Product Introduction

Development of New Controller for Impulse Test Stand

YOSHIMURA Yuki

1 Introduction

Recently, news about accidents attributable to industrial fatigue breakdowns or false inspections that compromise product safety have attracted publicity. One thing indispensable to fundamentally ensure product safety is fatigue testing machines of Kayaba System Machinery Co., Ltd. (hereinafter "KSM"). Most of existing fatigue tests are carried out using endurance testing equipment that applies a stationary wave load to specimens, such as material tester. Now the demand for fatigue tests using an even more accurate, realistic test waveform has risen with diversified product/testing needs. Among these is an impulse test stand that applies pressure loading to specimens such as hydraulic hoses.

KSM offers impulse test stands that can accept a variety of specimens using a dedicated controller. These impulse test stands have earned a reputation in the market, particularly for the reproducibility of the JIS waveform [Note 1]. This article introduces the latest model of impulse controllers.

Note 1) A test waveform with sharp peaks used for hydraulic-pressure impulse tests on hoses specified by the former JIS K6330-8.

2 What is the impulse test stand?

Fig. 1 shows the general configuration of KSM impulse test stands. The hydraulic pressure is generated by a special cylinder called a "boost cylinder" with a built-in pressurizer on its end. The boost cylinder is used to compress the fluid within the specimen, generating any given pressure.

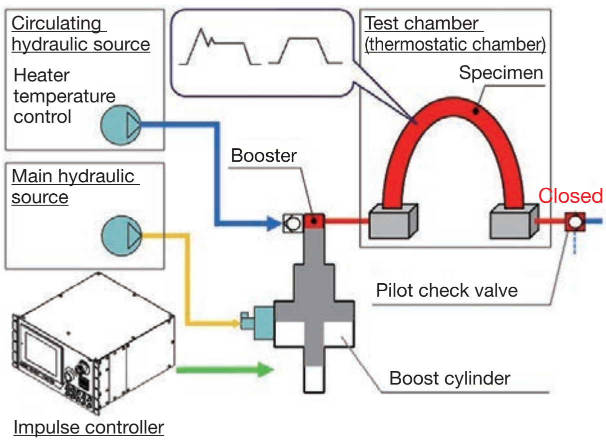

Fig. 1 Configuration of impulse test stand

The test stand mainly consists of a main hydraulic source that drives the boost cylinder, a circulating hydraulic source that circulates the service fluid, and a test chamber in which specimens are installed for testing. Another component of the test stand to control the boost cylinder and reproduce a specified pressure waveform for specimens is the controller for impulse testing, which is the development target.

3 Background of Development

Controllers used for KSM impulse fatigue test stands include the old 2107 model (hereinafter "old model") shown in Photo 1. Since many years have passed since the development, this old model is now difficult to manufacture because some of the components are out of production.

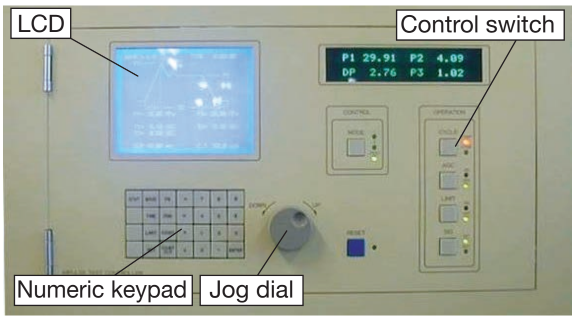

Photo 1 Appearance of old model

Also, the old model cannot satisfy customized specifications without changing its internal ROM. It has become difficult for the old model to meet customer testing needs that have diversified with various factors, including maintenance of the development environment, quality and cost issues. KYB has thus decided to develop Model 3100 (hereinafter "new model") using a general-purpose programmable logic controller (hereinafter "PLC"), which has recently produced a substantially higher performance, to implement the control requirements.

4 Concept and Outline of New Model

When developing the new model, the functionality, operability and customizability of the old model were improved. Moreover, the waveform reproducibility of the old model, which was still highly rated, was further enhanced to achieve a high-standard performance that cannot be caught up with by any competitor. The new model has the same size and external interfaces as those of the old model to support full backward compatibility, thereby enabling users to only replace/update the controller without changing the test stand itself. Photo 2 shows the appearance of the new model.

