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Research Paper

STUDY ON CORRELATIONS AMONG VARIOUS CRITICAL PARAMETERS OF LPG CYLINDER MATERIAL

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ABSTRACT

Liquefied Petroleum Gas (LPG) cylinders in India are designed, manufactured, tested and certified as per Indian Standard, IS 3196. These cylinders undergo various tests to get mandatory Bureau of Indian standards (BIS) certification for use in market. Acceptance and hydro-tests are two important destructive tests on newly manufactured cylinder lot to know various critical parameters of LPG Cylinder material viz. yield strength, tensile strength percentage elongation, nominal hoop stresses, burst pressure and volumetric expansion. All these critical parameters are related and correlations can be established among these parameters. An attempt has been made in this paper to study 40 domestic LPG cylinders acceptance and hydro-test data to establish correlations among these critical parameters and observed meaningful relations can be established among these variables. However, few factors like raw material selection, heat treatment process parameters, cylinder manufacturing methods, welding process parameters, sample preparation methods can affect the end results of these critical parameters.

KEYWORDS: Acceptance test sample, Hydro-testing of LPG Cylinder, LPG Cylinder material, interrelations of critical components

INTRODUCTION

Indian standard IS 3196 part 3 specifies various tests to be conducted on finished Liquefied Petroleum Gas (LPG) cylinders in a manufacturing location to get certification from Bureau of Indian Standards [2][3]. There tests include both destructive and non-destructive tests. Among the non-destructive tests, acceptance test and hydro-test are the important tests to be conducted on every cylinder batch produced in a manufacturing location [2][3]. These tests reveal critical properties of cylinder as a whole and cylinder material. One sample cylinder out of every 203 cylinders produced in a manufacturing location is subjected to acceptance test [2][3]. For the acceptance test, two tensile specimens are cut from cylinder body one in longitudinal and the other in transverse or circumferential direction to check material physical properties viz. Circumferential Tensile Strength (CTS), Longitudinal Tensile Strength (LTS), Circumferential Yield strength (CYS), Longitudinal Yield Strength (LYS), Circumferential Percentage Elongation (CPE) and Longitudinal Percentage Elongation (LPE)[2]. The values of these tests should complying standard requirements shown in Fig.1[1][2][3]. Similarly, one cylinder out of 403 cylinder batch is subjected for hydro-tests in which volumetric expansion (VE), burst pressure (BP) and nominal hoop stresses (NHS) of cylinder are revealed [3]. IS-3196 states specifications for these parameters and are given in Fig.1. These acceptance and hydro-tests contributes significant role in cylinder batch acceptance in a production unit. Thus, the parameters viz. CYS, CTS, CPE, LTS, LYS, LPE, BP, VE and NHS are the critical parameters in new LPG cylinder testing process [5][7][9].

An attempt has been made in this paper to check the relations among these parameters with experimental results and established various correlations among these parameters. Also an attempt has been made to justify the weak relations among some of these critical parameters with appropriate justifications.

