Development of an automated system for water-hydraulic and leakage test of pressure vessels

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ABSTRACT

This study developed a fully automated test system for pressure vessels, containing such as oxygen, nitrogen, which is widely used in many industries. The pressure vessel test has three major parts including weight measurement test, water-hydraulic test and leakage test followed by cleaning and drying. The control system for these tests consists of three parts: a PLC, a monitoring system and a database management system. The PLC oversees overall control of test machines, while the monitoring system measures and displays weight, pressure, flow etc. for every situations, and the database management system stores test data. These three modules are designed to communicate with one another at 1Hz frequency alerting problematic situations to the operator. The system has gone through actual field tests for verification of performances.

Key Words : Pressure vessel, Water-hydraulic test, Leakage test, Manufacturing automation

1. Introduction

Pressure vessels containing oxygen, nitrogen, or carbon that we normally encounter in everyday industrial environments are usually pressurized up to 100~300kgf/cm^2, the pressure level which imposes serious hazards on personnel. A single accident relating to inferior vessels or consumed fatigue is bound to claim lives of workers. For this reason, pressure vessels critically need to be checked for conditions relating to vessel life on a regular basis as well as during a manufacturing process. The test item includes three tests like weight measurement test, water-hydraulic test and leakage test, among which, the water-hydraulic and the leakage test, applying twice the magnitude of nominal vessel pressure, imposes danger constantly to workers in the shop, leading to a frequent occasion of explosion-involving accidents[3]. This study, therefore, developed an unmanned automated test system of pressure vessels free of accidents. The performance of the system proved satisfactory, after going through a test run which lasted for 100 days. Furthermore, by successfully localizing the system, investing just around 500 million won, contrasted to one billion won for the imported counterpart, creation of fresh demands from around 30 or more domestic production/recycling companies of pressure vessels and a growth of foreign marketing are expected.

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2. System design

This section describes configuration of the control system and overall test system, module by module.

2.1 Control system configuration

The pressure vessel test system consists of three parts as shown in Fig.1. The PLC oversees overall

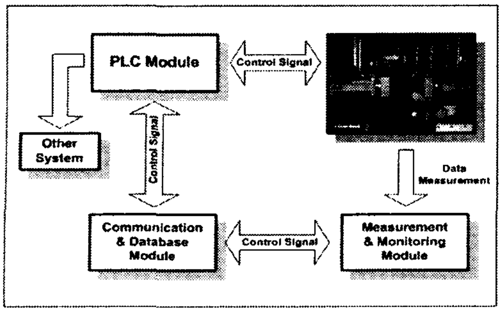

Fig. 1 Layout of developed system

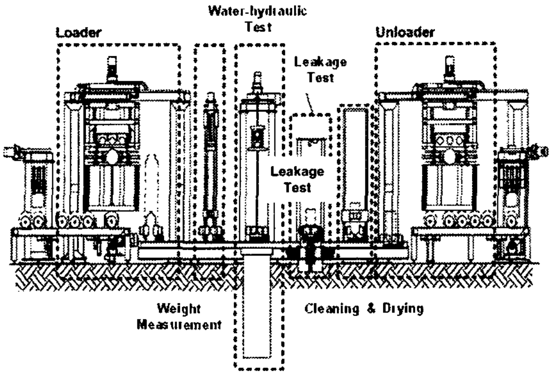

Fig. 2 The schematic view of test system

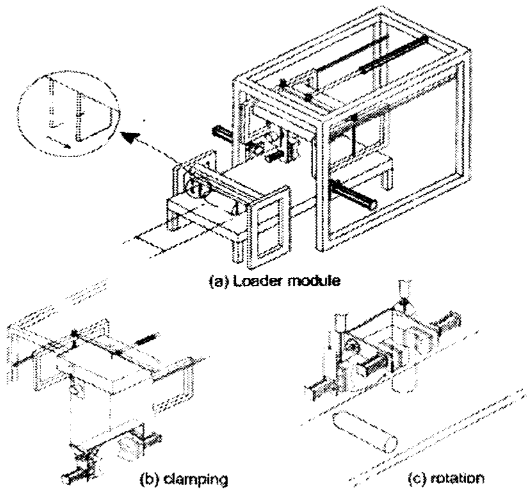

Fig. 3 The schematic view of loader module

machine control, while the monitoring system performs actual test measurements and global system status monitoring, and the database management system builds up a database and manages it. These three modules control the system, communicating with one another at

