



SURFACE VEHICLE RECOMMENDED PRACTICE

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CVJ Efficiency Test Recommended Practice

RATIONALE

Vehicle manufacturers are focusing on improving efficiency of components to reduce energy consumption. Constant velocity joints (CVJs) are used in many vehicle applications to transmit power from the power source to the wheels. Like other driveline components, CVJs have losses due to operating efficiency as well as parasitic loss (grease churning, seal deformation, etc.). This recommended practice proposes a procedure to measure and report CVJ efficiency.

1. SCOPE

This recommended practice describes the procedure to measure and report the operating efficiency for all types of constant velocity joints (including fixed and plunging/end motion type joints) used in cars, SUVs, and trucks. This includes halfshaft as well as propshaft applications. This does not apply to non-CV joints. Rotational inertia is not considered within the scope of this recommended practice.

This recommended practice provides a common method to quantify and report the operating efficiency characteristics of a CVJ. This practice does not apply to parasitic losses (spin loss, churning loss, or zero torque loss) as experienced on deactivated AWD/4WD systems. The losses in this condition are significantly less and require higher accuracy than what is required in this recommended practice.

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: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

AE-07 Universal Joint and Driveshaft Design Manual

SAE J670 Vehicle Dynamics Terminology

SAE J901 Universal Joint and Driveshafts - Nomenclature - Terminology - Application

Mondragon-Parra, E. and Ambrose, G., "Influence of Grease in Mechanical Efficiency of Constant Velocity Joints," SAE Technical Paper 2016-01-1132, 2016, <https://doi.org/10.4271/2016-01-1132>.

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2.1.2 Other Publications

UN Regulation No. 154 – Worldwide Harmonized Light Vehicles Test Procedure (WLTP)

U.S. CFR Title 40, Chapter I, Subchapter C, Part 86 – Control of Emissions from New and In-Use Highway Vehicles and Engines

3. ABBREVIATIONS

CVJ and CV-Joint	Constant Velocity Joint
OEM	Original Equipment Manufacturer
AWD	All-Wheel Drive
4WD	Four-Wheel Drive
SUV	Sport Utility Vehicle

4. BACKGROUND

The primary objective of this recommended practice is to provide insight to the efficiency of CVJs used in vehicle drivetrains under required regulatory vehicle efficiency test cycles (i.e., UN Regulation No. 154 [WLTP], U.S. CFR Title 40, Ch I, Subchapter C, Part 86 – Control of Emissions for New and In-Use Highway Vehicles and Engines, etc.). These regulatory vehicle testing methods measure the efficiency of vehicles in various “city” and “highway” conditions and environmental conditions (“low,” “room,” and “high” temperature). The conditions specified in this recommended practice provide insight into the efficiency of the CVJs used in vehicles being tested in these regulated test methods.

As of the writing of this recommended practice, only “room” temperature tests are included in this document. This is due to the difficulty in maintaining the CVJ test sample at “low” and “high” temperatures while conducting the efficiency test.

The testing conditions specified in this recommended practice do not directly simulate the regulated vehicle test conditions. The expert committee participating in creating this standard believes that the conditions specified in this document will provide good insight to the relative efficiency performance of CVJs. The intention of this standard is to evaluate the efficiency of CVJs under “normal” condition and not “extreme/transient” conditions. To meet this goal, very high and low torques and very high angles are not considered. These conditions typically represent a very small portion of the vehicle life and thus are not as important as evaluating CVJ efficiency at “normal” conditions.

In general, CVJs do not exhibit a great change in efficiency when subjected to different speeds and torques. Temperature can have a significant influence on efficiency at low temperatures. Once the grease warms up to normal operating temperatures (20 to 60 °C), temperature has little impact on efficiency. Typically, CVJ angle is the single largest influence on efficiency. Higher angles will result in less efficiency (greater losses).

