

Bench Durability Test Procedure for Manual Transmissions

1. Scope

This standard specifies a procedure of the constant input torque durability test on each shift position, a test which is one of the bench durability tests of the manual transmissions of automobiles (hereinafter referred to as "transmissions"). However, this standard shall not apply to motorcycles.

Remark: In this standard, units and numerical values are based on SI (International System of Units), while units and numerical values given in { } are customary units system, and are given for reference.

2. Purpose

This standard aims to standardize a durability test procedure for gears, a test which is one of the durability tests for transmissions, and aims to offer convenience to the customers.

3. Definitions

Meanings of main terms used in this standard shall be as follows, unless otherwise pursuant to **JASO C 801** (Glossary of Terms Relating to Manual Transmission of Automobiles).

(1) Constant input torque durability test on each shift position

A durability test to determine the life of gears, giving a pair of gears of each shift position under the conditions of the transmission unit constant torque and revolution.

(2) Gear life

Total number of revolutions or time until crack or breakage of a gear, or pitting or scoring of gear surface, occurs.

4. Test Conditions

Test conditions shall be as follows

(1) Input torque

Forward position:

Input torque shall be the maximum torque of the mounted engine. However, it must be set, as a rule, within the range of 80 ~ 150% of the maximum torque of the mounted engine when the torque is varied in order to get T-N (S-N) diagram.

Reverse position:

Input torque shall be set within the range of 50 ~ 150% of the maximum torque of the mounted engine.

Setting precision*:

Setting precision shall be $\pm 2\%$ of the set input torque.

Note: Allowance of variation of the test condition during the test.

(2) Input speed

Forward position:

Input speed shall be set, as a rule, in the vicinity of the speed at the maximum torque. However, the maximum engine speed may be taken if necessary.

Reverse position:

Input speed shall be set in the range between 1500 rpm and the speed in the vicinity of the speed at the maximum torque.

Setting precision*:

Setting precision shall be $\pm 1\%$ of the set input speed.

(3) Lubricant

Specified oil shall be kept at specified level.

(4) Lubricant temperature

Lubricant temperature shall be set within 60 ~ 120°C according to the purpose, and setting precision* shall be $\pm 10^\circ\text{C}$ to the set temperature.

(5) Installing angle of transmission

Transmission shall be installed horizontally or at the installing angle of drive train of the transmission.

Applicable Standard: **JASO C 801**

Reference Standards: **JIS B 0102**

JIS B 1741

JIS B 1752

Glossary of Terms Relating to Manual Transmission of Automobiles

Glossary of Gear Terms

Tooth Contact Marking of Gears

Methods of Measurement for Spur and Helical gears

(6) Break-in

Break-in is not necessary, as a rule. However, it may be done if necessary in particular.

5. Test Devices

Test devices shall be able to test the transmission in its unit state and shall satisfy the following conditions:

(1) Driving and loading devices

Driving and loading devices shall be a combination devices, which are able to drive a test transmission by a motor or an engine, to set loads by torque, and to measure and control the input speed and torque. Typical examples of the combinations of driving and loading devices are shown in **Attached Fig. 1 ~ 5**.

(2) Thermometer

Thermometer shall be able to measure the oil temperature of a transmission unit.

(3) Controlling device of lubricant temperature

Controlling device of lubricant temperature shall have a cooling system to control the oil temperature of a transmission unit.

The cooling system shall be either the one which directly cools the transmission unit by water or air (the transmission unit) or the one which cools the lubricant compelled to circulate into the heat exchanger.

(4) Recording device

Recording device shall be able to record the total number of revolutions of in- or output shaft or the test hours.

(5) Automatic stopping device

Automatic stopping device shall be able to constantly measure the number of revolutions, torque, and oil temperature during the test, and to automatically stop the test device when the measured values deviate from the set values.

Furthermore, the device is desirable to be able to measure also the vibration of a test transmission other than the number of revolutions, torque, and oil temperature, and to automatically stop the test device when the measured value deviates from the set value.

6. Measurement Item

Measurement items shall be as follows:

(1) Input torque

Input torque shall, as a rule, be measured. However, output torque may be measured and converted to the input torque if the measurement of the input torque is impossible.

(2) Revolving speed of input shaft

(3) Temperature of lubricant oil

Temperature of lubricant oil shall be measured at the position of drain plug or filler plug of the transmission.

