PROPAN - BUTAN PRESSURE VESSELS PRODUCTION PROCESS IMPROVEMENT

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ABSTRACT
This paper presents production process of propan – butan pressure vessels for household, with special view on possibilities of product quality improvement and production costs reduction. New equipment for automatic welding – automatic MAG (Metal Active Gas) and SAW (Submerged Arc Welding) – was installed in already existing propan – butan pressure vessels production process, and the process of propan – butan pressure vessels production was significantly improved. Special accent is given on production of new type of propan – butan pressure vessels nominal content of liquifield gas 7,5 kg. Due to fact that there is the serial propan – butan pressure vessel production, importance and significance of production continuity assurance are presented in this paper. Any delay on this type of production could have long-range negative consequences, due to limited possibility of accumulation of some positions or assemblies in production, which surely interrupt scheduled production process.

1. INTRODUCTION
Presence on the world market demands constant production process perfection and improvement. Whether there is product quality and/or product manufacturing technology improvement, just in time and appropriate investments in production equipment and also in personnel – people who are suppose to use that equipment in optimal way, are necessary. Without that kind of approach it is hard to even imagine survival on market in today conditions of hard competition and product quality demands. This paper presents some of the improvements accomplished in propan – butan pressure vessels production process, after the investment in equipment - arc welding automation.

Propan – butan pressure vessels are used as tanks for storage and transportation of liquefied gases: propan, butan and propan-butan mixtures, and also as energy source on different applications in households, industry, etc. Beside the possibilities of recharge and easy transportation, application of this products is characterized with handling simplicity and relative low price of pressure vessel itself and of gas too. Propan – butan pressure
vessels for this application is made in welded form. There are several types of vessel regarding on volume, actually mass of liquified gas in the vessel. Undoubtedly, in households today dominate propan – butan pressure vessels of nominal content of liquified gas 10 kg. Recently, propan – butan pressure vessels of nominal content of liquified gas 7,5 kg were delivered to market. Regarding the some benefits in relation with earlier larger vessel of 10 kg and smaller vessel of 5 kg, large trend of demands for vessels of 7,5 kg was observed. Actually, regarding the limitations in accommodation of vessel in kitchen furniture elements and optimal relation of full vessel mass and quantity of liquified gas (that is very important on handling and carrying the vessel, e.g. for elderly people or on higher buildings floors transport), this vessel is proved to be optimal solution for many of situations in household. That is exactly the reason for giving that type of vessel the special view in this paper, although there is a large similarity in production technology of all types of propan – butan vessel in welded form.

2. COMMON DATA OF PROPAN - BUTAN PRESSURE VESSEL NOMINAL CONTENT OF LIQUIFIED GAS 7,5 KG

As base material for production of “body” of propan – butan pressure vessel OF nominal content of liquified gas 7,5 kg, low alloyed steel type R St 37-2 is used, with following mechanical properties in normalised state: [1]
- Tensile strength \( R_m \geq 360 \text{ MPa}, \)
- Yield point \( R_p \geq 235 \text{ MPa} \)
- Elongation \( A_5 \geq 22 \% \).

Content of chemical compounds (mass weight) of mentioned base material is:[1]
- C \( \leq 0,17 \% \)
- P \( \leq 0,05 \% \)
- S \( \leq 0,05 \% \)
- N \( \leq 0,009 \% \)

Base dimensional data for pressure vessel 7,5 kg was given in table 1 and figure 1. [1]

<table>
<thead>
<tr>
<th>Nominal content of liquified gas (kg)</th>
<th>Outside diameter ( d ) (mm)</th>
<th>Maximal height ( h ) (mm)</th>
<th>Wall thickness of the (“vessel body”) (mm)</th>
<th>Volume (l)</th>
<th>Pressure vessel mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,5</td>
<td>300</td>
<td>500</td>
<td>2,5</td>
<td>18,52</td>
<td>~10</td>
</tr>
</tbody>
</table>

Allowing deviation of dimensions, volume and mass of the pressure vessel are following:
- outside diameter: + 5 mm, with maximal ovality 1,5 %
- plate thickness: + 0,3 mm, - 0,0 mm
- volume: + 5 %
- pressure vessel mass: ± 5 %.

Propan – butan pressure vessel have vertical, portable, multi – part realization with single wall (figure 1). Operating pressure is 16,7 bar, and test pressure is 25 bar.

