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Evaluation Criteria of Reliability on Transmission Control Unit for Passenger Car

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Abstract. There has been a recent upsurge in demand for the improvement of car reliability in the Northern American which is the primary market of South Korea automobile industry. It has been required that the warranty for transmission control unit for passenger cars directly related to passenger safety or security should be extended for 10 years and 160,000 km. In this paper, the test method for reliability and evaluation criteria is presented to evaluate the reliability on the automatic transmission controller. Reliability certification test can be roughly divided into two types: a quality test and life assessment test and a quality test can be subdivided into a basic performance test and environmental resistance test. There are 3 types of tests on the performance test for automatic transmission controller and environmental resistance test is composed of 14 items. Life test is performed with only the product passed this quality test. In this study, operation limit test at the high-temperatures, accelerated life test under specific temperature and accelerated life test for 2 or 3 stress levels are shown as a way for life test.

Key Words : *Reliability, Transmission control unit, Quality test, Life assessment test, Accelerated life test.*

1. INTRODUCTION

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The transmission control unit for passenger cars is a device that controls appropriate transmission shifting by detecting vehicle condition through the Crankshaft Position Sensor used to monitor engine speed and the vehicle speed sensor used to sense car speed. Automatic transmission controller is a crucial part of vehicle since its failure may lead to not only an irregular transmission shifting, but also a severe transmission damage caused by each abnormal shifting. Like this, the malfunction of transmission is able to have influence on the trouble of automobile driving. A driver may also get into severe dangerous situation on account of abnormal controlling. Because there should be no malfunction of automatic transmission controller functionally while driving, it is a very important part in aspects of reliability. It is necessary that the reliability and completeness on automatic transmission controller should be improved by establishing and using the criteria of lifetime, reliability and durability test for the automatic transmission controller. Improvement in reliability for vehicle has been strongly demanded in various fields. Since the transmission control unit for passenger cars directly is related to passenger safety, it is warranted for 10 years, or 160,000 km. The test method for reliability in automatic transmission controller is classified into several types: performance test, insulation resistance, withstanding voltage, and operation test at a low-temperature, the test for heat stress and the cycle of thermal and humidity, vibration resistant test, electromagnetic wave test, life test, and so on. However, recovery of reliability for appropriate domestic product is confronted with some troubles since the standard of reliability test method regulated in the world's top auto-making countries is different. To solve this problem such as above, the need for standardization for reliability test method and criteria for reliability evaluation is suggested. The car industry is in the desperate need of the shorter testing period for reliability in proportion to the shortened development period for new vehicle. To achieve this, it is required to follow the accelerated testing being carried out in the developed country. This paper attempts to show the criteria for environmental resistance test including accelerated lifetime testing in accordance with these needs.

In this paper, we try to show that the general criteria for reliability evaluation test method of automatic transmission controller which controls shift form of automatic transmission installed inside a car and transmission hydraulicity and damper clutch in torque converter. In Chapter 2, we discuss the general terms for reliability qualification test. The quality test consisting of reliability qualification test is considered in Chapter 3. In Chapter 4, we explain the reliability test for life qualification.

2. THE GENERAL TERMS FOR RELIABILITY QUALIFICATION

2.1 The limit of application

Products that comply with this standard can regulate a reliability test for automatic transmission controller which controls the shift form of automatic transmission installed inside a car and transmission hydraulicity and damper clutch in torque converter. In case there is a difference between this standard and product specifications, it is advisable to adopt the latter.

2.2 Test condition and requirement

In case the laboratory specific condition is not designated, the laboratory condition complies with the regulation in KS A 0006(2001) - higher temperature and humidity. A crack, transformation and decomposition must not be detected in all sample used for test in visual inspection before and after test. In addition, unless there is specific guideline, the followings should be recorded and notified.

a) Relevant part form (the Manufacturer's mane, form number, lot number)
b) Test date
c) Test place
d) Tester
e) Laboratory temperature
f) Sample size
g) Correction date of test device
h) The picture being able to understand the content of test
i) Test result and the result of observing each part

2.3 Test condition and requirement

In case of the process that the complete survey is taken in principle before the final release, the samples for automatic transmission controller used for reliability qualification have to be selected among the latest qualified items produced under identical condition to be able to check environment test and life test, but additional preliminary sample should be chosen to replace the defected sample made by not a manufacturer but an accident. The number of sample for each test is stated at the test standards.

