〈**Line Tester**〉

Testing Facilities for Torque Converter Production Lines

Torque converter, Lockup response test, Friction test

Kiyohide Abe, Norihiro Maezato,
Masaru Masui, Tatsuya Inami

Abstract

We manufactured and delivered the testing facilities for torque converter production lines. This features new test items of lockup response and friction tests in addition to the conventional stall slip test items.

In order to realize new evaluation tests, we adopted a CPU system to carry the measurements of transient phenomena. In addition, the test result waveforms can be checked on the monitor and data can be analysed at the production site.

To improve the productivity at the production efficiencies on production lines, the test Station (ST) is divided into two test STs. The test items are divided into the different test STs to reduce the cycle time.

1. Preface

The torque converter is a major component in a vehicles' automatic transmission. It is to transfer engine rotating power to a rotating drive shaft (wheels).

We manufactured and delivered the testing facilities for torque converter production lines. To meet the demands of the times of cars: less environmental impact, better fuel efficiency, and better riding comfort, the torque converter testing facilities are required to implement new performance evaluation test items. In addition, for volume increase in production, it also calls for the reduction of cycle time in conducting such tests.

This paper introduces the torque converter testing facilities featuring the additional new evaluation test items and the reduced cycle time.

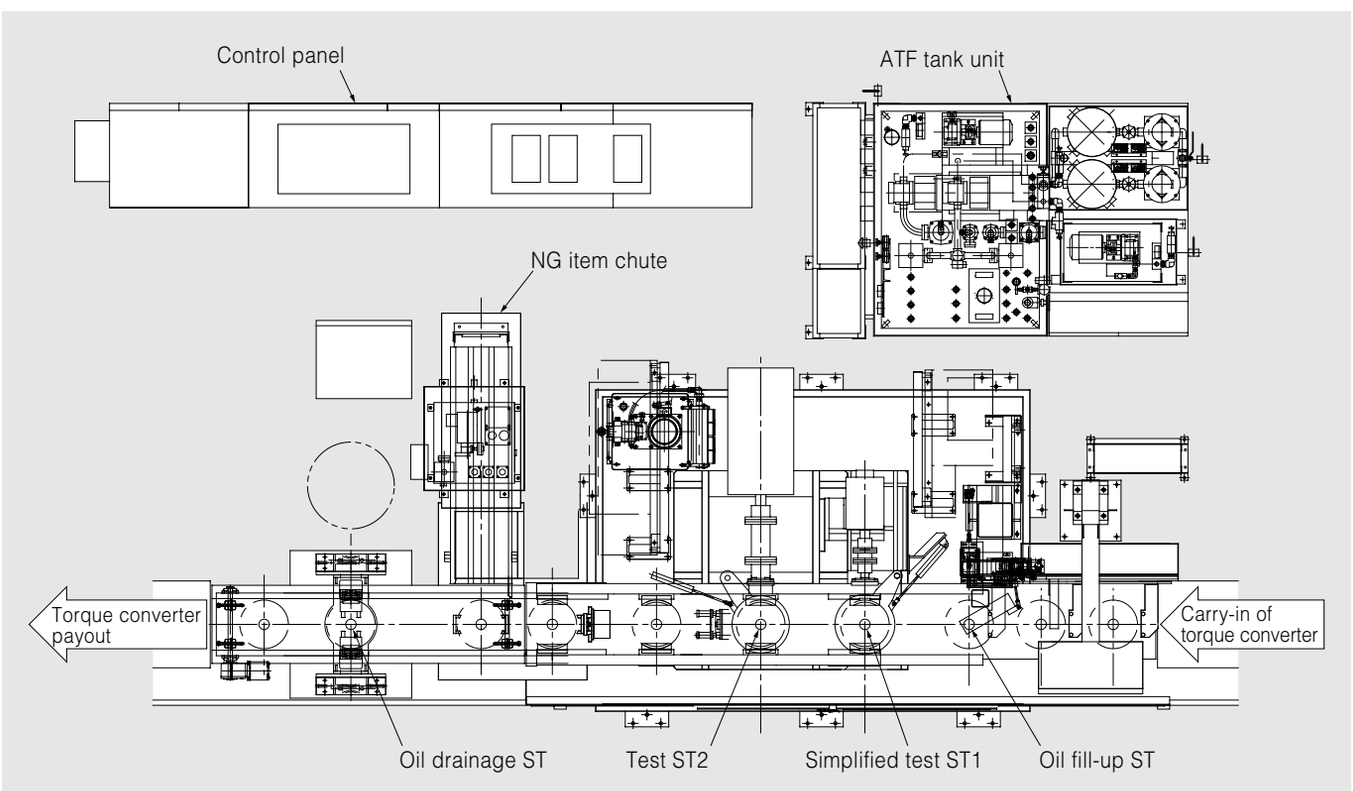


Fig. 1 Overall Layout Drawing (Top View)