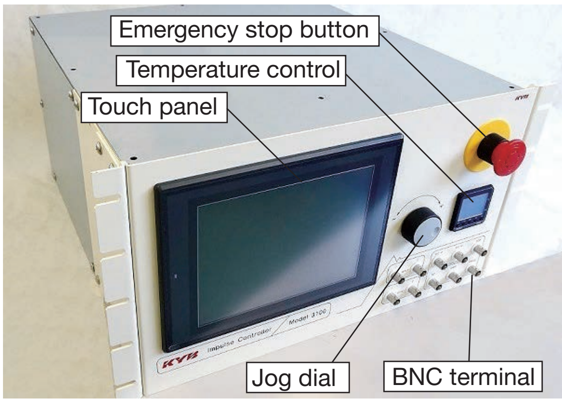

Photo 2 Appearance of new model

A large-sized touch panel LCD is mounted on the front panel, achieving comfortable operability and customizability. Test parameters can be set by direct input of numeric values or by just turning the jog dial. The jog dial can also be used for intuitive control to adjust the neutral position of the boost cylinder. BNC terminals for connecting the temperature control or various measuring instruments are put together on the front panel. Almost all operating actions and connections with measuring devices can be collectively operated on the front panel.

5 Internal Structure

Hardware includes analog amplifier circuits as a minimum component, which is modularized by function. They can be optimally designed by selecting a combination of necessary boards and PLC units for the actual scale of the test stand (Photo 3). This structure makes it possible to replace the hardware in units on site if a failure occurs, contributing to shorter recovery.

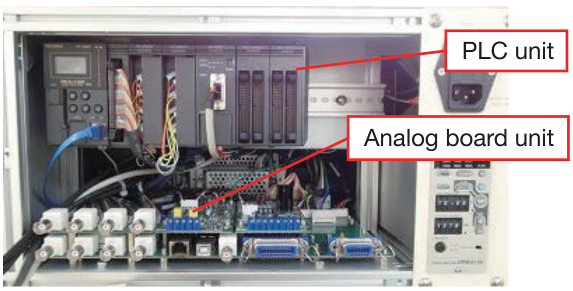

Photo 3 Internal structure

6 Control Software

The main control section is based on the PLC. It uses not only the ladder language Note 2), but also a description called "script" that is similar to the BASIC or C Language, making it possible to achieve complex control processing such as cylinder displacement control and specimen pressure control.

Unlike the old model, the new controller accomplishes all control processing tasks by calculation on the PLC, except the final physical controls including the servo valve drive and pressure amplifiers. Thus this is a fully-software-controlled controller. That is why the extended control functions, including error correction control to be described later except PID control Note 3), were successfully implemented. The new design also allows easy additional customization such as modifications suited to each specific test stand or programming for customer-specific testing. Furthermore, the control of peripheral equipment including hydraulic sources, which was carried out by a separate PLC, is now integrated into the controller. This new integral model only requires a smaller space for the control board than the old model, contributing to resource conservation and power saving as well.

Note 2) A programming language mainly used in PLCs that represents a program with a graphical diagram like a ladder using symbols representing electric relay circuit devices.

Note 3) Stands for proportional-integral-derivative control. This is one of the traditional feedback control mechanisms and implements control with three elements: output proportional to an error value as the difference between an actual value and a desired setpoint (P), output proportional to the integral of the error values (I), and output proportional to the differentiation of the error values (D).

7 Reproduction of JIS Waveform

Reproduction of the JIS waveform is one of the requirements for impulse test stands. An expandable specimen

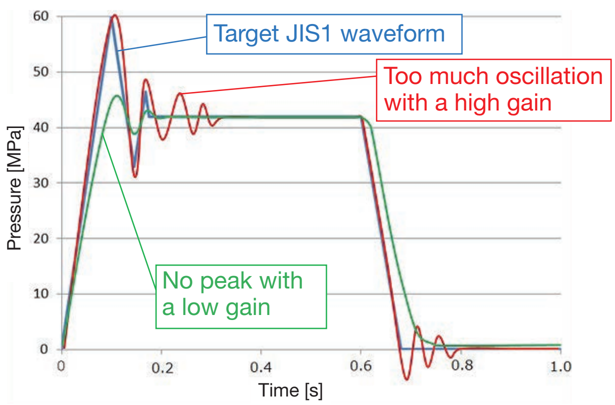

Fig. 2 Reproduction of JIS waveform 1 by PID control

filled with compressive fluid is subjected to an impulse test to verify the high-accuracy quick control of the internal pressure with a pressure waveform called the JIS1 waveform, consisting of a prominent peak and its subsequent flat section as indicated by the blue line in Fig. 2. In reality, it is quite difficult for the regular PID control alone to reproduce the exactly same waveform as the JIS1 waveform due to the specimen's pressure responsivity attributable to its own properties.