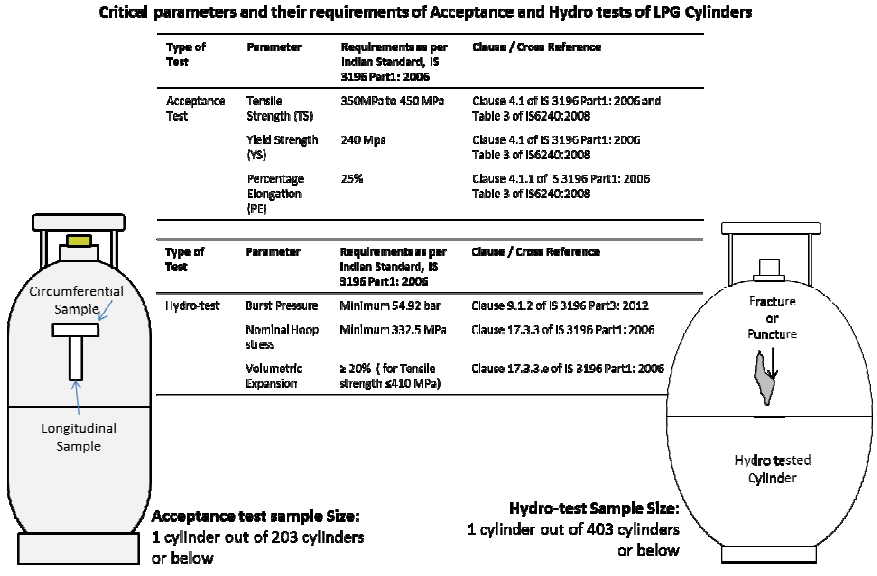

Fig.1: Critical parameters of LPG Cylinder Material

LPG CYLINDER TESTING

Acceptance test

One random sample out of 203 or below new cylinder batch produced in a manufacturing location should undergo this test [3]. Two tensile samples one in longitudinal direction and the other in circumferential direction are carefully cut from cylinder and tested on a universal testing machine to get LYS, LTS, LPE, CYS, CTS and CPE [2]. These

results are verified against standard values and decide whether the batch to be accepted or rejected [2][3].

Hydro-test

One random sample out of 403 or below new cylinder batch produced in a manufacturing location should undergo this test [3]. The cylinder is subjected to hydrostatic test pressure and checked for permanent volumetric expansion (VE) of cylinder under test pressure conditions. Further the same cylinder is subjected to hydrostatic internal pressures till it bursts and records the burst pressure (BP). Based on the burst pressure, calculated thickness, and cylinder diameter, Nominal hoop stresses (NHS) are calculated at burst pressure conditions. The values of VE, BP and NHS are checked against standard values to decide whether to accept the cylinder batch or not [3].

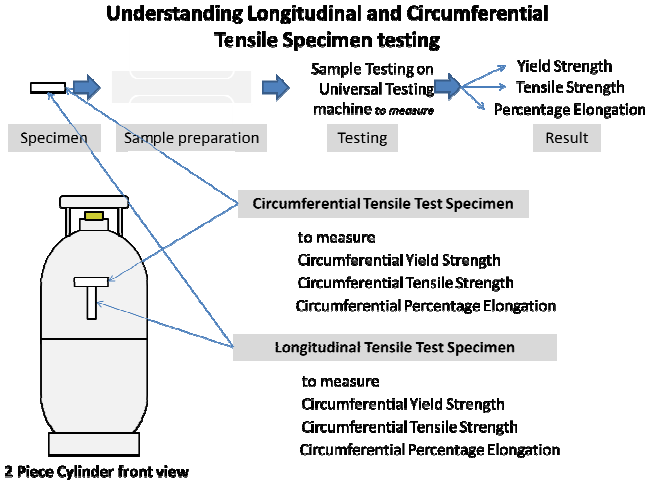

Fig.2 Acceptance test of LPG Cylinders

METHODOLOGY

Data Collection

Domestic LPG Cylinders of 33.3 litre water capacity are selected for to check the correlations among the critical parameters of cylinder material. These cylinders are most common type of cylinders in India and are constructed in two piece construction [6]. 40 such random cylinders Acceptance and hydro test data from Bureau of Indian Standards (BIS) approved and National Accreditation Board of Laboratories (NABL) accredited laboratory is collected for analysis. These cylinders are manufactured from several manufacturers in India and are tested and certified as per IS 3196. For correlations study purpose, Hydro-test and acceptance test samples are selected in such a way that both the samples are manufactured from same manufacturer with same batch number, manufacturing date.

Analysis and Results

Minitab16, Microsoft windows based a statistical analysis software is used for analysis purpose. Acceptance and hydro-test results are tabulated in terms of CTS, CYS, CPE, LTS, LYS, LPE, BP, VE and NHS and validated the data using control charts. All possible pairs among the identified parameters are listed in the Table.1.

