is longer by 14,3 s or about 38%,
- in the *calibration* phase, the value of the working pressure of the fluid is higher by $7{,}1 \cdot 10^5$ Pa or about 8% and the duration is longer by 13,3 s or 50%.

The graphic display of the comparative values of the fluid working pressure for manual control and automatic control (MC-p_{sr} and AC-p_{sr}) is given in **Fig. 6** [8, 9].

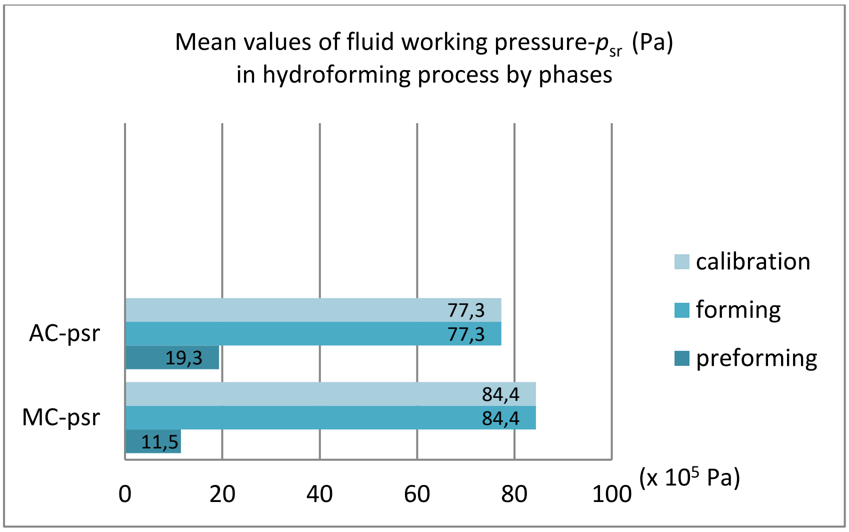


Fig. 6 *- Fluid pressure during hydroforming of welded sheets by phases for manual control (MC) and automatic control (AC)*

Fig. 7 shows the comparative value of the duration of the hydroforming process of welded sheets in phases, for manual control (MC-t_{sr}) and automatic control (AC-t_{sr}) [8, 9].

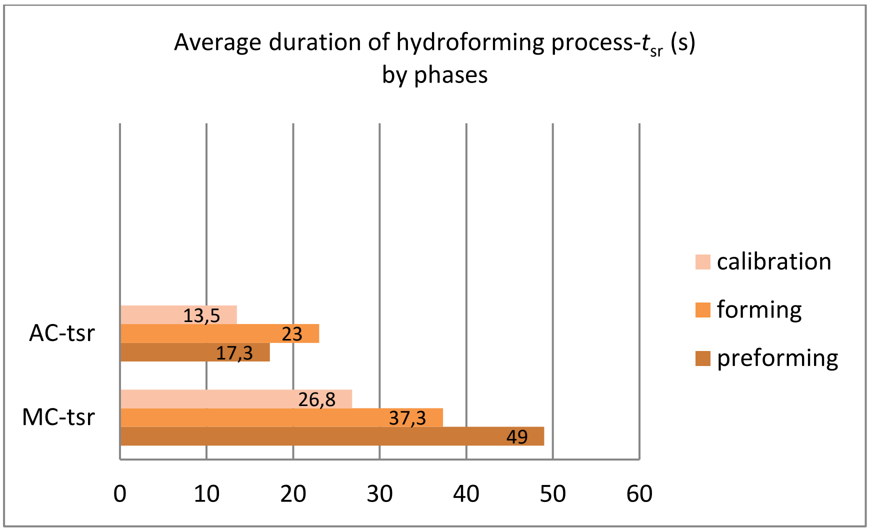


Fig. 7 *- Duration of hydroforming of welded sheets by phases for manual control (MC) and automatic control (AC)*

The obtained values show that the hydroforming process of welded sheets with manual control depended on the evaluation and experience of the experimenter. By inspecting the results, in the preforming phase, a lower value of the working pressure of the fluid required a longer time of its action. In the forming and calibration phases, in addition to the longer duration of the phase, the value of the fluid working pressure was greater in relation to the automatic process control.
In both control modes, formed pieces were satisfying in quality and wall thickness, **Fig. 8**.

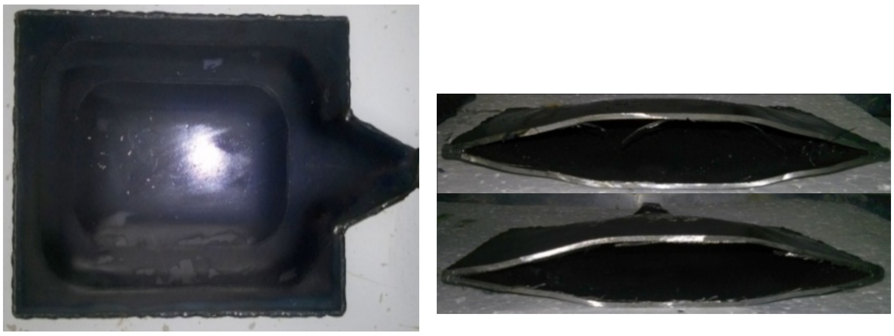


Fig. 8 *- Formed piece [8]*

Given the obtained experimental results of measurement and comparison, this analysis precedes the next step, which is related to the optimization of input process parameters.