This shows the layout of each key piece of equipment. The torque converter is sent from the right to the left. In the main body area, it is equipped with STs for each specific test.

Table 1 List of Major Equipment Specifications

This shows the specifications overview of major system equipment.

Sub-system name	Specifications/Configuration/Functions
Test ST1	Input shaft motor capacity: 11kW Revolutions: 1500/3000min^{-1}
Test ST2	Input shaft motor capacity: 55kW Revolutions: 1150/4500min^{-1} Output shaft motor capacity: 55kW Revolutions: 1150/4500min^{-1}
AFT tank unit	Oil temperature regulation Inlet block: 80 ± 10℃ Outlet block: 130℃ or below Tank capacity Dirty side: 125L Clean side: 250L Heating capacity 20℃ → 80℃/30 minutes
Work carrier unit	Carrying system: Transfer system (servomotor driving)
Oil draining unit	Carrying system: Conveyer transportation Drainage system: Reverse mechanism + Air purge system
Control panel (installed in CPU unit)	Dimensions: W2900 × H1980 × D600mm Configuration: Switchgear, motor panel, sequencer panel (CPU unit functions: Waveform display, data storage)

Table 2 List of Measuring Items

This shows the overview of the measuring and computing items by the system.

No.	Measuring and computing items	Measuring range	Detection converters
1	Input shaft revolving speed (Ni)	0～3000min^{-1}	Encoder
2	Output shaft revolving speed (No)	0～3000min^{-1}	Encoder
3	Input shaft torque (Tqi)	0～±500N･m	Torque meter
4	Output shaft torque (Tqo)	0～±500N･m	Torque meter
5	IN port pressure (Pi)	0～1MPa	Pressure sensor
6	OUT port pressure (Po)	0～1MPa	Pressure sensor
7	IN port temperature (Tei)	0～200℃	Thermocouple K (CA)
8	OUT port temperature (Teo)	0～200℃	Thermocouple K (CA)
9	ATF oil temperature	0～200℃	Thermocouple K (CA)
10	Coefficient of friction (μ)	0～1.0	Operation
11	Ratio of coefficient of friction	0～2.0	Operation
12	Torque changing time dt	0～10.00s	Operation
13	Torque gradient dTQ/s	0～500N･m/s	Operation
14	Torque oscillation	0～500N･m	Operation

2. System Outline

Fig. 1 shows an overall system layout drawing. Table 1 shows a list of specifications for major equipment units. A torque converter is filled up with Automatic Transmission Fluid (ATF) oil at the oil fill-up Station (ST) and then goes through the simple test, ST1. Only the slip test is carried out at that location. After that, the stall lockup response and friction tests are carried out at the test ST2. Once the torque converter is judged as "passed" at the test ST1, 2 is sent to the oil drainage unit to remove the filled oil, and the successive processes follow. However, if the torque converter is judged as defective or Not Good (NG), then it is carried to the NG item chute.

The AFT tank unit installed as a subsidiary facility is used for the oil supply, oil collection (with a filtering function), and temperature control. The control panel is composed of the switchgear, the motor panel, and the sequencer panel with a built-in CPU system.

Table 2 shows a list of measuring items by this system. Based on the result of measurements, torque converter performance is evaluated.