2.4 The procedure for reliability qualification test

Reliability qualification test is divided into a quality test and a life test as shown in Figure 2.1. Quality test is subdivided into the basic performance test and environment test. The basic performance test should be carried out in proportion to the assigned sample, and evaluate insulation resistance and withstanding voltage known as a basic operation of product, and electrical characteristics. If there is any sample that doesn't get through the basic performance test, it is required to randomly choose and replace the sample with the reserved sample selected for provision. Only the samples passed in the performance test should be taken for an environment test. Environment test is composed of 14 test items, including inverse voltage, and the number of samples assigned to each test, a detailed test condition and a criteria are going to be shown in Chapter 3. After it passes environment test, accelerated lifetime test for reliability qualification is performed. Detailed test standards and procedure are covered in Chapter 4.

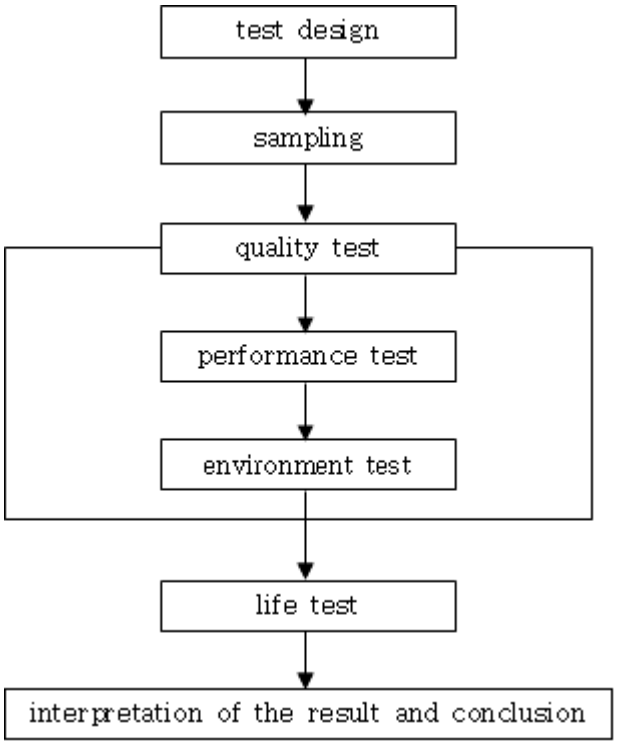

Figure 2.1. The procedure of reliability qualification test

3. QUALITY TEST

A quality test can be divided into a basic performance test and an environmental test. 2 samples used for an environmental test should be a reliable product proven in the performance test.

3.1 Performance test

All samples should be placed on the basic performance test that would evaluate electrical characteristics by the criteria shown in the table 1 before an environmental test and a life test are carried out. Basic performance test should meet each criterion content in Table 3.1. An acceptable standard on the performance test has to depend on product specifications. For the purpose of electro-optics characteristics evaluation, make preparations for measurement condition stated in product specification, keep the test performed at least for 30 minutes, operate product under the regulated condition and measure the result of the test. An operating-condition and performance criteria should be based on product specification, and the main equipments for measurement such as detector have to be marked on the measurement table when taking measurements. It is recommended to refer to the detailed test standards in "Guideline for reliability evaluation - transmission control unit for passenger cars".

Table 3.1. The criteria for performance test

Test item	Criteria	No of sample	No of Fault - Tolerant
Basic operation test	Operating normally	Complete	0
Insulation resistance	Insulation resistance value should be not less than 1 MΩ	2	0
Withstanding voltage	No dielectric breakdown and flash	2	0

3.1.1 Basic operation test

The basic operation test, basic performance evaluation test for transmission control unit for passenger cars, is designed to conform whether there is a failure or not after preliminary performance, environmental resistance test and life test. Besides, basic operation test is carried out to make sure it operates normally under the assumption of FTP-75 mode. The details related to the test standards were determined after referring to the standards of domestic and foreign company and discussing them in the working group.

3.1.2 Insulation resistance test

Insulation resistance test is established to evaluate the electronic insulation characteristics for transmission control unit for passenger cars. The details related to the test standards were determined after referring to the standards of domestic and foreign company involved in electric apparatus and discussing them in the working group.

