



SURFACE VEHICLE RECOMMENDED PRACTICE

J3011™

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Superseding J3011 APR2021

Measurement and Characterization of Electronically Controlled Driveline Clutch Systems

RATIONALE

To recommend test configuration parameters, procedures, and analysis techniques of electronically controlled active clutch system for measurement of specific performance characteristics. This revision has been made to clarify test method and update the process to reflect modern testing techniques.

SAE J3011 has been reaffirmed to comply with the SAE Five-Year Review policy.

FOREWORD

The intended scope of this SAE Recommended Practice is to encompass all types of electronically controlled driveline coupling devices including active on-demand (AOD) and cross-axle devices. This practice is not intended for launch devices and transmission related systems.

1. SCOPE

This SAE Recommended Practice covers the most common applications of electronically controlled on-demand clutch systems used in passenger (car and light truck) vehicle applications. This practice is applicable for torque modulation devices used in transfer cases, electronic limited slip differential (eLSD) cross-axle devices, rear drive module (RDM) integrated torque transfer devices with or without disconnect capability, and other related torque transfer devices.

1.1 Purpose

The purpose of this SAE Recommended Practice is to provide a means to define, measure, and quantify the operating characteristics of electronically controlled on-demand all-wheel drive (AWD) coupling systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1952 All-Wheel Drive Systems Classification

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3. DEFINITION

Electronically controlled coupling systems consist of a mechanical coupling device controlled by an electronic control unit (ECU). The ECU contains control algorithms and the communication interface to allow access to key vehicle information, as well as for communication with such systems as anti-lock braking systems (ABS), electronic stability control (ESC) systems, etc. (Please refer to SAE J1952 for further definitions.) As a result of this level of vehicle system integration, the performance of the coupling may be assessed either with or without an ECU.

In order to reduce the fuel consumption of passenger vehicles, AOD coupling systems may incorporate a driveline disconnect or two-wheel drive (2WD) mode that substantially reduces drag torque (typically at the expense of response time). The unique usage of these devices makes it important to distinguish between standard couplings and couplings with disconnect capability. Except where noted, all test procedures outlined in this document should be made and measured while in the AWD mode. Notable exceptions to this include the measurement of drag torque losses in Section 10.

The rated torque capacity of the device shall be defined by the device supplier.

4. SYSTEM CONTROL METHODOLOGY

A vehicle representative ECU or other electronic control method may be used to control the coupling. In any case, coupling performance will be assessed based on when a commanded input is first received by the coupling or ECU, as shown in Figure 1. The particular system control methodology used must be defined and documented as part of the data reporting process.