(4) Total number of revolutions or test hours

7. Test Method

7.1 Study Items before Test

Following items shall be studied on the gear to be tested, if necessary:

- (1) Over pin (ball) diameter
- (2) Precision of tooth profile and tooth trace
- (3) Fillet radius
- (4) Tooth contact under unloading condition in transmission unit
- (5) Material and heat treatment

7.2 Test Piece

Test pieces shall be sampled at random, and three or more units are desirable to be tested for one torque setting.

7.3 Test Procedure

Test procedure shall be as follows:

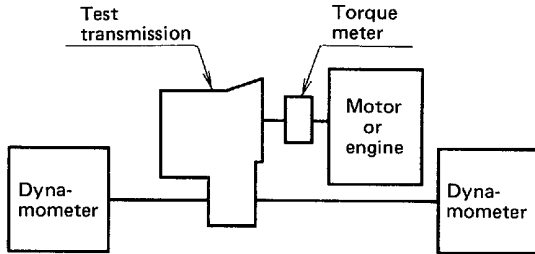
- (1) The test transmission shall be attached to the test device and be shifted to the position to be tested.
- (2) Torque, revolving speed of input shaft, and lubricant oil temperature shall be set under test conditions, and then recording of total number of revolutions or test hours shall be started.
- (3) In the case of long term continuous driving, the position shall once be put in neutral after a certain time of driving, the position of engagement shall be changed, and the test shall be continued.
- (4) When the driving is automatically stopped because of one of the torque, revolving speed, oil temperature, or vibration, the transmission to be tested shall, as a rule, be disassembled and the gear conditions shall be studied.

7.4 Study Item after Test

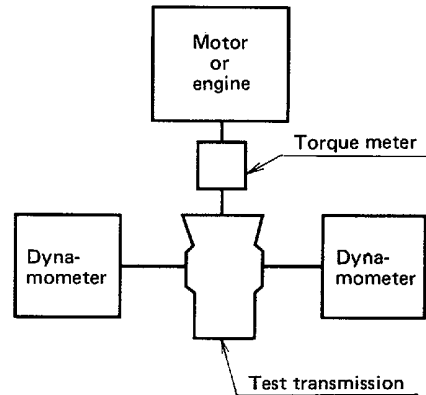
The pair of gears tested shall be studied on the following items:

- (1) State of breakage of the gears
- (2) State of pitting and scoring on tooth surface and tooth contact
- (3) Characteristic analysis on material of gear, heat treatment, and lubricant oil, if necessary.

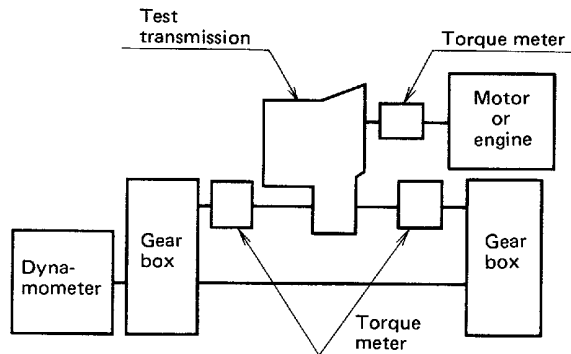
Attached Fig. 3 FF-type Test Device (Example 1)



Attached Fig. 4 FF-type Test Device (Example 2)



Attached Fig. 5 FF-type Test Device (Example 3)



Remarks 1: In case of engine drive, torque meters shall not be set.

2: In cases of RR- and MR-type transmissions, devices shall be applied correspondingly to FR- and FF-type ones.

Attached Table 1 Example of the Form of Test Record

Name of test transmission:	Test date: From	Test personnel:
Test pair of gears:	To	
Test shift position:	Gear ratio:	Final gear ratio (in case of built-in final gear):

1. Test Gear Specification

	Drive gear	Driven gear
Module		
Pressure Angle		
Helix angle (Direction)		
Number of teeth		
Over pin (ball) diameter	Pin (ball) dia.	Pin (ball) dia.
Precision		

	Drive gear	Driven gear
Dedendum bending stress MPa { kgf/mm ² } (Input torque = N·m { kgf·m })		
Tooth surface contact Stress MPa { kgf/mm ² } (Input torque = N·m { kgf·m })		
Total contact ratio		