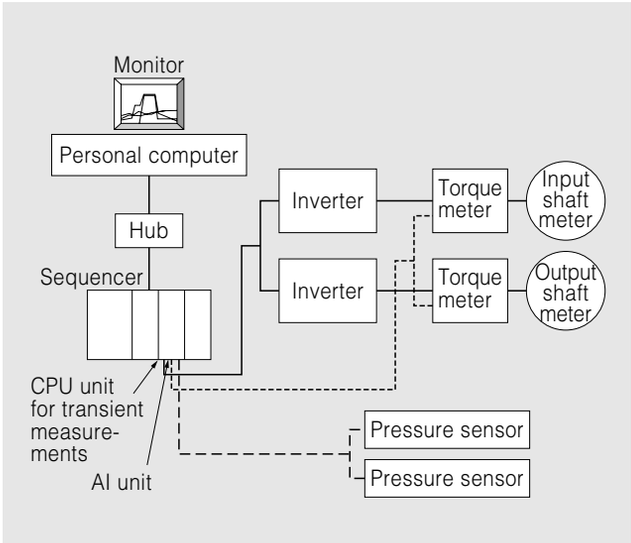


Fig. 2 PLC Hardware Configuration

A hardware configuration diagram of the test ST2 sequencer and major equipment is shown for transient measurements.

Table 3 List of Various ST Functions

Functions of the respective STs in the main area are shown.

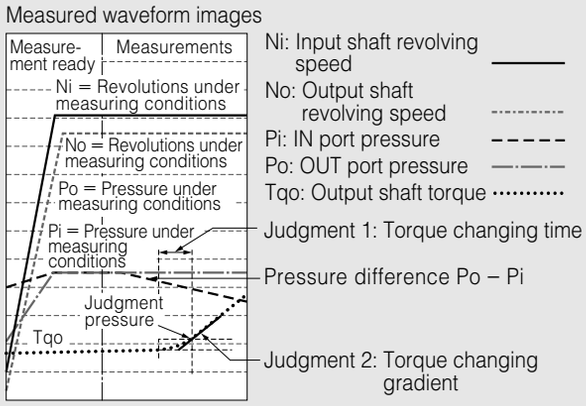
ST name	Measuring items	Configuration
Oil fill-up ST	Oil filling before testing	Simplified ST construction of upper/lower combined spline structures only
Test ST1	Steady-state measurement: Slip test	Mechanisms of input shaft motor + combined elevator
Test ST2	Steady-state measurement: Stall test Transient measurement: Lockup Response test Friction test	Mechanisms of input/output shaft motor + combined elevator

3. New Evaluation Tests

This system uses a CPU unit to perform the processing of transient measurements and is made possible with the new evaluation tests. Fig. 2 shows a PLC hardware configuration. Table 3 shows a list of various ST functions.

The term "transient" means a phenomenon that changes from a steady state (a constant condition) to another steady state. For example using a car, the period from the state of rest to the point of reaching a

Measured waveform images



Testing conditions

Category	Items	Conditions
Revolutions	Input shaft revolving speed (Ni)	Revolutions fixed under measuring conditions
	Output shaft revolving speed (No)	Revolutions fixed under measuring conditions
Pressure	IN port pressure (Pi)	Pressure under measuring conditions reduced to a constant pressure
	OUT port pressure (Po)	Pressure fixed under measuring conditions

Contents of measurements and judgments

Items		Contents
Contents of measurements	1	Output shaft torque (Tqo)
	2	IN port pressure (Pi)
	3	OUT port pressure (Po)
Contents of judgments	1	Torque changing time dt
		Time is examined from the time when pressure difference between IN and OUT port pressures has exceeded the prescribed level until the time when output shaft torque has attained the judgment pressure.
	2	Output shaft torque changing gradient dTQ/dt
		Torque gradient at the time when output shaft torque has attained the judgment pressure.

Fig. 3 Contents of Lockup Response Test

Contents of the testing conditions for the lockup response test and those of measurements and judgments are shown.

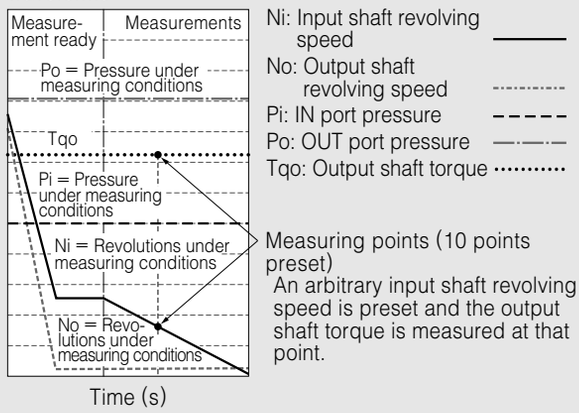
particular speed is considered a transient state. The new evaluation test items for conducting the processing of transient measurements are described below.