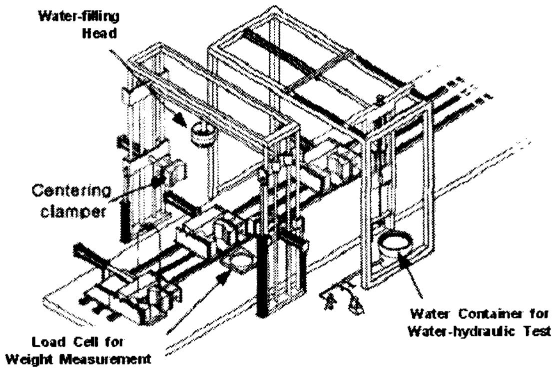

Fig. 4 The schematic view of weight measurement and water-hydraulic test module

1Hz frequency, and if a problem arises in any of these modules, the other two modules stop testing temporarily and report to the operator.

2.2 Loader and unloader module

The loader module, at the first part of the test system, shown in Fig.2, loads a pressure vessel on the test line. On the opposite end, the unloader module moves the vessel on the test line over to the next step after tests are finished. Fig.3(a) depicts the loader module, (b) the part for moving the vessel in prone position after clamping and (c) the device for rotating the vessel by 90° to an upright position following the clamping. Here, the loader part is assisted by actuating cylinders on left/right hand sides to push the test subject to the center line of clamping to assure clamping is always done on the mid section of the vessel[1-2].

2.3 Weight measurement module

The weight measurement module depicted in Fig.4 has three stages including measurement of empty vessel, water filling and measurement after water filling. The process functions as follow. The transfer device places a pressure vessel on the load-cell guide; the system measures the weight of the empty vessel as it raises the load-cell, which was in receded position below, and lifts the vessel. After the measurement is over, the system moves the water-filling head to the vessel inlet, fills the vessel up with water, and measures the weight again thereby measuring the volume of the pressure vessel. Measured water-filled weight could range to the

