

## Experimental Study of the Performance of Base Metal and Welding Line of the Household LPG Cylinder Manufactured in Kurdistan Region

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### ABSTRACT

Liquefied petroleum gas (propane or butane) is a colourless liquid which readily evaporates into a gas. It has no smell, although it will normally have an odour added to help detect leaks. Liquefied petroleum gas is stored and handled as a liquid when under pressure inside an LPG cylinder. Liquefied petroleum gas cylinders are subjected to various tests to ensure their compliance requirements as per standard. This research studies the durability of welding and performance of base metal of LPG. Home cylindrical in Kurdistan region. The experiments were carried out on three types of LPG cylinder using in Kurdistan regions A, B, and C and an unformed plate. To carried out the samples and tests during the research we depending on the standard tests for LPG cylinders. Three samples are extracted from each of LPG cylinders and unformed plate for each of tensile test, Bending test and Hardness test according to ISO 6892-2016 and ASME standards from each type of LPG cylinders and from unformed plate to examine the mechanical properties. In addition, chemical compositions also were carried out. These values are compared with standard.

**Keywords:** LPG, ASTM, ASME, ISO, BS 5045, LPG cylinder, Pressure vessel, Welding

### 1 INTRODUCTION

Liquefied Petroleum Gas (LPG) is a colourless liquid which readily evaporates into a gas. It has no smell, although it will normally have an odour added to help detect leaks. When mixed with air, the gas can burn or explode when it meets a source of ignition. It is heavier than air, so it tends to sink towards the ground [1]. LPG is composed predominantly a mixture of hydrocarbons such as propane, propylene, butane or butylene. The gas can be liquefied at moderate pressure, and can be stored in cylinders as a liquid under pressure and is drawn out and used as gas. This means that it can be transported and stored as liquid and burnt as gas. The expansion ratio of gas liquid is 270:1 at atmospheric pressure. The expansion factor makes LP-gas more economical to transport and stored with large quantities of gaseous fuel in a small container. Containers are normally filled 80-85% liquid, leaving 15-20% vapour space for expansion due to temperature increase. The household gas cylinder weighs approximately 14 kg. Nowadays, composite materials have been used widely which are proved to be more effective. These composite materials are wound over metal liner thus acting as over wrapped composite pressure vessel. LPG cylinder is one kind of pressure vessel that stores pressurized gases. LPG cylinder material should have high tensile and compressive strength for withstanding the high pressure of the gases [2].

The Cylinders play a crucial role in containing and transporting hazardous LPG from filling plant to end consumer [3]. LPG Cylinders are to be manufactured from definitely prescribed raw material to ensure safety of cylinders through material quality specifications [4]. Although there are clear standards and statutory norms for design,

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manufacturing and usage of cylinders, there are certain gaps in these standards in terms of ensuring material safety compliance. LPG cylinder production is composed of several sheet metal forming, surface treatment and testing processes. The process starts with blanking, deep drawing and piercing, trimming and joggling. Next are the welding operations for valve boss, valve guard ring, foot ring and the two halves. The finished cylinder is then heat treated, tested, shot blasted, painted and then the valve is attached and tested finally [5]. The main steps involved in manufacturing process of LPG cylinders are shown in Figure 1.