2. Result of Precision Measurement

	Over pin (ball) diameter	Tooth profile error	Lead error	Radius of fillet curvature
Drive gear				
Driven gear				

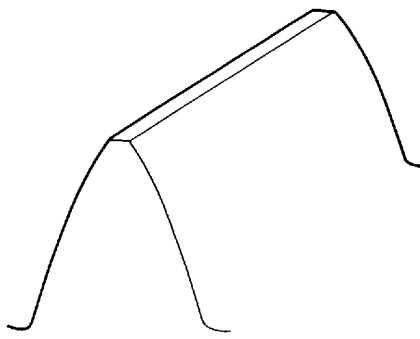
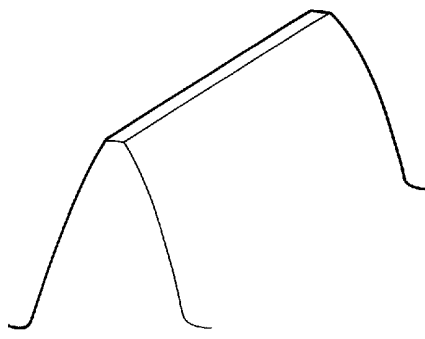
3. Test Condition

Input torque N·m { kgf·m }		Transmission installing angle (°)	
Input speed rpm		Lubricant oil	Kind of oil
Driving device	Motor • Engine (Type)		Oil temperature °C

4. Test Results

Total number of revolution	Drive gear	x 10 ⁴ rev.	Driven gear	x 10 ⁴ rev.
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State of Breakage of Gears

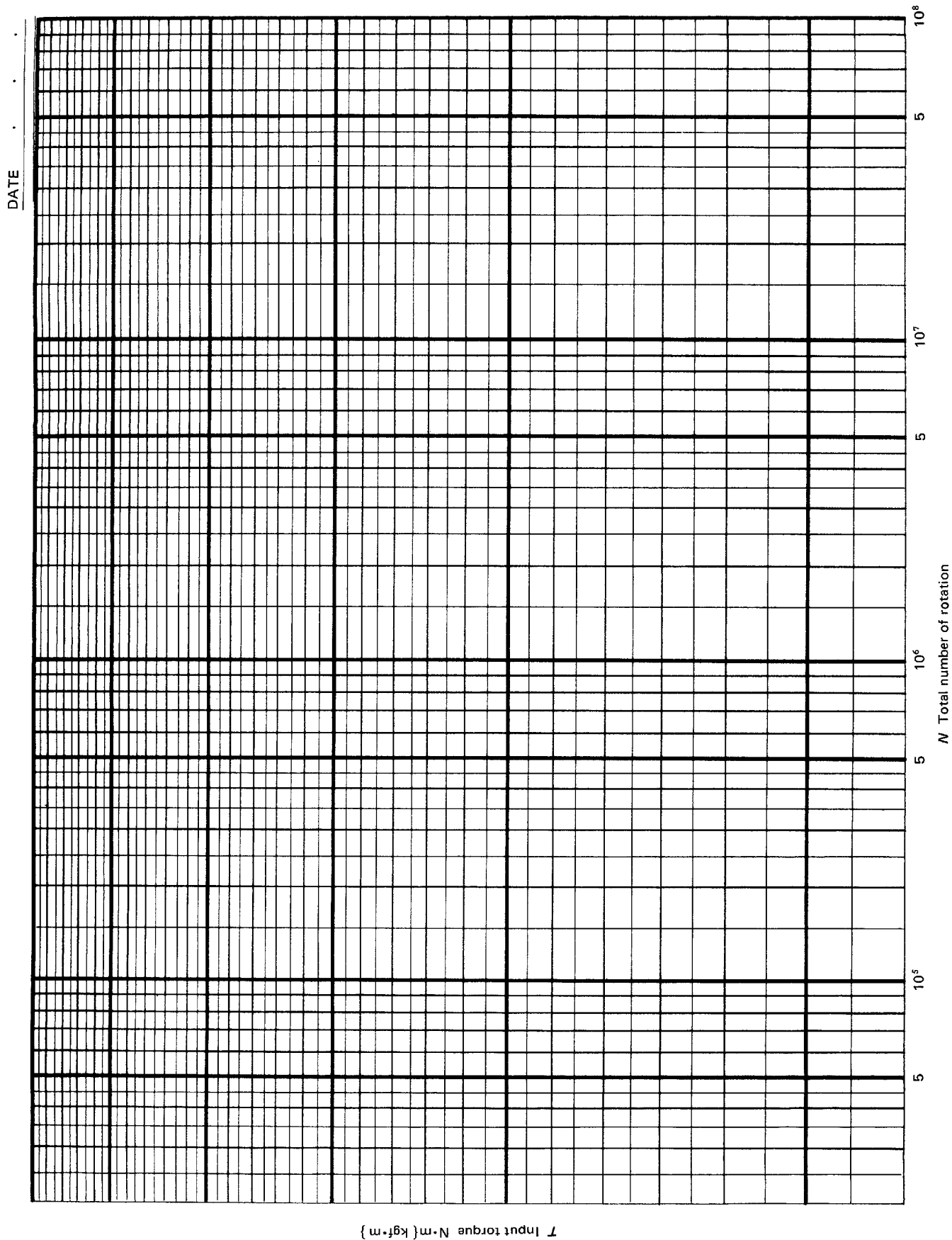
Drive gear 	Driven gear 	Other abnormality and state of breakage
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Attached Table 2 Example of Test Result Table