8 Error Correction Control

A new control mechanism called error correction control has been developed and implemented in the new model. In this error correction control, the error between the target and response waveforms of each wave is stored as time-series data and is superimposed on the target waveform of the following wave in the feedforward manner [Note 4)] so that the response waveform is closest to the original target as much as possible. This procedure is repeated over and over again. Fig. 3 shows a flow of the error correction control for the JIS1 waveform.

Note 4) A control system that preliminarily measures data such as disturbance to the control system and determines in advance the control amount with the data taken into account.

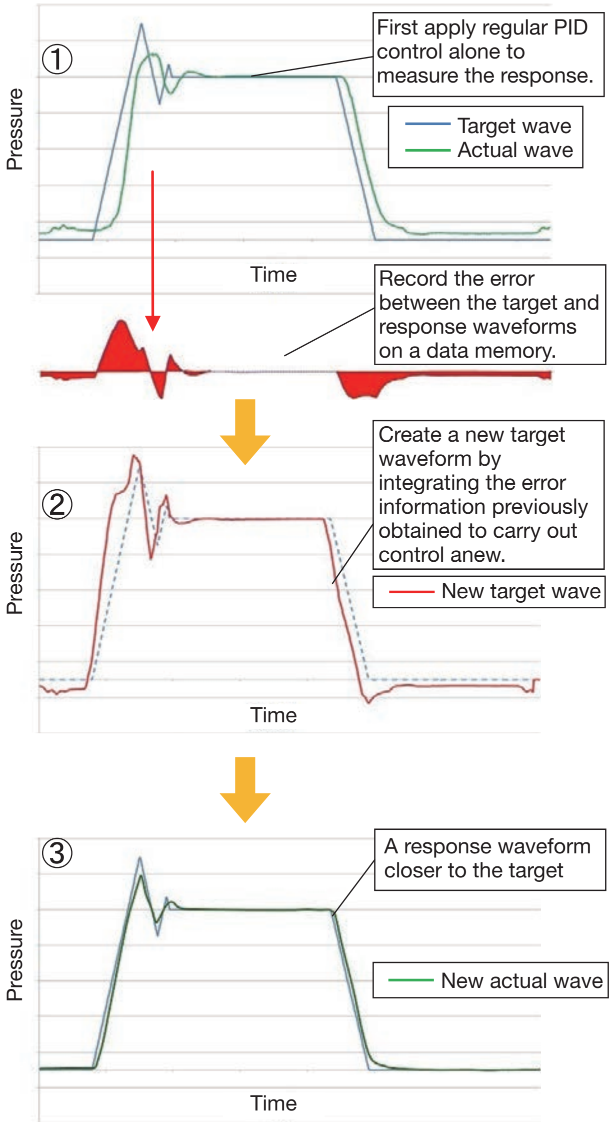

Fig. 3 Error correction control

It is essential for this impulse test with the JIS1 waveform that measurement values for the highest pressure peak coincide with the target value stably. Another control mechanism to keep only the peak value at a constant level independent of those obtained by PID or error correction control has also been conducted separately, achieving stable generation of the peak value.

Also, the error correction control automatically adjusts the correction gain according to the degree of coincidence of the peak values. The controller is designed to temporarily stop the correction processing when waveforms coincide with each other to a certain extent, helping achieve stable operation.

For the old model, many analog quantities had to be adjusted by trial and error to obtain a coincidence of waveforms. Now the new model can almost automatically reproduce accurate pressure waveforms with error correction control. Once parameter settings are entered on the test screen, just turning on the error correction will enable correction processing unless the specimen's characteristics are considerably changed.

Fig. 4 Test screen

9 Results of Measurement in Actual Machines

Using an impulse test stand of the specifications shown in Table 1 with the new and old controllers, waveform measurement was carried out under the same test conditions for comparison of response waveforms. The results are shown in Fig. 5.

For the old model, the actual waveform is off the target in some sections, including the 2nd peak and the trailing edge. The new model diagram shows that the actual waveform coincides exactly with the target waveform throughout the entire zone.

For the new model, the controller automatically adjusts the waveform itself. A waveform with only a slight error as shown in the graph above can be obtained regardless of whoever carried out the setting. The new model has the great advantage of being able to ensure stable test quality.