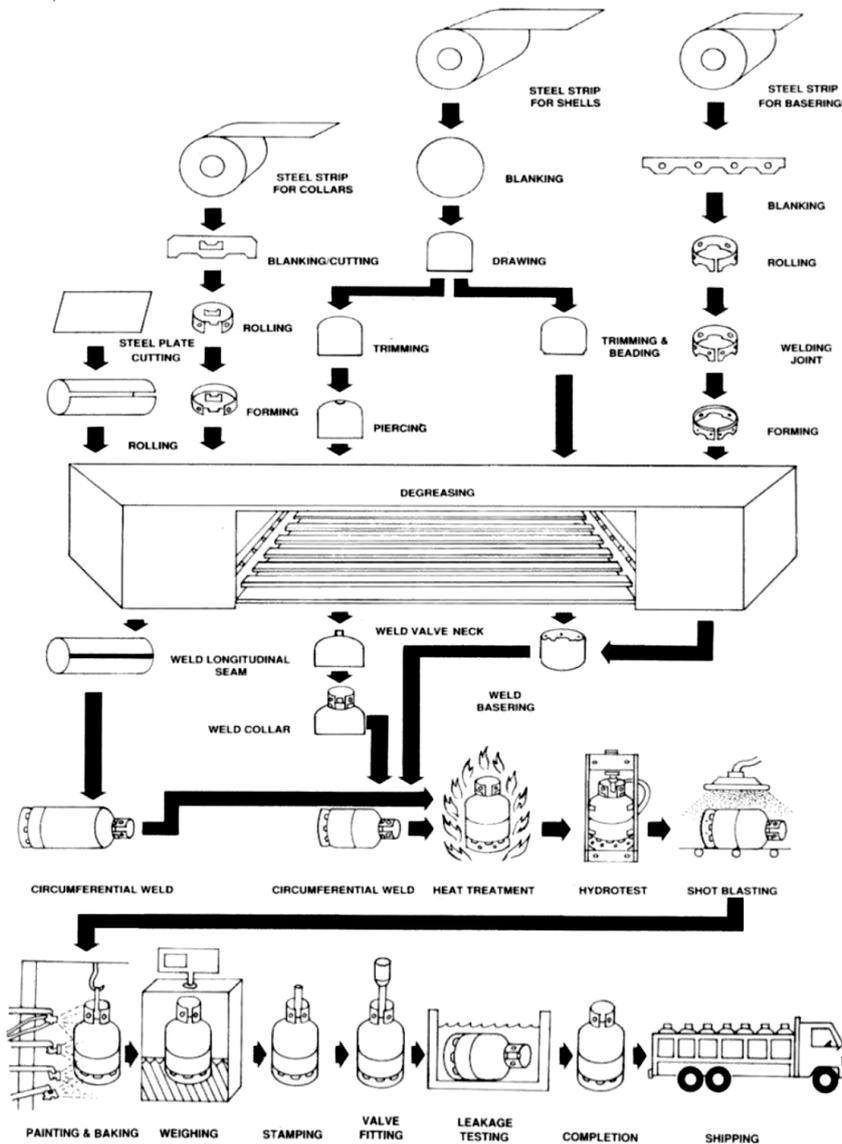


Figure 1: The process of manufacturing of LPG cylinders (Bhadur and Marg, 2008).

## 2. LITERATURE REVIEW

Liquefied petroleum gas (LPG) cylinders that have an important position from the point of use have been taken into consideration. So, many researches have made by researcher as explained below. Nihal A. Siddiquia, et al. (2013) investigated a study on the welded low-carbon steel cylinders exceeding 5 litres of water capability which are produced and tested as per Indian Standard (IS 3169). Ramakrishna, Siddiqui and Sojan (2013) conducted several tests on LPG cylinders, in which acceptance test is one of the important tests to reveal cylinder parent metal mechanical properties. Two tensile specimens are prepared from finished cylinder batch for this test and tested on a universal testing machine to determine, yield strength, percentage elongation and ultimate tensile strength of parent metal. Values of these test results are compared against standard values prescribed in Indian standards to decide acceptance of cylinder batch for market release. Mahmud, et al. (2017) study the effect of annealing temperature on the mechanical properties of SG 255 steel.