Several methods have been identified to evaluate CVJ efficiency:

1. Heat generation: This involves measuring the heat generated by the CVJ. Heat generated is due to losses within the joint. This method is very difficult to replicate results on different types of joints and at different locations. This method is also subjective to the joint outer race design (wall thickness, mass, etc.) and where the temperature is measured.
2. Measurement of secondary couple: This method involves measurement of any forces that do not directly contribute to the transfer of torque. The measurement of these forces in a dynamic environment is complicated and expensive.
3. Torque in versus torque out: This method involves measuring the input torque to the CVJ and measuring the output torque of the CVJ. The difference between these two torque measurements is the loss due to CVJ efficiency.

The best approach accepted by industry at the time of writing of this recommended practice is the torque in versus torque out method. The torque in versus torque out measurement method is the subject of this recommended practice.

A review of industry testing capability generally showed two methods of testing using the torque in versus torque out method: discrete angle or dynamic angle. The discrete angle method involves setting the test stand at a discrete angle and collecting data. The test stand is then stopped and a new angle is set. The dynamic angle method allows for collection of data while the angle is varied under dynamic conditions. It is recommended to limit the rate of angle change to a maximum of 0.3 deg/s. This dynamic angle method is advantageous as it collects data at all angles, thus giving better resolution. The disadvantage is that the required test equipment and control systems are more complex and expensive.

In the development of this recommended practice, there were a lot of discussions on setting the torque levels. It was decided that typical torque levels for daily driving should be targeted. Extreme torque events should not be considered as they are typically short lived. Several methods of setting the torque levels were investigated. The expert team decided that simply choosing three torque levels is the best approach. The torque levels of 200 Nm, 400 Nm, and 600 Nm were chosen. Higher torque levels can influence efficiency; however, as long as the lubrication film between CVJ components does not break down, torque is NOT considered a primary driver for efficiency.

5. TEST EQUIPMENT

The equipment used to measure CVJ efficiency shall consist of a test stand to fixture the test sample, apply torque angle and speed to the sample, and record data.

5.1 Test Stand

The basic configuration of the recommended test stand is a motor/absorber arrangement with the test sample between the motor and absorber (see Figure 1). The test stand can accept a single CVJ or a halfshaft (or driveshaft) assembly. If the halfshaft (or driveshaft) assembly is used and a single joint is being tested, the joint that is not being tested must remain at 0-degree angle for the duration of the test. The test samples must be rigidly fixed to the test rig. Splined interfaces can be used but no free play (axial or radial) is allowed in the interface.

The test stand should have the following capabilities:

1. Must fixture the CVJ test sample such that the input and output torque cells are coupled directly to the CVJ (no bearings between the test sample and the torque cells). The test stand must be capable to fixture the test sample to simulate the power flow in the vehicle (drive condition). That is, for an inboard joint, the flow is from the outer race to the inner race. For an outboard joint, the power flow is from the inner race to the outer race. The test sample center must be directly aligned with the center of rotation of the test rig. This will avoid any axial loading of the joint when the joint is articulated to angle.
2. Capability to articulate the CVJ to the maximum test angle plus 1 degree. The capability to set the angle under static (between test steps without torque or speed) or dynamic (as the test is being run under torque and speed) should be considered.
3. Allow for axial movement to accommodate different test sample types and sizes.
4. Control torque to within ± 2 Nm
5. Control speed to within ± 5 rpm
6. Control angle to within: ± 0.25 degrees
7. Measure temperature of the CVJ outer to within ± 5 °C. Use of infrared (IR) pyrometers is suggested. The IR pyrometer should be aimed at the outer body of the CVJ (not the boot or shaft). The outer body of the CVJ (not the boot or shaft) should be painted flat black (emissivity = 0.95-0.97) when using IR pyrometers.
8. Apply cooling air (compressed air or fans) to the test sample when required.

9. Measure input and output torque of the test sample.
10. The test stand must be capable of testing to 37.3 kW (50 hp) at minimum.
11. Ambient temperature of the room the test is being conducted in shall be measured at the start of the test and at the completion of the test. It is not necessary (however it is recommended) to collect ambient temperature data.

Current calibration records for the test stand and all measurement equipment should be available upon request.