After the fabrication of propan – butan pressure vessel, heat treatment of normalisation in gas furnance on temperature 890 - 930 °C is carried out afterwards. After that pressure test and outside surface protection of plastification are carried out. During the production of the pressure vessel, in all of production phases appropriate quality control and qualiti assurance activities are carried out according to control technology certificated by authorized pressure vessel production inspector.
3. MOST IMPORTANT DETAILS OF WELDING OF PROPA-N-BUTAN PRESSURE VESSEL POSITIONS BEFORE AND AFTER PRODUCTION PROCESS IMPROVEMENT

Old conception of technological process of propan-butan pressure vessels production was adapted to old welding equipment and it differs from new conception of technological process. But there are certain production process elements which remain the same because there was no reason or necessity for modification of these elements. These elements are preparation activities of certain positions, and activities after the completing of propan – butan pressure vessel by welding (heat treatment, hydrostatic pressure test, surface protection, ...). Due to paper simplification, for comparison of most important production process details before and after the improvement, scheme of new – improved production process will be used (figure 2). Propan – butan pressure vessels production process in both cases starts the same. After cutting circular plate (roundabout), follows material forming on two hydraulic pressure machine and obtaining the round form of one half pressure vessel body (see figure 1, pos. 1a and 1b). From this point of process forward there are differences in pressure vessel production process conception.
TIJELO BOCE
siječenje lima
prosijecanje rondela
rondela (platina)

duboko izvlačenje lima u polutku (dance)

pertlovanje
poravnavanje
probijanje rupe za usad.
zavarivanje usadnika

zav. stopala na polutku
zav. štitnika na polutku

zav. tijela boce

toplinska obrada (normalizacija)

USADNIK
otkivak
razvrtnje konusa
urezivanje navoja

zavarivanje stopala
oblikovanje stopala

STOPALO
siječenje lima
probijanje stopala "štancanje"
predsavijanje i savijanje stopala

ZAŠTITNI LIM (KRAGNA)
siječenje lima

predsavijanje
utiskivanje nepromj. podataka

I. oblikovanje
II. oblikovanje
III. oblikovanje

Figure 2. Scheme of production activities after improvement in propan-butan pressure vessels production process.
According to old conception, on pos 1b (see figure 1) follows cutting around and cutting the hole for valve implant (pos.3, figure 1). In the next production activity follows setting up and welding of valve implant by automatic SAW (Submerged Arc Welding) welding process.

On pos. 1a (see figure 1) follows material forming of the edge due to setting up with upper position 1b. Formed edge is backing of circular SAW joint, too.

Finally, follows joining and welding of propan-butane pressure vessel body (pos. 1a and 1b), which is shown at figure 3. Next activity is welding of foot and valve protector by MAG welding process in one pneumatic device (figure 4). Welding of the pressure vessel is finished in this moment and appropriate activities of quality control by nondestructive testing and in certain ratio by destructive testing (e.g. pressure test until destruction of vessel) are performed.

Beside problems caused by using too old equipment (power sources, positioning devices), significant problem was the fact that weld joint quality depended on human factor. There are many reasons for the production process improvement. First of all, it was modernization of equipment, improvement of production and quality, elimination of human factor, work humanization and improvement of quality of welded joints on pressure vessels.

Figure 3. Welding of the pressure vessel body by SAW process according to old production conception.
New production conception is based on new welding equipment. It is different in relation to old conception. After the material forming of positions 1a and 1b (see figure 1), material forming of the edge position 1a due to setting up with upper position 1b, and cutting the hole for valve implant, follows different pressure vessel production activities order. On position 1b valve implant in automat for MAG welding is welded (figure 5 a). In next step of the production process on the other automat for MAG welding, the valve protector is welded (figure 5 b). After those two activities upper half of the pressure vessel is obtained (figure 5 c). From this moment it is ready for connecting with lower half of the pressure vessel which is obtained on the second parallel production line.

The third automat for MAG welding is used on the side of lower part of the pressure vessel body. On the bottom side of the pos. 1a, the foot of the pressure vessel is set up and welded by automatic MAG process (figure 6 a). Figure 6 b shows the view of lower part of the pressure vessel after mentioned production activity. From this moment it is ready for connecting with upper half of the pressure vessel which is obtained on the first parallel production line.
Figure 5. Details of implant valve and valve protector welding in two MAG automats. Figure c shows upper part of the pressure vessel before setting and welding with lower part.
Figure 6. Details of welding of pressure vessel foot on the bottom part of the pressure vessel body on the automat for MAG welding. Figure b shows bottom part of the pressure vessel before welding and completing the pressure vessel.