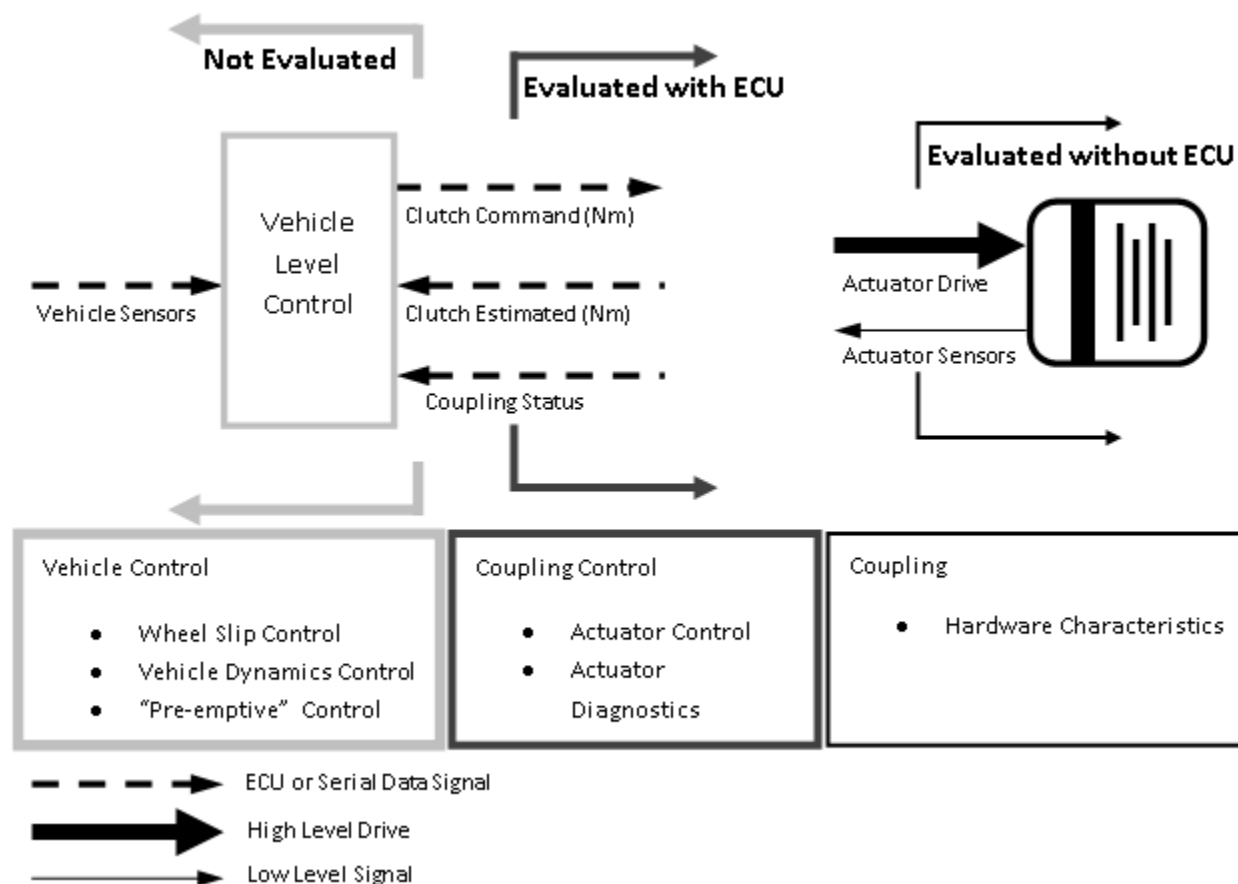


Figure 1 - Coupling test control methodology

5. TEST RIG SET-UP

Coupling output is to be grounded (stationary) with an inline torque transducer recommended on the grounded side, as shown in Figure 2 (optionally, the torque transducer may be located on the rotating input side or in a reactionary torque arm, so long as all accuracy and system requirements are achieved). Though not the intention of this document, the procedure could be adapted to account for an absolute speed of the system and a delta speed achieved through a variance between the input and output speed.

Two fixturing options are acceptable:

1. Grounding the clutch housing.
2. Grounding the main shaft.

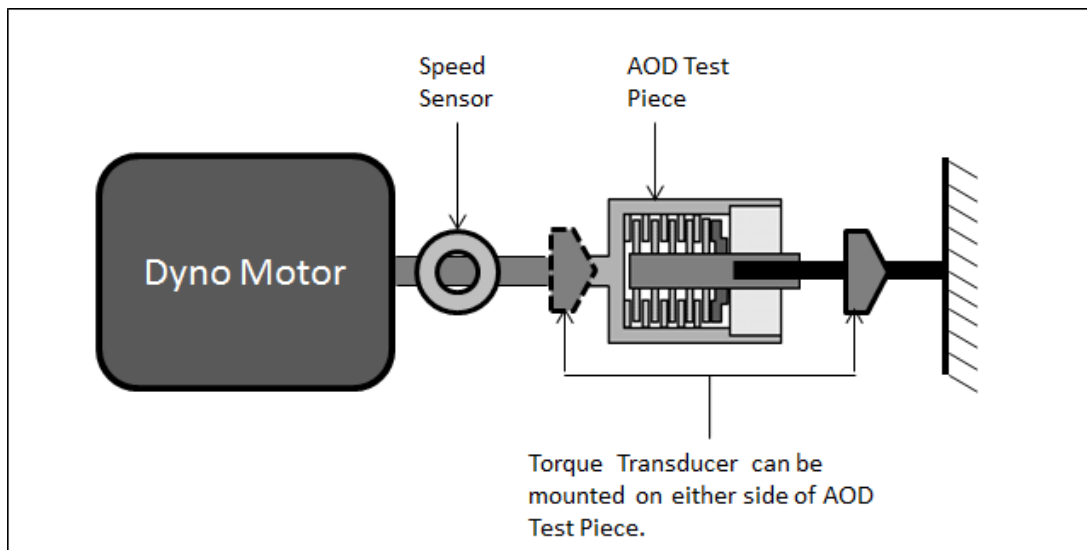


Figure 2 - Test rig set up

Basic test rig capabilities should include the following:

- Maximum torque capacity shall be a minimum of 10% above the test requirements.
- Torque transducer resolution shall be $\pm 0.50\%$ of full scale based on 150% of the rated clutch torque capacity for all testing, except Section 10. For drag torque in connected mode, measurement resolution shall be ± 0.75 Nm; for disconnect capable couplings, the resolution shall be ± 0.05 Nm.
- Maximum speed capacity should be a minimum of 10% above test requirements.
- The measured speed sensor shall be mounted to the unit under test.
- Dyno output stiffness shall be enough to effectively measure the unit under load. Recommendation is that the dyno and test shaft stiffness shall be at least ten times the system stiffness.
- Speed shall be controlled to within ± 0.5 rpm or 0.50% of max rpm, whichever is greater.

- Minimum and maximum speed requirements:
 - Connected mode: 2 to 200 rpm.
 - Disconnected mode: up to 3000 rpm.
 - If ramp up rates indicated in Section 10 cannot be achieved, please indicate actual rates used for the test minimum and maximum temperature, respectively: -40 to 150 °C.
- Clutch initial condition temperature shall be measured at either (as shown in Figure 3):
 - Clutch reaction plate by grounding the clutch housing and spinning the main shaft.
 - Core of the main shaft by grounding it and spinning the outer housing.

If the temperature sensor is located in the main shaft, it is unacceptable to run more than one cycle before thermally reconditioning (cold soaking) the test unit since the difference in temperature between the clutch housing and the main shaft may be significant, as shown in Figure 4. This graph demonstrates the thermal deviations between the clutch plates, sump, inner shaft, and skin of the coupling, thus requiring special cooling practices in between sections and cycles. It also shows why clutch housing surface temperature cannot be used for control temperature.

Coupling testing shall be performed in phases.

1. As shipped: New coupling intended for installation in a production vehicle.
2. As broken in: μ -V is stabilized such that with additional energy in, the torque transfer characteristics (μ -V) does not change. "Broken in" is approximately 10% of the target life energy, in Joules, based upon the application usage.
3. Target life: Coupling which has completed the life cycle durability testing.