The SG 255 steel is used in manufacturing of domestic LPG cylinder in Kurdistan region. Furthermore their work aims to obtain experimentally better mechanical properties at particular ductility with lower annealing temperature and to minimize the cost of the manufacturing of LPG cylinders. A number of samples were made according to ISO 6892, and then heat treated with different annealing temperature (850, 900 and 950 °C). Moreover, the tensile tests of these samples were carried out until failure to obtain the mechanical properties. It was shown that higher elongation percentage 34.18% with an annealing temperature 900 °C can be achieved, and this leads to minimize the cost of manufacturing of the cylinders without degrading of their quality. Y. Li, and F. Wang (2019) was proposed an integral manufacturing process with hot drawing and cold flow forming for large diameter seamless steel gas cylinders. The primary aim of this research was to find out the impacts of the manufacturing method on gas cylinders made of 34CrMo4 steel's microstructure and mechanical characteristics. Two preformed cylinders were produced by hot drawing. One cylinder was then further manufactured by cold flow forming. The experiments were carried out using three types of material sample, namely, base material (BM), hot drawing cylinder (HD), and cold flow-formed cylinder (CF). Tensile and impact tests were performed to examine the mechanical properties of the cylinders in longitudinal and transverse directions. Microstructure evolution was analysed by scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) to reveal the relation between the mechanical properties and the microstructure of the material. It is found that the mechanical properties of the 34CrMo4 steel gas cylinders were significantly improved after hot drawing and flow forming plus a designed heat treatment, compared with the base material. The observations of microstructure features such as grain size, sub grain boundaries, and residual strain support the increase in mechanical properties due to the proposed manufacturing process.

In this study, an unformed plate and the sheet materials of liquefied petroleum gas (LPG) cylinders that have an important position from the point of use have been taken into consideration. The household LPG cylinders can be divided in to two main groups, the first group imported by the central government and the second group locally produced in the Kurdistan region from different companies and different cities. A group of specimens were taken from the unformed plate and base metal of the cylinders, while another one were taken across the cylinders from the weld zone transversely in the middle of the cylinders, which had the same initial thickness of 3 mm. Note that effect of geometric discontinuities due to weld toe was eliminated since the thickness of entire samples was kept constant. Different test results are compared against standard.

**Table 1:** Mechanical properties of LPG cylinders [10]

Mechanical properties of LPG cylinders	Value
Minimum yield strength	240 N/mm <sup>2</sup>
Tensile strength	360-430
Minimum elongation	30 %

**Table 2:** Chemical composition of LPG cylinders [10]

Chemical composition	% max
C	0.16
Mn	0.50
Si	0.20
P	0.03
S	0.03

### 3. Materials

The material of the LPG cylinders and unformed plate is low alloy carbon steel with 3mm thickness. The mechanical and chemical composition required according to BS 5045 [10] are given in Tables 1 and Table 2 respectively.

### 4. Methodology

#### 4.1 Chemical Composition Analysis of LPG Cylinder:

To achieve this study, we used three of LPG cylinder from different company and different cities (B, C, D), and an unformed plate (A) to making the specimens. To distinguish between the LPG cylinders, and also to mention the name of the companies or cities are indicated by letters. The letter (A) is the mentioned to the unformed plate, (B) is the letter for the first cylinder, (C) is the letter for the second cylinder and (D) is the letter for the third cylinder. The chemical compositions examination of the test specimens was achieved by spectrometry instrument See Figure 2. It is also the results of chemical composition are shown in Table 3.

From the above chemical compositions of cylinders and unformed plate from Table 3 it can be seen that the contents of all elements, except for silicon and manganese in all samples were nearly same. Sample (B) had somewhat lower silicon content and higher manganese content than the other samples, since all cylinders came from different production batches and thus likely from different raw steel sheet. With respect to the investigations of this work this small deviation could be omitted. However, all the chemical contents of all cylinders and unformed plate were in the acceptable range of the standard of steel grades used for LPG cylinder except manganese.