3.1.3 Withstanding voltage test

This test, an assessment test on withstanding voltage characteristics of transmission control unit for passenger cars, is designed to verify a withstanding voltage in between housing and terminal. The details related to the test standards were determined after referring to the standards of domestic and foreign company and discussing them in the working group.

3.2. Environmental resistance test

Only the product passed in basic performance evaluation test should be intended to take a test for 14 items on the environmental resistance test with sample size in accordance to the criteria specified in Table 3.2. It is recommended to refer to the detailed test standards in "Guideline for reliability evaluation - transmission control unit for passenger cars".

Table 3.2. Judging criteria and number of sample for environment resistance evaluation

Test item	Judging criteria	No of sample
1. Inverse voltage	Should pass basic operation test after the test	2
2. Overvoltage	Should pass basic operation test after the test	2
3. Low temperature operation	Operating normally	2
4. Temperature and humidity cycle	Operating normally	2
5. Thermal shock	NO crack and transformation, and should pass basic operation test after the test	2
6. Vibration resistance	Should pass basic operation test after the test	2
7. Mechanical shock	Should pass basic operation test after the test	2
8. Absorber-lined shielded enclosure	Should meet the table 3 of 8.8.1 in the 『Guideline for reliability evaluation - transmission control unit for passenger cars』	2
9. Radiated emission	Should meet the level 3 in the table 11 included in KS C CISPR 25(2002)	2
10. Conducted emission	Should meet the level 3 in the table 7 included in KS C CISPR 25(2002)	2
11. Transient immunity	Should pass basic operation test after the test	2
12. Short circuit protection	Should pass basic operation test after the test	2
13. Electrostatic Discharge	Should meet the table 5 of 8.13.1 in the 『Guideline for Reliability evaluation - transmission control unit for passenger cars』	2
14. Power source micro interruption	Should pass basic operation test after the test	2

3.2.1 Inverse voltage test

Inverse voltage test is used primarily to check the resistance caused by a wrong battery terminals connection. Test voltage is set up to be DC -14 V, in consideration of battery terminal voltage for ordinary vehicle- DC (12~14) V. Criteria is regarded as being passed the basic operation test after the test.

3.2.2 Overvoltage test

Overvoltage test, called 'jump start' test, is planed to identify the resistance to voltage impact which may take place while charging up a dead battery due to misconnecting two batteries in series caused by user error. The test voltage was determined to be DC 20 V after referring to the standards of company and discussing them in the working group.

3.2.3 Operation test at a low- temperature

An operating test at a low-temperature is designed to detect the change of physical characteristics in controller when operating at a low temperature. It was determined after referring to the temperature under the user condition and the standards of domestic and foreign company and discussing them in the working group.

3.2.4 Temperature and humidity cycle test

Temperature and humidity cycle test is intended to identify the corrosion on printed circuit board, physical transformation, electrical characteristics, aging, and so on, by accelerating the deterioration of the above mentioned performance in a way that humidity resistance test is put into the alternating temperature cycles test at a high and low temperature. Test standards and criteria were determined after referring to the standards of company and ISO standards related to electric apparatus, and discussing them in the working group.

3.2.5 Thermal shock test

Thermal shock test is designed to evaluate the reliability of a controller exposed to repetitive impact at a high and low temperature. The factor of thermal shock test is temperature differences, a duration and transition time at a high and low temperature, and the number of entire cycle. Each high and low temperature level is decided in consideration of user environment since the selected sample is placed on the interior seat, in addition, the temperature holding time is determined by considering a heat capacity of the attached sample. Test methods were determined after referring to the standards of domestic and foreign company and discussing them in the working group.

3.2.6 Vibration resistance test

Vibration resistance test is designed to evaluate a housing damage and a breakaway of circuit component caused by repetitive mechanical impact. Test method was determined after referring to the guideline of KS R 1034(2006) and discussing them in the working group.

3.2.7 Mechanical shock test

Mechanical shock test to verify the mechanical performance of controller is half sine shock test utilizing a vibration tester and impact tester. While the company commonly takes a drop test from a 1 meter high as a impact test, we replaced the impact of half sine in accordance with keeping up with the global trend of impact test. Test standards and criteria is determined after referring to the impact test standards related to electric apparatus for vehicle, and considering the above mentioned component is equipped to the engine in the working group.

3.2.8 Absorber-lined shielded enclosure test

Absorber-lined shielded enclosure test, electromagnetic waves test item, is designed to evaluate conductive resistance affected by external electromagnetic waves which would damage controller. It is decided to comply with KS R ISO 11452-2(2002) in the working group.