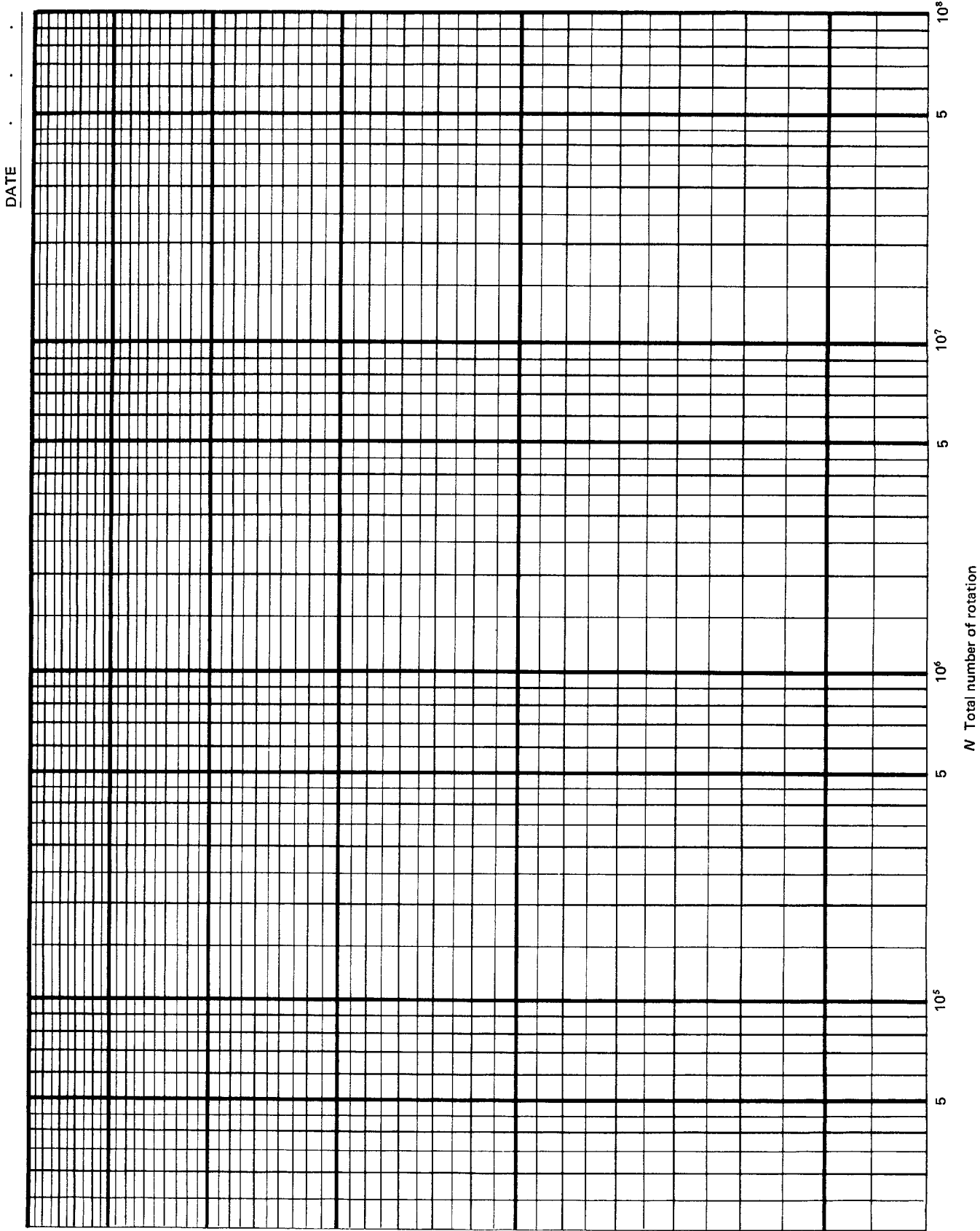
Name of tested transmission: _____

Test No.	Test gears	Input torque N·m { kgf·m }	Input speed rpm	Total number of revolution (x10 ⁴ rev.)		State of breakage of gears
				Drive gear	Driven gear	
	1st					
	2nd					
	3rd					
	4th					
	5th					
	6th					
	Rev.					
	1st					
	2nd					
	3rd					
	4th					
	5th					
	6th					
	Rev.					
	1st					
	2nd					
	3rd					
	4th					
	5th					
	6th					
	Rev.					

Attached Table 3 Example of T-N Diagram Recording Table



Attached Table 4 Example of S-N Diagram Recording Table



Explanatory Note
on
JASO C 204-86 Bench Durability Test Procedure for Manual Transmissions

Preface

There are few standards concerning the transmissions for automobiles. Especially for manual transmissions **JASO C 203** (Bench Performance Test Procedure for Manual Transmission) which has been standardized in 1984 fiscal year is the only standard, which is concerning the performance, and not for durability test. Therefore, a subcommittee has been settled and started to draft a standard on bench test procedure for transmissions, partly because of active request from the Chassis Committee of JSAE.

Although there are many items on the bench durability test for manual transmissions; durability tests for gears, bearings, synchronizers, shifting systems, assembly units, etc.; now the durability test for a gear which is the one of the important items for manual transmissions has been drafted.

It is desirable that this bench durability test procedure, being added by other items in future, becomes comprehensive ultimately.