Table.1: Various combinations of LPG Cylinder material

Bottom and top half shows possible combinations for correlation and trend analysis									
	LTS	LYS	LPE	CTS	CYS	CPE	VE	BP	NHS
LTS		LTS vs. LYS	LTS vs. LPE	LTS vs. CTS	LTS vs. CYS	LTS vs. CPE	LTS vs. VE	LTS vs. BP	LTS vs. NHS
LYS	LTS vs. LYS		LYS vs. LPE	LYS vs. CTS	LYS vs. CYS	LYS vs. CPE	LYS vs. VE	LYS vs. BP	LYS vs. NHS
LPE	LTS vs. LPE	LYS vs. LPE		LPE vs. CTS	LPE vs. CYS	LPE vs. CPE	LPE vs. VE	LPE vs. BP	LPE vs. NHS
CTS	LTS vs. CTS	LYS vs. CTS	LPE vs. CTS		CTS vs. CYS	CTS vs. CPE	CTS vs. VE	CTS vs. BP	CTS vs. NHS
CYS	LTS vs. CYS	LYS vs. CYS	LPE vs. CYS	CTS vs. CYS		CYS vs. CPE	CYS vs. VE	CYS vs. BP	CYS vs. NHS
CPE	LTS vs. CPE	LYS vs. CPE	LPE vs. CPE	CTS vs. CPE	CYS vs. CPE		CPE vs. VE	CPE vs. BP	CPE vs. NHS
VE	LTS vs. VE	LYS vs. VE	LPE vs. VE	CTS vs. VE	CYS vs. VE	CPE vs. VE		VE vs. BP	VE vs. NHS
BP	LTS vs. BP	LYS vs. BP	LPE vs. BP	CTS vs. BP	CYS vs. BP	CPE vs. BP	VE vs. BP		BP vs. NHS
NHS	LTS vs. NHS	LYS vs. NHS	LPE vs. NHS	CTS vs. NHS	CYS vs. NHS	CPE vs. NHS	VE vs. NHS	BP vs. NHS	

Table.2: Pearson Correlation Constants and Trend Analysis

Bottom half refers correlation constants and top half refers trends between two parameters identified parameters									
	LTS	LYS	LPE	CTS	CYS	CPE	VE	BP	NHS
LTS		+ve Trend	-ve Trend	+ve Trend	+ve Trend	-ve Trend	-ve Trend	-ve Trend	-ve Trend
LYS	0.559		-ve Trend	+ve Trend	+ve Trend	-ve Trend	-ve Trend	-ve Trend	-ve Trend
LPE	-0.491	-0.232		-ve Trend	-ve Trend	+ve Trend	+ve Trend	-ve Trend	-ve Trend
CTS	0.76	0.32	-0.434		+ve Trend	-ve Trend	+ve Trend	+ve Trend	+ve Trend
CYS	0.28	0.47	-0.328	0.126		-ve Trend	-ve Trend	-ve Trend	-ve Trend
CPE	-0.503	-0.101	0.541	-0.627	-0.188		+ve Trend	+ve Trend	+ve Trend
VE	-0.093	-0.315	0.165	0.028	-0.051	0.133		+ve Trend	+ve Trend
BP	-0.049	-0.114	-0.08	0.02	-0.038	0.018	0.334		+ve Trend
NHS	-0.049	-0.114	-0.08	0.02	-0.038	0.018	0.334	1	

Pearson correlation constants were calculated among the possible relations using Minitab 16 and the values are tabulated in Table.2. Trend analysis is also carried out on each identified pair to establish trends among these parameters. These trends are reported in Table.2. Referring to the Table.2, Positive trend indicates, the slope of the trend is directly proportional and negative means, the slope of the trend is indirectly proportional. From the person correlation constants, correlations can be established among Tensile strength, Yield strength, percentage elongation, volumetric expansion, Burst pressure and nominal hoop stresses. Further the interrelations among these parameters are given in terms of directly proportional or inversely proportional in Fig.3

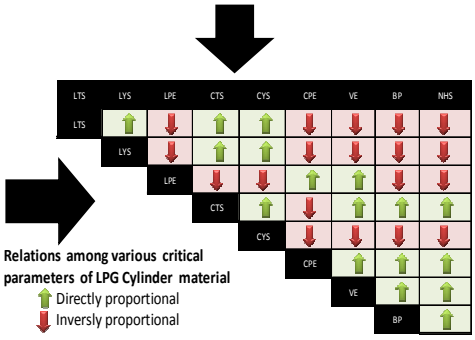

Fig.3: Relations among various critical parameters of LPG Cylinder material

DISCUSSION

Form the correlation constants, meaningful correlations can be established among tensile strength, yield strength percentage elongation, volumetric expansion burst pressure and nominal hoop stresses. However, in some pairs, the correlation constant is not really showing strong relations. This is possible because, of variety of reasons. Few possible reasons are raw material, heat treatment process parameters, welding parameters, test methods, and test setup, sample preparation etc.