5. CONCLUSION

The application of the designed mechatronic system in the process of hydroforming of welded sheets provided insight into the growth of the fluid working pressure during the execution of all phases of the design process, which in case of need gives the operator the possibility to act accordingly.
In addition, rapid and better measurement results were obtained in the research, which would achieve the technological and economic justification of the process at the industrial level by applying appropriate methods of modeling and optimization.
The obtained results showed that the mean value of the total fluid working pressure for forming one piece in the case of manual control is about 8% higher than the mean value of the total fluid working pressure generated by the automatic control of the hydroforming process.
The duration of the forming one piece by manual control of the hydroforming system was on the average 52% more than the time of forming one piece using automatic control of the system.
The application of a designed mechatronic system in control of the hydroforming process of welded sheets has a positive impact on the productivity, process reliability, the quality of the design of finished pieces, the savings in material and energy, etc.

REFERENCES

[1] Harijinder S.: Fundamentals of Hydroforming, Society of Manufacturing Engineers, Michigan, USA, 2003.

[2] Karabegović E., Brezočnik M., Mahmić M. i dr.: Nove tehnologije u proizvodnim procesima (Razvo i primjena), Mašinski fakultet Mostar, Univerzitet Mostar, Bosna i Hercegovina, 2014, pp. 94-100.

[3] Aleksandrov S. i dr.: Savremeni pristup projektovanja mehatronskih sistema, 6. Međunarodna konferencija, Fakultet tehničkih nauka, Čačak, Srbija, 2016.

[4] Matuško J. i Kolonić F.: Dizajn mehatroničkih sustava, Fakultet elektrotehnike i računarstva, predavanja, Zagreb, 2014.

[5] Miklós Tisza: Recent development trends in sheet metal forming, University of Miskolc, Hungary, 2015.

[6] Šemić E., Karabegović E.: Dizajniranje mehatroničkog sistema za eksperimentalno hidrooblikovanje tankostjenih elemenata, 3rd International Scientific Conference „New Technologies NT-2016“ Development and Application, 2016, Mostar, pp.153-160.

[7] Jurković M., Mamuzić I., Karabegović E.: The Sheet Metal Forming with Hydraulic Fluid Pressure, Journal Metallurgy 43 (2004) 4, ISSN 0543-5846, pp. 315-322.

[8] Šemić E.: Razvoj mehatroničkog sistema za hidrooblikovanje tankostjenih elemenata, Magistarski rad, Univerzitet “DžemalBijedić”, Mašinskifakultet Mostar, 2016, pp. 69-91.

[9] Poljak J.: Matematičko modeliranje i optimizacija pritiska fluida kod hidrooblikovanja limova, Master rad, Univerzitet u Bihaću, Tehnički fakultet, Bihać, 2014, pp. 41-56.

[10] http://www.tatasteelautomotive.com/file_source/StaticFiles/Automotive/Tube%20Hydroforming%20in%20Automotive%20Applications.pdf

[11] www.metal forming handbook Schuler

[12] http://www.unidu.hr/datoteke/majelic/ABP-5.pdf

UPRAVLJANJE SISTEMOM ZA HIDROOBLIKOVANJE ZAVARENIH LIMOVA

Edina Karabegović[1], Edin Šemić[2], Poljak Jasmir[1]

[1] Univerziteta u Bihaću, Tehnički fakultet Bihać, Dr. Irfana Ljubijankića bb, 77000 Bihać, Bosna i Hercegovina
[2] Univerzitet "Džemal Bijedić" u Mostaru, Mašinski fakultet, Univerzitetski kampus, 88104 Mostar, Bosna i Hercegovina

REZIME

Današnji zahtevi industrijske proizvodnje bazirani su na izradi proizvoda sa što manjim ulaganjem u što kraćem roku, što jednostavnije i sigurnije, sa uvidom u svaki nivo izvođenja procesa. Uvođenje novih tehnologija zahteva pouzdana istraživanja kako bi se postigao kvalitetniji, brži i jeftiniji način njihovog izvođenja. Proces hidrooblikovanja najširu primenu nalazi u automobilskoj industriji, gde su promene u cilju postizanja konkurentne kvalitete proizvoda stalno prisutne, pa su i istraživanja u tom pravcu vrlo značajna. Za izvođenje ovog istraživanja i analize, dizajniran je mehatronički sistem, zatim je izvršena simulacija i eksperimentalna provera procesa hidrooblikovanja radnog komada definisanog oblika i dimenzija. Oblikovanje radnih komada obavljeno je u sistemu za hidrooblikovanje sa ručnim i automatskim upravljanjem. Dobijeni rezultati pokazuju mala odstupanja u vrednostima pritiska fluida, dok je vreme trajanja procesa dvaput duže za ručno upravljanje u odnosu na automatsko. Primena neke od metoda optimizacije imala bi značajan uticaj na tehno-ekonomske karakteristike procesa.

Ključne reči*: kontrola procesa, hidrooblikovanje, mehatronički sistem, senzori*