Explanations will be given, hereafter, for the items which appear to need supplemental descriptions. (Numbers of items are the same to those in the **Test**.)

1. Scope

This procedure aims at the transmissions for passenger cars, busses, and trucks excluding the transmissions for constructional and industrial equipments. Driving systems (FR-, FF-, RR-, and MR-type manual transmissions) are not limited. However, concerning the manual transmissions with built-in final reduction gears, the final reduction gears using helical gears are included, but the final reduction gears using hypoid gears are excluded because of the opinion that the hypoid gears somewhat differ from the helical gears by test method and philosophy.

2. Purpose

As for the life-time of the gears which are important components of the manual transmissions, many data have presented in various literature, but the data which make it possible to compare the life-times of gears directly under the state of transmission units are comparatively few.

With such background, this standard aims to make the comparison or examination of these data easier by standardization of test conditions and tabulating forms of test results, and aims to contribute to raise the reliability of manual transmissions and effective evaluation of their durability.

3. Definitions**Constant Input Torque Durability Test on Each Shift Position**

- (1) There are two kinds of durability tests for manual transmission gears as follows:

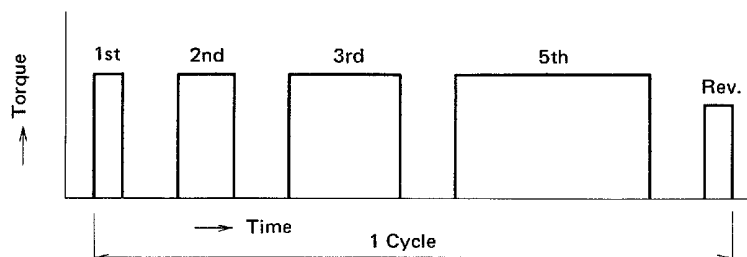
(a) Constant input torque durability test on each shift position

This test is for the life-time of a pair of gears at a shift position selected from the all speed gears, and the gears are tested until they are damaged.