3.2.9 Radiated emission test

Radiated emission test, electromagnetic waves item, is planed to evaluate electromagnetic wave which is emitted out from a controller due to radiation. It is decided to comply with KS C CISPR 16-1(2002) and KS C CISPR 25(2002) in the working group.

3.2.10 Conducted emission test

Conducted emission test, electromagnetic waves test item, designed to evaluate electromagnetic waves which is emitted out from a controller due to conduction. It is decided to comply with KS C CISPR 16-1(2002) and KS C CISPR 25(2002) in the working group.

3.2.11 Transient immunity test

Transient immunity test is planed to evaluate the resistance to impulse voltage caused by battery terminal loss. It is decided to comply with JASO D 001(1994) in the working group.

3.2.12 Short circuit protection test

It is test item for evaluating characteristics test according to broken external wire connected to a controller. Test items were determined after referring to the standards of company and discussing them in the working group.

3.2.13 Electrostatic discharge test

Electrostatic discharge test, electromagnetic waves item, is designed to evaluate a radiated resistance affected by external electromagnetic waves which would damage controller. It is decided to comply with ISO/TR 10605(1994) in the working group.

3.2.14 Power source micro interruption test

It is determined to refer to the company standards evaluating characteristics when momentary power connected to a controller is turned off and discussing them in the working group.

4. LIFE QUALIFICATION TEST

4.1 Warranty and amount of operating time

The transmission control unit for passenger cars comes with 10 years or 160,000 km warranty. Average annual car mileage for each country is taken into consideration to calculate the amount of operating time for automatic transmission controller. Average annual and daily car mileage for each country is about 16,197 km and 44.38 km respectively. Divide it by 33.8 km/h, average car speed for each country, straightforward calculation for average daily driving time can be established as follow;

Average daily driving time = (44.38 km/day) / (33.8 km/h) = 1.313 h/day

The amount of operating time for automatic transmission controller is equivalent to car driving time or engine operating time. If we convert it into the 10 year and 160,000 km respectively, the converted equation for operating time can be obtained as

Operating time per 10 year = (1.313 h/day)×(10×365 day/10 year) = 4792 h/10 year
Operating time per 160000 km = 160000 km/h ÷ 33.8 km/h = 4733 h/160000 km

On the basis of this, it is noted that since if the converted operating time comes to over 4,800 hour, the warranty of 10 years and 160,000 km was chosen respectively.

4.2 Life qualification test

After life evaluation test based on 4.3 is performed with 3 samples, if it produces highly satisfactory results under the criteria in Table 4.1 after the test, the converted operating time per each 10 years and 160,000 km can be guaranteed with 90% confidence level.

Table 4.1 criteria for life time evaluation

Test item	Criteria	No of sample
Life time	After the test, The number of defected sample must be less than or equal to 1. Must meet the evaluation criteria for performance test.	5

Life qualification test be able to be taken according to the operation limit test at a high temperature in 4.3.1, accelerated life test under the specific temperature in 4.3.2,

accelerated life test at two or three stress level in 4.3.3. It is desirable to take accelerated life test under the specific temperature for prompt certification work, and accelerated life test at two or three stress level is also advisable to get the information for product life-span quickly.

4.3. The method for life qualification test

4.3.1 Test for operation limit at the higher temperature

Item	Condition
Test condition	Ranging from 70 ℃ ~ 180 ℃, but it can be changed depending on each operation limit temperature.
Testing device	Test device for being consistent with the regulated test conditions, and for basic operation test.
Testing method	**a)** Put the sample into a thermal chamber, and then operate automatic transmission controller at 70 ℃ on FTP-75 mode. Operation time is asked to match 1-cycle condition on FTP-75 mode. For the purpose of shorter test time, it is advisable to omit the paused time when the controller does not control a shift between II and III mode in FTP-75 mode. **b)** After the test at the 70 ℃ is completed, do the test in a) by raising the temperature by 10 ℃ degrees. **c)** In case phenomenon which the controller is fixed to a certain kind of shift is detected, let the test remain constant at high temperate for 2 hours as it is, restart operation test at 10℃ lower temperature than that of the above mentioned phenomenon, and then if it is functioning normally, the temperature which the fixed phenomenon was detected is regarded as an upper operation limit. **d)** The test is conducted continuously by a 10 ℃ higher temperate than that of an upper operation limit, but if a shift fixed phenomenon still occurs or it does not work normally, let the test remain constant at high temperate for 2 hours as did in c), then do a test again at a 10 ℃ lower temperate. However, if it still does not work, that temperature is counted as an upper breakdown temperature. It is not necessary to figure out an upper breakdown temperature, but record it as a reference
Record	a) Test condition b) An upper operation temperature, or upper breakdown temperature,