From Fig. 3, LTS-LYS, LTS-CTS, LTS-CYS, LYS-CTS, LYS-CYS, LPE-CPE, LPE-VE, CTS-CYS, CTS-VE, CTS-BP, CTS-NHS, CPE-VE, CPE-BP, CPE-NHS, VE-BP, VE-NHS, BP-NHS shows relation which is directly proportion to each other. It means any one of the parameter is reported higher than typical values during the test, surely the other parameter in the pair exhibits higher values compared to the typical value. For example, referring to LTS-LYS; in a cylinder material if a longitudinal tensile strength (LTS) values is reported higher than a typical value or routinely observed value, the longitudinal yield strength (LYS) will also report higher values in parent metal testing. On the other hand, if LTS reports low LYS will also report low. This phenomenon is clearly evident in a low carbon steel stress strain curve [4].

Similarly, from Fig.3, LTS-LPE, LTS-CPE, LTS-VE, LTS-BP, LTS-NHS, LYS-LPE, LYS-CPE, LYS-VE, LYS-BP, LYS-NHS, LPE-CTS, LPE-CYS, LPE-BP, LPE-HS, CTS-CPE, CYS-CPE, CYS-VE, CYS-BP, CYS-NHS exhibits inversely proportional relation among these pair elements. That means any one in a pair is reported lower values then a typical value, the other parameter in the pair reports higher value than the typical value and vice-versa. In simple terms, in LTS-LPE relation, if longitudinal tensile strength (LTS) is reported higher than the typical values, the percentage elongation will report lower than its typical value of a cylinder material. This phenomenon can be justified again with a low carbon steel stress strain curve i.e. lower carbon steel reports, higher the tensile strength, lower the percentage elongation [4].

Form this study, it is evident that the longitudinal and circumferential samples, the yield strength and tensile strength are proportional to each other and the percentage elongating is inversely proportional to these values. Similarly the volumetric expansion, burst pressure and nominal hoop stresses are always proportional to each other. However, the Hydro-test results are proportional to elongation values of acceptance test results and inversely proportional to tensile and yield strength. It means, if the percentage elongation of a cylinder material is more than a typical value, the volumetric expansion will be report more than the typical value of a LPG cylinder. On the other hand, if the tensile strength of a cylinder material is more, the volumetric expansion will report lesser than a typical value of a cylinder. Similarly, all other correlations can be established among all possible pairs of acceptance and hydro-test results using the Table.1 and Table.2

Interestingly, in some pairs of acceptance test results, the trends exhibit contradictory relations comparative to their counterpart results of circumferential or longitudinal tests. In such cases it is advised to verify person correlation constant to check whether the results are having any correlation or just scattered apart. Such kind of contradictory relations are possible due to various factors when analysing practical test results and the this phenomenon can be attributed to various factors such raw material selection, heat treatment process parameters, cylinder manufacturing methods, welding process parameters, sample preparation methods [5][7][8][9]. Means, if the cylinders manufacturer from different raw materials sourced from different steel mills, produced different production methods, different welding processes and treated with different heat treatment process parameters[6][7][8]. It is also possible if the test methods and sample preparation methods adopted are different [9]. Considering all these conditions, the test results may be varied slightly.

CONCLUSION

It is possible to establish relation among acceptance and hydro test parameters of a cylinder material. Tensile and yield strength are in proportional to each other in both longitudinal and circumferential samples. On the other hand, percentage elongation is inversely proportional to both tensile and yield strength. The values of volumetric expansion, burst pressure and nominal hoop stress are always proportional to each other. Further these values are proportional to percentage elongation of both circumferential and longitudinal acceptance samples. However, the hydro test parameters are inversely proportional to yield and tensile strength. Although, various relations can be established among various parameters, the results may vary due to various manufacturing and testing parameters.

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