(b) Programmed durability test on all shift positions

This test is for general evaluation of pairs of gears on all shift positions. Total number of revolutions or test hours for each shift position of 1st ~ 5th (in case of the five speed transmission) ~ Rev. shall be decided in advance, and the test shall be executed cyclically. An example of test program is shown in **Explanatory Fig.**

Explanatory Fig. an Example for Five Speed Transmission



Said cycle shall be repeated until the gears are damaged. When a specific pair of gears is damaged, the test shall be continued in conformity with the program excluded the pair until other pair of gears is damaged. When the test is conducted, the frequency of use, total number of revolutions or hours, of each shift position shall be decided in relation of the kind of vehicle (passenger car or truck), purpose of use (for private or business), country where the vehicle is used (destination of export), etc. to the life-time of the vehicle.

- (2) In this standard, after the discussion in the subcommittee, constant input torque durability test on each shift position has been adopted by following reasons:
 - (a) Basic evaluation of durability of gears shall be made by the constant input torque durability test on each shift position, and the programmed durability test is only its programmed one for all shift positions.
 - (b) The programmed durability test on all shift positions aims to evaluate the durability of not only gears but also whole transmission, and its test conditions differ from the philosophy and purpose of vehicle use in each company, so that the subcommittee has reached a conclusion that the unification as a standard is difficult at this moment in time.

Gear Life

We can clearly regard the cracked or broken gear to be its life-time. The subcommittee has discussed the degree of gear surface damaged as the life-time, and has resolved that the gear life shall not be defined quantitatively, but be given an expression as the occurrence of pitting or scoring, as shown in the Text, because exact quantification of the damage conditions and clear understanding of the occurrence time of the gear surface damage are difficult at the moment.

4. Test Conditions

Only fewest necessary items are specified, and the details are to be decided in accordance with test purposes.

(1) Input torque

The maximum value of the engine torque shall be net indicated value. In case of the test aimed to make T-N (S-N) diagram, torque load setting shall be in the range of invariable trouble mode; therefore, the values in the range of 80 ~ 150% of the input torque are adopted, considered the state of each company. It is desirable that the tests will be done in the range of said values and under the conditions of three levels; the maximum engine torque level, and the levels above and below it. As for the transmissions for heavy duty trucks, however, the philosophy of their design and way of being loaded by torque sometimes differ from the cases of other vehicles (passenger cars, small and middle sized trucks). For these transmissions, tests may be executed under the conditions over said range.

There are the opinions that for the reverse position, in real vehicle running, loading torques are generally less than for the forward positions; and in case of 100% test torque setting, troublesome phenomena may happen for some transmissions relating to the other items than durability, and then accurate gear life cannot be grasped.

From these reasons and considering the state of each company, the test torque load is decided to be set within 50 ~ 100% of maximum value of engine torque for the reverse position, and the load is less than the case of forward positions.

(2) Input speed

The input speed for reverse position is decided to be set between 1500 rpm ~ revolving speed at the maximum torque, considering engine driving in relation to the torques to be set.

(4) Lubricant temperature

Although the lubricant temperature is desirable to be decided after the studies on oil temperatures under vehicle running conditions, it is decided to be set within the range of 60 ~ 120°C, because the oil temperatures vary according to the vehicles and their running conditions. However, during the test, a temperature shall be set according to the test transmission, considering the state of use of the vehicle which carries the transmission, and the value shall be controlled with the precision of $\pm 10^{\circ}\text{C}$ for that value. There is an opinion that the controlling temperature range $\pm 10^{\circ}\text{C}$ is too large and $\pm 5^{\circ}\text{C}$ is desirable because high oil temperature will affect the gear life, but $\pm 10^{\circ}\text{C}$ is adopted, considering the problems of capacity of test facilities, etc.

(6) Break-in

Break-in has been left to individual necessity as shown in the **Text**, because of the opinion that it has few influence on the gear life, but it is necessary in the meanings of the irregularity check of the test device and transmission unit to be tested and break-in for the parts other than the gears.

5. Test Devices**(1) Driving and loading devices**

It is desirable that a clutch is set between the driving device and the test transmission, and the clutch is disengaged at the same time when the driving device is stopped by abnormality warnings from the torque, revolution, oil temperature, vibration, etc.; then a precise investigation on the state of tooth breakage will be possible by immediate stoppage of the revolution of test transmission.