(1) Lockup response test

The term "lockup" means an action of no slippage of the torque converter by locking the input shaft and the output shaft together in order to reduce the loss in the torque transmission efficiency during the car running at a constant speed.

Fig. 3 shows the contents of the lockup response test. While keeping the input and output shaft motors running at a constant revolving speed, we measure

Images of the measured waveforms



Testing conditions

Category	Items	Conditions
Revolutions	Input shaft revolving speed (Ni)	Revolutions reduced under measuring conditions to a constant speed
	Output shaft revolving speed (No)	Revolutions fixed under measuring conditions
Pressure	IN port pressure (Pi)	Pressure fixed under measuring conditions
	OUT port pressure (Po)	Pressure fixed under measuring conditions

Contents of measurements and judgments

Items		Contents
Contents of measurements	1	Output shaft torque (Tqo)
	2	IN port pressure (Pi)
	3	OUT port pressure (Po)
Contents of judgments	1	Coefficient of friction μ
		Coefficient of friction is calculated from the output shaft torque, pressures, and various coefficients using the formula below. $\mu = Tc/(Rm \times A \times P \times 10^{-3})$ Tc: Clutch torque (To – To') To: Output shaft torque at each speed To': Output shaft torque in stall mode Rm: Mean radius (m) A: Pressure receiving area (mm^2) P: Pressure difference (Po – Pi)
	2	Ratio of coefficient of friction
		Ratio of coefficient of friction μ is calculated at each point. Ratio of coefficient of friction = μ Point1 – μ Point2

Fig. 4 Friction Test Contents

This shows the contents of the testing conditions of the friction test and gives its measuring items and judging factors.

and evaluate the torque variations in the output shaft by changing the AFT oil pressure.

(2) Friction test

The friction test is a test to evaluate the coefficient of friction μ under the condition that the torque converter is engaging the locked up mode.

Fig. 4 shows the contents of the friction test. After

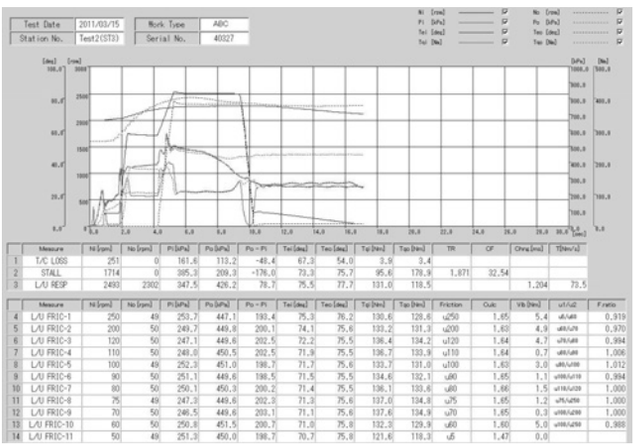


Fig. 5 Example of Monitor Screen

A monitor screen for the result of measurements is shown. The upper part of the screen displays the measured waveforms and the lower part displays data of measurements and operation. The waveforms and test results are stored in the CSV file format.

running the input and output shaft motors at a particular revolving speed, we gradually lower the revolving speed of only the input shaft motor. Then we measure the output shaft torque at each randomly preset point (revolving speed of the input shaft). Based on the measured output shaft torque, the coefficient of friction and ratio of coefficient of friction are calculated for evaluation.

(3) Waveform display and data storage

During testing, measured items such as revolving speed, pressure, torque, etc., are displayed in real-time mode in the form of waveforms on the monitor screen of a personal computer. Therefore, the conditions of field-testing can be monitored. Fig. 5 shows an example of a monitor screen.

The test results are stored in the CSV file format together with waveforms data. These data are being managed for the traceability of the torque converter.

4. Reduction of the Cycle Time※1

Compared with the past test cycle time under conventional facilities, we could reduce the cycle time under this system that has been reduced to 27 seconds, half of the time of the conventional one. In the past, a single test ST was used to perform all test items; however, this system uses the 2-test ST method where functions and test items are divided into two blocks. The test ST1 was simplified (only one set of input shaft motors) and we increased the maintainability.

5. Postscript

This paper introduced the testing facilities for torque converter production lines. Going forward, we would like to perform the update product development to incorporate the various needs which will change with the times. We would like to produce the best possible product experience for the customer.

Note: ※1. A cycle time means a duration of time from the start of a certain work test until the start of the next work test.