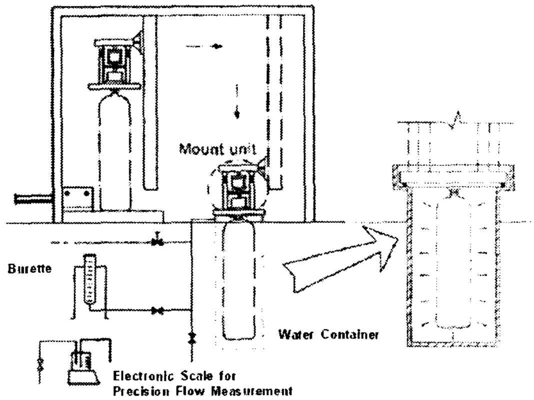

Fig. 5 The schematic view of water-hydraulic test module

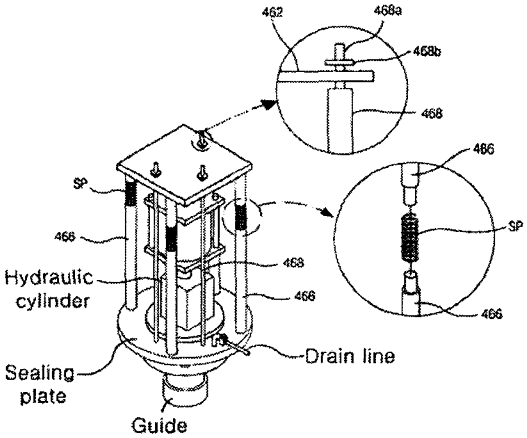

Fig. 6 The schematic view of mount unit

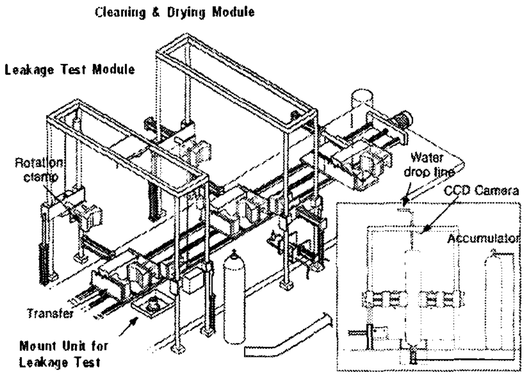

Fig. 7 The schematic view of leakage test module

maximum of 200kg, where the measurement error must not exceed ±0.2g. Empty vessel weight, marked on the vessel surface, bares a significant meaning for regular-base examination of vessel condition.

2.4 Water-hydraulic test module

Fig.5 shows the schematic view of water-hydraulic test module. Water-hydraulic test, which is the most critical test in examining pressure vessels, forces a hydraulic pressure ranging 250~450kgf/cm^2 into pressure vessels to measure a permanent increase rate during a specified time. Test procedures are as follows[3].

(1) Assemble a mount unit to apply pressure into the pressure vessel. Here, if the center of the vessel and mount unit do not coincide, the pins inside the unit could fracture during assembling or will not be removed when disassembling. Therefore, the most critical point in assembling the mount unit is to give some degree of freedom of motion in either one of the two, enabling self-aligning during assembling. Fig.6 shows a mount unit designed and developed in this study with degree of freedom for three axes using springs and double-stage support bar.

(2) Put the assembled vessel into water-filled container and make sure no leakage takes place during water-hydraulic test by having the sealing plate tightly pushed against the water container. Then open the drain valve for a precise measurement of expansion and contraction flow, and remove the air inside the water container by supplying enough volume of water into the water container.

(3) Close the drain valve, the water-filling valve and the burette valve; apply water-hydraulic pressure ranging 250~450kgf/cm^2 into the container by opening the valve connected to an electronic scale and using the pump. After it reaches a specified pressure, maintain it for 30 seconds and release the pressure. In this test, the vessel, subjected to a high inside pressure, expands by a definite amount and hereby a volume of water, proportional to the expansion rate, flows into the beaker on the electronic scale. Before releasing the pressure, measure the weight of the beaker and calculate the volumetric expansion of the vessel. When pressure is released, the expanded vessel contracts by a definite amount pushing the volume of water that once filled the

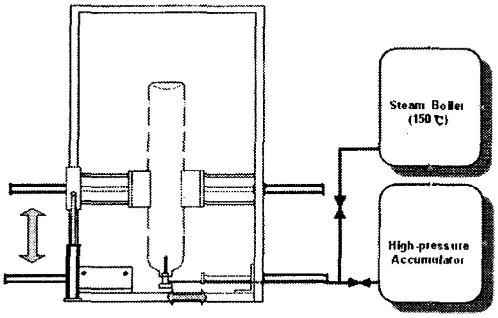

Fig. 8 The schematic view of cleaning and drying module

beaker back to the water container; here, the contraction volume is calculated in the same manner as used for the expansion volume; permanent increase rate is figured out from these results[4-5].

2.5 Leakage test module

The leakage test module shown in Fig.7, following the water-hydraulic test, checks for any leakage in the pressure vessel by measuring pressure variation for a specified time while applying high pressure ($150kgf/cm^2$). Test procedures are as follows.