Parts of the pressure vessel, prepared as it is described earlier in the paper, are then welded in automat for SAW process which consists of two separate welding equipments, separate working places and separate control mechanisms. Figure 7 shows automat for SAW process during the welding of two pressure vessels at the same time.

The main reason of modification of the propan – butan pressure vessel production process activities is optimal exploitation of the welding equipment regarding to the pressure vessels amount planned to be processed in one working shift. Automats for MAG welding process (which are used for welding the pressure vessel foot, valve implant and valve protector) replaced semi – automatic MAG welding and automatic SAW process. According to the old conception welding of the pressure vessel foot and valve protector was welded in one device by semi – automatic MAG process, and valve implant in another by automatic SAW process. The influence of the human factor on the welded joint quality was eliminated by that.

On the SAW welding of circular weld joint at propan-butan vessel it was noticed satisfactory weld joint quality was obtained by installed welding equipment.
4. ACTIVITIES ON QUALITY DURING PROPAN-BUTAN PRESSURE VESSELS PRODUCTION

Quality control and assurance during propan-butane pressure vessels production was performed in each phases of production process, according to certified production technology and quality control & quality assurance technology. It is possible roughly to show quality control activities as:
- entrance control,
- control during the production process and
- final (exit) control.

**Entrance control covers:**
- visual and dimensional control of plates
- visual and dimensional control of valve implant,
- visual and dimensional control of valve,
- control of base and filler materials and welding equipment control
- control of short peening equipment and surface protection equipment and plastification powder

**Process control covers:**
- control of all technological activities during the pressure vessel production,
- control – hydrostatic pressure testing of the pressure vessel by water pressure of 25 bar,
- control of joint valve – valve implant leakage by air with pressure of 10 bar,
- control – examination of mechanical properties of the pressure vessel,
- control – examination of the pressure vessel until destruction

**Final (exit) control covers:**
- visual control of pressure vessel integrity,
- visual and dimensional control of surface protection,
- control of vessel mass,
- control of data imprinted on the pressure vessel.
After the heat treatment of normalization, according to control plan certain number of pressure vessel is taken for mechanical properties examination of the base material and of the welded joint by tensile test and bending (Figure 8).

Figure 8. Locations of test probes for mechanical properties examinations (tensile test - 1 and bending – 2) after the heat treatment of the propan – butan pressure vessel

After heat treatment each vessel must pass hydrostatic pressure test on pressure 25 bar. One vessel among 1000 produced vessels will be loaded until destruction. On figure 9 shows a view of pressure vessel after examination until destruction with characteristic location of crack.

Figure 9. A scheme of pressure vessel hydraulic test and view of pressure vessel after hydrostatic pressure test until destruction
Pressure in cracking moment is 4 – 5 times higher than pressure during hydrostatic pressure test. Increase of pressure vessel diametar after examination is 14 %, what is higher than referent value of 9 %.

Before final examination, pressure vessel with setted up valve must pass air pressure test, too. Figure 10 shows scheme of examinatin with air pressure of 10 bar.

Figure 10. Scheme of examinatin of leakage with air pressure of 10 bar

Pressure vessel must pass all quality requirements before delivering to storage and market.

5. CONCLUSION
Achieved results of the planed process improvement by installing the new welding equipment have fulfill expectations. Additional analysis of the effect of process improvement has shown that there are following improvements of the production process:
- line capacity increase – achieved working cycle times are around 30 and 40 s on MAG welding process, and cca 80 sec. on SAW process – times like that are allowing accomplishing of the requested capacity;
- decrease of the influence of the operator on the parameters setting – all parameters of the automatic process are stored under the password, and welding operator can’t change them - there is a possibility of changing the parameters on the welding set, but those parameters practically do not change with alternation of the pressure vessel type – welding speed and geometrical parameters are satisfying the changes of parameters.
- decrease of the operator tasks – during the operating with all the equipment tasks of the welding operators are decreased, that refers to obtaining the process performing concentration (on equipment for valve implant, valve protector, and vessel foot welding it is not necessary at all), replacement of the hand welding by machine welding, easier monitoring of the welded joint on SAW process, …
- welders who had welded valve protectors and vessel foots by hand now can perform
other welding operations.

Continuation of the scientific and professional researches on the field of the production of the propan - butan pressure vessels in welded form will refer to researches in order to contribute and improve standards for pressure vessels production.

6. REFERENCES