Table 1 Test stand specifications and test conditions

Max. specimen volume	6000cm^3
Specimen expansion	9cm^3 MAX
Max. dynamic pressure	25MPa
Max. static pressure	30MPa
Specimen	Hydraulic hose
Fluid	Automatic transmission fluid Note 5)
Test conditions	Peak pressure: 30 MPa Test frequency: 1 cycle/sec.

Note 5) A kind of gear oil used to lubricate gears or operate valves and torque converters of vehicles equipped with reduction gears

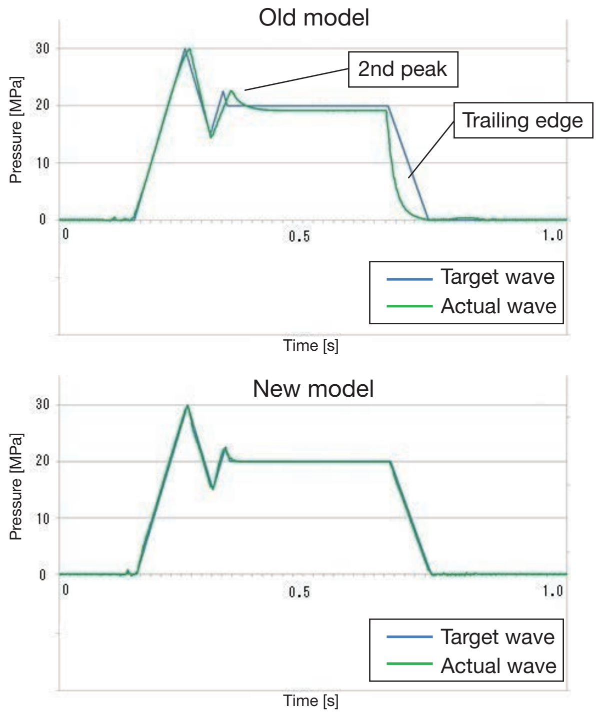

Fig. 5 Comparison of waveforms for actual machines

10 Future Outlook

This development project has demonstrated that fatigue test stands can be sufficiently controlled by a PLC-based controller. We will apply this technology to various other testing machines. The error correction control proposed in this development project can be applied not only to impulse test stands but also to other testing machines. For example, it has already been confirmed that a shock absorber (SA) testing machine with its displacement control integrated with the error correction control shows improved results of velocity waveform in testing (Fig. 6).

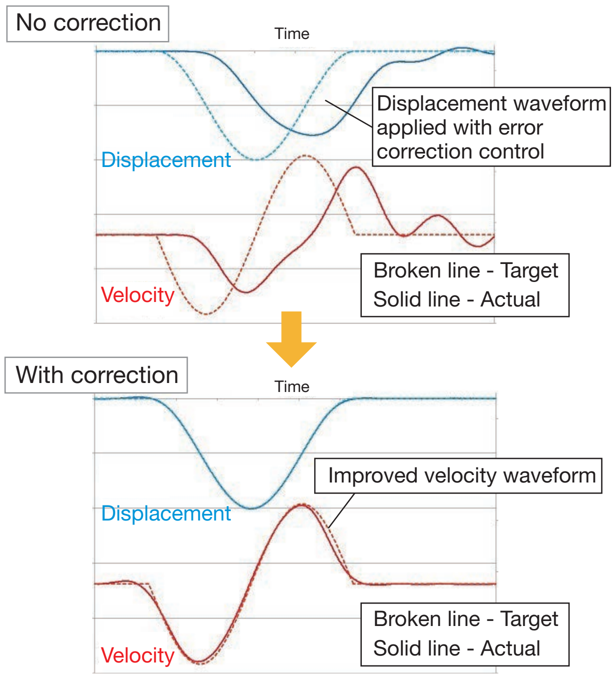

Fig. 6 Improvement of velocity waveform of SA testing machine

11 In Closing

The new model has gained a good reputation with customers in field tests. We have already received many inquiries. We can expect the technology to grow in future by exploring new markets, making use of the customizability.

Finally, I would like to deeply thank the related KSM departments, all the related partner companies and all those who extended cooperation in the field tests for the development.

Author

YOSHIMURA Yuki

Joined the company in 2013.
Engineering Dept., Mie Plant, KAYABA SYSTEM MACHINERY Co., Ltd.
Engaged in design and development of control devices for simulator products.