(1) Using the revolving clamp, rotate the water-filled vessel by 180° to a reversed position. At this point, part of water(0.5ℓ ~1ℓ) in the vessel flows out. (2) Raise the mount unit for leakage test below and assemble it with the vessel. (3) Fill the groove at the lower part of the vessel with water. (4) After applying high pressure into the vessel, close the overpressure valve when the preset value is reached, maintain the pressure for a specified time(one minute) and release the pressure by opening the valve.

In this test, while maintaining the pressure for one minute, pressure variation inside the vessel is recorded and examined for possible leakages. In addition, a monitoring function was installed to enable visual checking, from CCD control room, of leakage at the lower concave part of the vessel for bubbles forming around the weakest spot.

2.6 Cleaning and drying module

The cleaning and drying module are as depicted in Fig.8. When all the test procedures are over completely, water is drained and swarf is removed from inside the vessel by blowing pressurized air. Then by supplying steam at 150℃, heated in a steam boiler, the pressure vessel is dried completely.

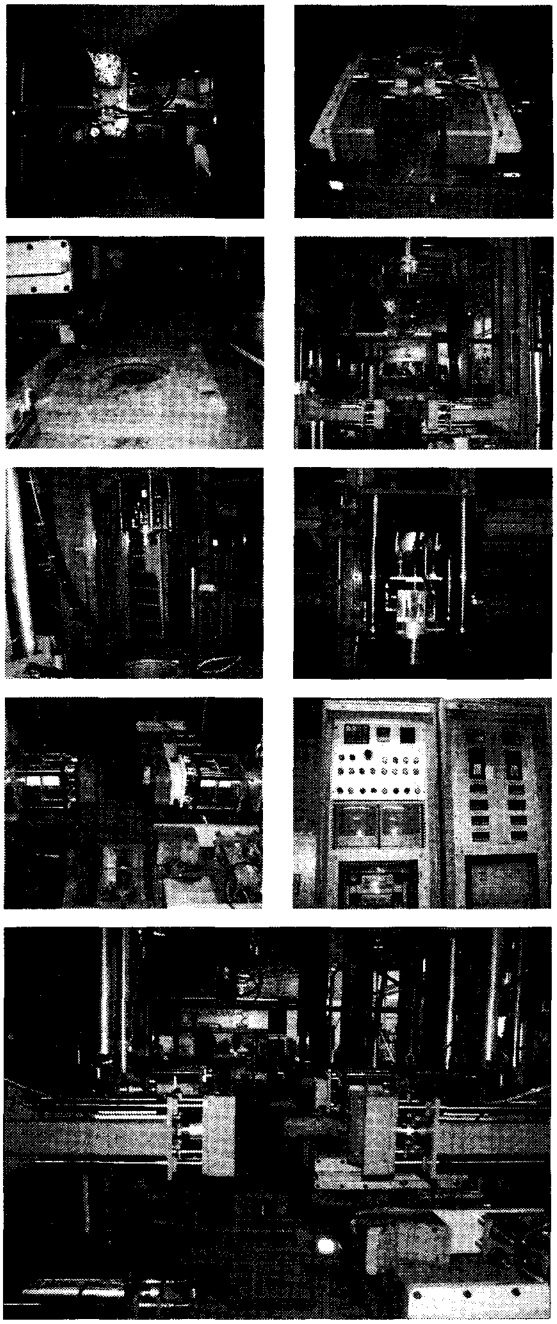

Fig. 9 Different views of the developed test system

3. Fabrication of the test system

Fig.9 below shows the entire test system to perform the tests described in the previous sections installed in the shop with machines for each stage.

4. Conclusion

This study developed an automated test system for high pressure vessels. To summarize the detailed achievements, this study:

1) succeeded in developing a localized test system at half the cost of highly priced foreign imported counterparts.
2) established methods of water-hydraulic and leakage test.
3) developed a specialized mount unit for water-hydraulic and leakage test.
4) developed a monitoring system, a database system specialized for testing high pressure vessels, and a specialized communication system between the systems and PLC.

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