(5) Automatic stopping device

An automatic stopping device is indispensable for accurate grasp of the gear life; because continuous driving is main to evaluate the gears. When large vibration is indicated by the vibration meter attached to the transmission, it is desirable that the test is stopped for a while and the test transmission is disassembled and examined for check on the state of damage on the gear surface.

6. Measurement Item**(1) Input torque**

In case of engine driving, direct measurement of input torque is difficult, so that the input torque is set to be computed from the value of measured output torque.

(4) Total number of revolutions or test hours

Although the measuring positions are different by the test devices and test transmissions, the total number of revolutions may be computed from the revolutions measured on input or output shaft.

And when the test hours measured, they shall be converted to the total number of revolutions of the test gears.

7. Test Method**7.1 Study Items before Test**

The tooth contact, fillet curve, material and heat treatment are clearly written in the **Text** as the study items before test, because of their large influence on the gear life.

And, if further precise study is necessary on the tooth contact, the torque and revolution shall be given in the state of transmission unit to examine the tooth contact, considering the play of bearings, etc. and deflection of shafts and the case.

Further, the fillet curve is desirable to be studied also on the difference of levels by shaving.

7.2 Test Piece

There are some opinions that the evaluation with the worst parts is necessary for grasp of the variance of life-times, but the subcommittee has concluded that production of the worst gear in all items and exact definition of "the worst" for the life-time of a gear are difficult at present, so that the random sampling is adopted in the **Text**.

7.3 Test Procedure

- (3)** Especially in case of long time continuous driving, fretting is apt to be generated at the part without relative rotation between gear and shaft, etc., and the fretting affects the gear life; therefore, the relative position is necessary to be changed regularly. Limit of allowable continuous driving may be decided around five hours according to convenience of the test.

7.4 Study Items after Test

- (2) As for the examination on damage of the tooth surface, state of damage shall be exactly recorded by photography or sketch.

Further, abnormal portions which are not indicated in the items in the **Text** and seem to affect the life-time of the test gears shall be examined and recorded.

In the event of any doubt, the original standards in Japanese should be referred.

 : SECOND PHASED STANDARD

(The standard where customary units and converted values are given in brackets after specified values of SI units.)

Established by the Standard Council of JSAE

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Investigating Committee: Standard Committee under the Standard Council

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8. Calculation of Test Result

8.1 Symbol and Unit of Measured Value

Symbols and units to be used in calculations of test results shall be as follows:

- | | | |
|---------------------|-------|-----------------|
| (1) Input torque | T_i | (N·m) { kgf·m } |
| (2) Output torque | T_o | (N·m) { kgf·m } |
| (3) Input speed | N_i | (rpm) |
| (4) Output speed | N_o | (rpm) |
| (5) Oil temperature | T | (°C) |
| (6) Oil quantity | L | (l) |

8.2 Calculating Formula

Calculating formula shall be as follows:

(1) Input torque

$$T_i = \frac{T_o}{i_t \cdot \eta}$$

In case of a transaxle with built-in final reduction gears

$$T_i = \frac{T_o}{i_t \cdot i_f \cdot \eta}$$

where, η : Torque transmission efficiency

i_t : Gear ratio

i_f : Final gear ratio

(2) Revolving speed of input shaft

$$N_i = N_o \cdot i_t$$

In case of a transaxle with built-in final reduction gears

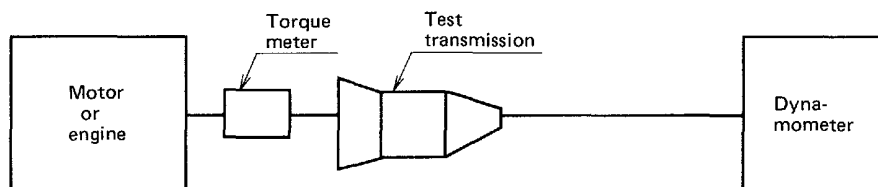
$$N'_i = N_o \cdot i_t \cdot i_f$$

9. Tabulation of Test Result

Test results shall be tabulated on the total number of revolution or hour of test, and state of breakage of the gears.

Further, examples of the tabulating form of the test results are shown in **Attached Table 1 ~ 4**.

Attached Fig. 1 FR-type Test Device (Example 1)



Attached Fig. 2 FR-type Test Device (Example 2)