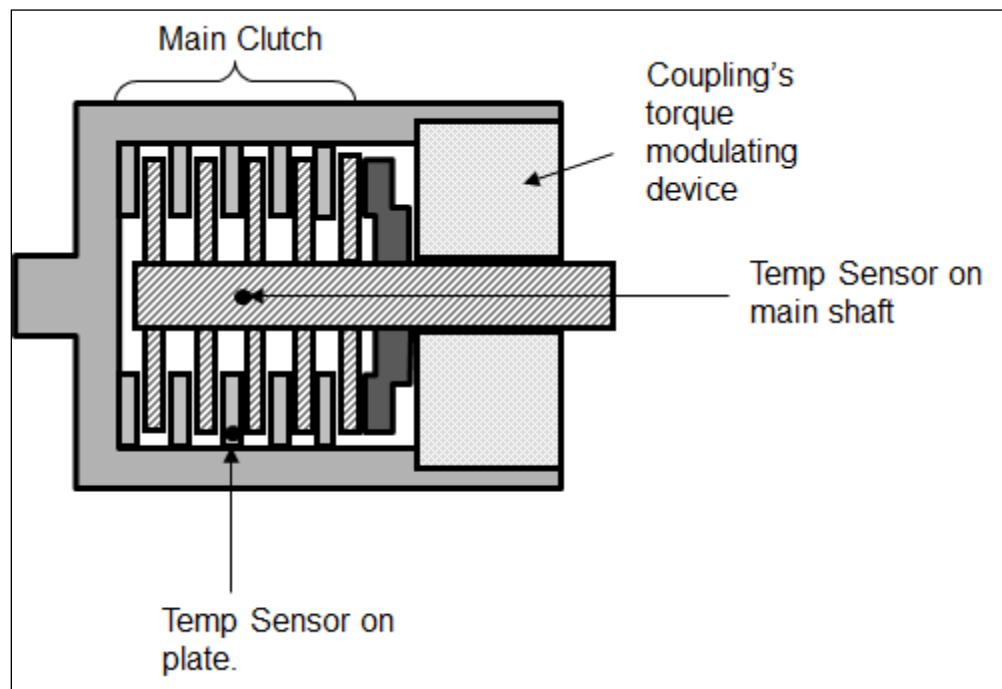


Figure 3 - Temperature sensor location options

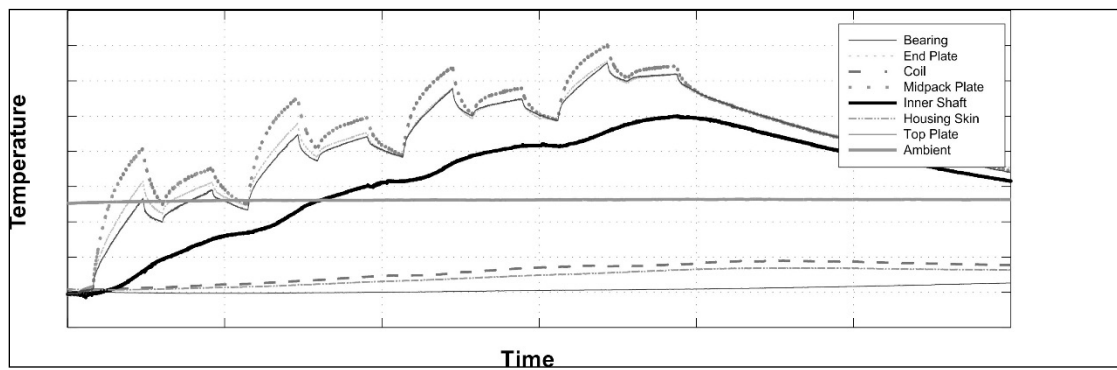


Figure 4

6. TESTING AND ANALYSIS

For the purpose of characterizing the system performance, the recommended tests for the full coupling assembly will consist of:

- Step input: Section 8.
- Dynamic response profile: Section 9.
- Drag torque behavior: Section 10.
- μ -V characteristics: Section 11.

7. GENERAL TEST REQUIREMENTS

All single point data collection shall be run a minimum of three times for all test sections. The data shall be tabulated for the three sets and averaged as a final graph.

Due diligence shall be taken to stabilize the coupling temperature between runs for at least 30 minutes or as required to ensure the desired core temperature has been reached. Stabilized temperature is defined by the temperature fluctuating less than two degrees once it is within the required temperature range.

8. STEP INPUT TEST

The purpose of this test is to characterize the torque engagement and release response of the system at various delta speeds and start temperatures whilst at various requested torque levels (see Figure 5).

8.1 Minimum Level of Parameters to be Monitored and Recorded

- Coupling reacted torque.
- Coupling temperature (measured according to the options outlined above).
- Delta speed.
- Coupling input current, voltage, and pressure (where applicable).

8.2 Coupling Torque Measurement Procedure

- Document 100% and 50% of the clutch's design rated torque capacity.
- Supply a report on two couplings:
 - As shipped: New coupling intended for installation in a production vehicle.
 - Target life: Coupling which has completed the life cycle durability testing (such as from design validation testing).
Note: The total energy profile showing, load versus speed versus time, and Joules exerted during the test shall be provided with the test report.
- The results should be tabulated in the matrix shown in Table 1.
- Torque evaluation with and without ECU (if applicable).
 - With ECU: Response time to be measured from the input of the clutch command torque request (Nm) into the actuator controller (see Figure 1) to the measured reacted torque of the coupling. ECU processing time is included in the total response time.
 - Without ECU: Response time to be measured from the initial application of actuator power (see Figure 1) to the final reacted torque of the coupling.
 - If disconnecting clutch system is to be used, the actuator must be past the synchronization point and be ready for controlled torque command (at "kiss point," "ready state," or "prep position") to measure response.
- Test conditions: Step duration with torque applied should be long enough to achieve settled torque with duration noted in reporting.
 - Document 100% and 50% of the couplings rating torque capacity.
 - Controlled power source capability for the ECU (12 V nominal $\pm$ 3 V).
 - Sampling rate: Minimum 1000 Hz (to capture 100 ms response time).
 - Coupling start temps: -20 °C, 0 °C, +20 °C, +50 °C, +100 °C ($\pm$ 2 °C).
 - Delta rpm values:
 - 5 rpm
 - 10 rpm - Steady state
 - 20 rpm - Dynamic event
 - 50 rpm - Homogeneous launch
 - 100 rpm - Step μ Curb
 - 150 rpm - Step μ Curb + 50% (GVWR - Curb)
 - 200 rpm - Step μ GVWR