#### 4.2 Tensile Test

The investigated LPG cylinders were manufactured by using deep drawing process from two low carbon steel plate with dome shape and an intermediate cylinder, which were subsequently welded together along the peripheral direction (Figure 1). Microstructure and mechanical behaviour of the welding line were differed from the base low carbon steel and could considerably affect the structural integrity and performance of LPG cylinder. Tensile testing was carried out at room temperature (23C°) as per ISO 6892-2016 [11]. The tensile test specimens with the gauge length of 50 mm were prepared from the sidewall of cylinders in the longitudinal direction. A group of specimens was taken from the base metal, while another one was taken across the cylinders and had the weld zone transversely in the middle according to ASME section IX 2013 [12]. As shown in Figure 3 and Figure 4.

Note that the effect of geometric discontinuities due to weld toe was eliminated since the thickness of entire samples was kept constant. The tensile tests were carried out on a universal testing machine as shown in Figure 5. The achieved mechanical properties such as yield strength, tensile strength and elongation of the base metal and weld area of the specimens were presented in Tables 4, and Table 5.

**Table 3:** Chemical composition of LPG cylinders and unformed plate

Sample	C %	Si %	Mn %	P %	S %
A	0.129	0.192	0.92	<0.0005	<0.0005
B	0.119	0.082	1.05	<0.0005	0.0054
C	0.135	0.163	0.926	0.0005	0.0030
D	0.124	0.181	0.966	<0.0005	0.0034



**Figure 2:** chemical composition of samples



**Figure 3:** Tensile test samples (weld metal)



Figure 4: Tensile test samples (base metal)



Figure 5: Tensile test machine

Table 4: The tensile test results of the cylinders and unformed plate (base metal)

Sample	Ultimate strength (MPa)	Yield strength(MPa)	Elongation
A	456.86	325.56	33.8
B	389.86	249.33	28.8
C	417.2	283.33	25.9
D	447.4	304	28.53
Standard	(360-430)	min (240)	Min (30)%

Table 5: The tensile test results of the cylinders on welded area

Sample	Ultimate strength (MPa)	Yield strength(MPa)	Elongation
B (tensile shear strength)	361.9	306	47.8
B (ASME)	405.5	310	28.3
C (ASME)	447.8	310	35
D (ASME)	434.7	305	35.5
Standard	(360-430)	min (240)	Min (30)%

By observing the tensile test results, we found that the unformed metal (sample A) and sample (D) exhibited highest yield and tensile strengths whereas sample (B) had lower ultimate and yield strength while its elongation similar to sample (D) and higher than of sample (C). Furthermore the yield and tensile strengths of sample (C) were greatly higher than those of sample (B) while the elongations of sample (c) much decreased as compared to sample (A). It is

obvious that the tensile properties especially the elongation of sample B, C, D were little different from BS50445 standard [13] and the yield stress is higher than 240 MPa in all cases; all gas cylinders are within the range of BS5045 standard however, the ultimate strength of sample (A), (D) are greater than that of the standard as shown in the Table 4. It is concluded that the subsequent forming process does not cause significant changes in the mechanical properties of the material after heat treatment.

On the other hand, from table 5 it can be seen that sample (C) and sample (D) exhibited high ultimate tensile strengths and yield strength with similar elongation whereas sample (B) had lower ultimate tensile shear strength while its elongation higher than of those samples. Furthermore the elongation of sample (B) was greatly lower than those of the other samples. It is obvious that the tensile properties especially the elongation of sample B, C, and D were little different from BS50445 standard and the yield stress is higher than 240 MPa in all cases; all gas cylinders are within the range of BS5045 standard however, the ultimate strength of sample (A), (D) is are greater than that of the standard as shown in the Table 5. It is appearing that the material of the cylinders exhibits good ductility.

#### 4.3 Hardness Test

The preparation of hardness test samples has carried out with an appropriate cutting method, which involves selecting the correct cutting tool with using a cooling liquid to avoid the samples from burning and distortion. To cut and prepare the specimens for the hardness exam, a milling machine process with cooling liquid was used as shown in Figure 6. After cutting, the samples were grinded and polished in order to prevent any scratches and to accomplish right reading. The Vickers hardness testing was carried out for different locations of the sample face, as shown in Figure 7, to check the consistency and uniformity of the properties. The micro-hardness testing was carried out as per ASTM A384 [13]. Diamond indenter (pyramid) with face angle of  $136^\circ$  was used. During testing (1kg) load was applied on sample with dwell time of 15 seconds, and both the diagonals of pyramid indenter ( $d_1$  and  $d_2$ ) were measured with microscope at a magnification of 500X. The results of the hardness tests have shown in the Table 6. The average hardness results revealed that the values of (sample D) offered the highest value as compared to other samples while sample (C) shows the lower result as compared to others.