4.3.2 Accelerated life test under the specific temperature

Item	**Condition**
Test condition	Take a test on the basis of a specific temperature in Table 4.2 at a temperature less than an upper operation limit of high operation limit test.
Testing device	Test device for being consistent with the regulated test conditions, and for basic operation test.
Testing method	a) Put the sample into a thermal chamber, and then operate automatic transmission controller on FTP-75 mode. The test is conducted without the paused time between II and III mode in FTP-75 mode b) After the test, take a basic operation test, and then record the test result.
Record	a) Test condition b) The result of basic operation test

Table 4.2. Test hour for accelerated life test at the specific temperature according to temperature

Test temperature (℃)	Test hour(h)
70	16000
80	7000
90	3300
100	1600
110	820
120	440

4.3.3 Accelerated life test at two or three stress level

Item	**Condition**
Test condition	Over 2 temperature conditions of a interval of 10℃(2 or 3 temperature stress levels) in less than upper operation limit temperatures of operation limit test at a high temperatures should be used to decide on a test temperature. The test should be conducted with over 12 samples in each condition of temperature stress on the basis of dividing samples into a similar size. It is desirable to make a final decision by considering the time taken for the test and estimating acceleration factor.

Method for estimation of acceleration factor	Acceleration factor for the calculations of the expected testing time can be estimated by the equation based on Arrhenius Model as follows; $AF = L_u / L_a = exp[(E/k) \cdot (1/T_u - 1/T_a)]$ L_u, where : controller life in user's condition, h L_a: controller life in temperature condition of accelerated test, h E: activation energy, eV but in case of the estimation of acceleration factor, it is assumed to be 0.8 eV k : Boltzmann constant($8.6173 \times 10^{-5} = eV/℃$) T_a: absolute temperature in accelerated test, K T_u: absolute temperature in user's condition, Let temperature in use condition of controller equipped inside the cars be 70 ℃ - $343.15\ K$
Testing time	Time to failure
No of sample at each level	The total number of sample should come to 12. In case of level 2, divide it into two groups having each 6 samples, on the other hand, divide it into three groups having each 4 samples in case of level 3, but the number of sample may be changed, depending on the test circumstance.
Testing device	Test device being consistent with the test conditions 9.3.1 and based on 7.1.2
Testing method	a) Put the sample into a thermal chamber, and then operate automatic transmission controller on FTP-75 mode in 9.3.1 condition. The test is conducted without the paused time between II and III mode in FTP-75 mode b) Operate the controller continuously until failure at each temperature level. c) Check whether to operate normally during the test, and then record the test result. d) After the test is completed at the each temperature level, carry out the identity test and acceleration test for a shape parameter. life data analysis e) If the acceleration is conformed, then do life data analysis. It is necessary that in the analysis for life, the converted lifetime in 4.1 should come to over 4,800 hours under the user's condition with 90% confidence level. f) Calculate and record activation energy of acceleration factor based on each lifetime data.
Record	a) Test condition b) Lifetime data c) Analysis for life d) Activation energy and acceleration factor e) Life prediction equation and lifetime under user's condition

5. CONCLUTION

There has been a recent upsurge in demand for the improvement of car reliability in the Northern American which is the primary market of South Korea automobile industry. It has been required that the warranty for specifically transmission control unit for passenger cars directly related to passenger safety or security should be extended for 10 years and 160,000 km. In this paper, the test method for reliability and evaluation criteria is presented to evaluate the reliability on the automatic transmission controller. Reliability certification test can be roughly divided into two types: a quality test and life assessment test and a quality test can be subdivided into a basic performance test and environmental resistance test. There are 3 types of tests on the performance test for automatic transmission controller and environmental resistance test is composed of 14 items. Life test is performed with only the product passed this quality test. In this study, operation limit test at the high-temperatures, accelerated life test under specific temperature and accelerated life test for 2 or 3 stress levels are shown as a way for life test.

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