Figure 6: Cutting process of LPG cylinders



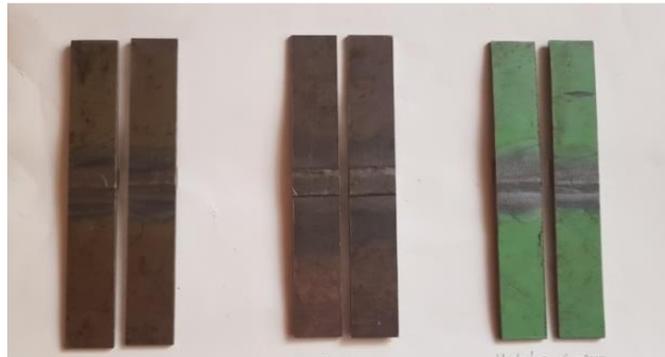
Figure 7: Hardness test samples

Table 6: Results of the average hardness test

Sample	Average Vickers hardness ( $\text{kg}/\text{mm}^2$ )
Sample (A)	147.24
Sample (B)	153.28
Sample (C)	142.7
Sample (D)	162.66

#### 4.4 Bending Test

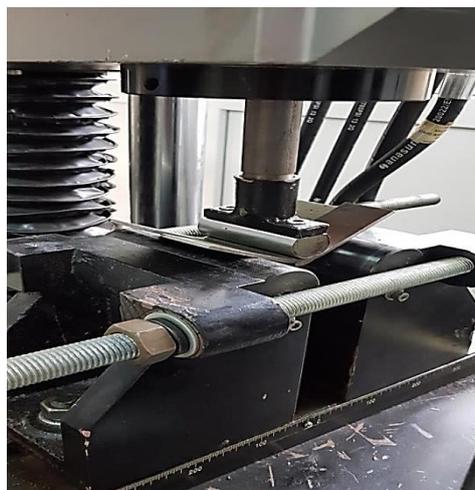
Bending test is a one of an important test that standard required to achieve. This test achieved perpendicular to the weld zone which has been bent through angle  $180^\circ$ . Bending tests for ductility provide a simple way to evaluate the quality of materials by their ability to resist cracking or other surface irregularities during one continuous bend condition. The bending tests were carried out in accordance with AWS standard [14] for all three LPG cylinders to evaluate their welding qualities. The results of such a test obtained by the same tensile machine, the bending test samples and machine has shown in Figures 8, 9, and 10. The bending test results showed that the samples were bent at 180 degrees without breaking or cracking in the samples. This means that the samples met the requirements of the standards. The ductility of weld was satisfactory and there are no defects in the welding joints for all samples.



**Figure 8:** Prepared bending test samples



**Figure 9:** Bending test sample



**Figure10:** Bending test machine

## 5. Conclusions

From the above study, the following points can be concluded based on the results of tensile, hardness, bending tests, and chemical composition:

1. All the chemical contents of all cylinders and unformed plate were in the acceptable range of the standard of steel grades used for LPG cylinder except manganese.
2. The tensile properties of the unformed plate and base metal of the LPG cylinders were show little different from BS50445 standard and they are in the acceptable range.
3. The ultimate tensile strength, yield strength and elongation of the weld metal of the LPG cylinders are nearly similar according to ASME standard.
4. It is clear that from the results that average hardness values of sample (D) have recorded greatest value as compared with other samples.
5. Bending results showed that there was no development of crack was noticed during the bending test.

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