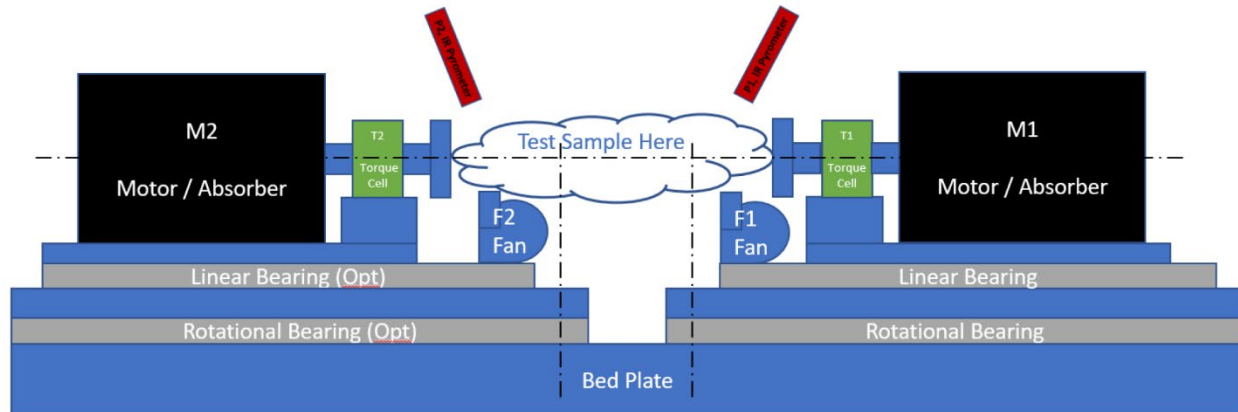


Figure 1 - Typical CVJ efficiency test stand

5.2 Accuracy

Accuracy of the efficiency measurement is highly dependent on the proper selection of the torque cells. The accuracy of torque cells is usually expressed as a percentage of the full-scale torque capacity of the cell. That is, a torque cell can be rated for 5000 Nm full scale and has an accuracy/repeatability rated at 0.1%. The repeatability of this torque cell is $5000 \text{ Nm} \times 0.001 = 5 \text{ Nm}$. It is highly recommended to select the most accurate torque cells that are available for the load range. The correlation testing performed in this standard (see Annex A) used load cells with accuracy as high as $\pm 2.25 \text{ Nm}$. It is recommended to use load cells with an accuracy of less than $\pm 2.25 \text{ Nm}$.

To minimize errors in the testing method the input and output torque cells should be “zeroed” with each other before the start of each section of the test. See the data collection and data reduction section (Section 10) for further explanation on zeroing load cells.

5.3 Data Collection

The test stand must have capability to record the following data (minimum) during the test.

1. Time in seconds, t
2. Torque command signal in Nm, T_c
3. Measured Input torque in Nm, T_i
4. Measured Output torque in Nm, T_o
5. Speed command signal in rpm, V_c
6. Measured speed in rpm, V_m
7. Angle command signal in degrees, A_c
8. Measured Angle in degrees, A_m

9. Ambient temperature in degrees Celsius, AT
10. Test sample temperature in degrees Celsius, ST
11. Cooling fan operation (on/off)

6. TEST SAMPLES

The driveshaft (or test joint) should have a permanent identification number marked on its exterior before testing. Such permanent identification shall not interfere with the ability of the pyrometers to collect temperature during the test. The condition of the test part before testing should be known (i.e., has the part been tested previously, has the joint been run-in, is the joint new, etc.). The identification number and joint condition should be recorded and attached/linked to the results of the test with the date of testing and description of the test part.

For the examination of new parts, a batch of at least four identical joints should be tested. When possible, the interior of new parts should be metrologically characterized before testing. Clearances, track surface form, and surface finish can have a large influence on efficiency test results. For the examination of previously operated parts, at least two joints must be measured (right and left half shaft from the vehicle). There may be instances (i.e., single field return) that only one part is available. Any parts tested that have already been run in a vehicle, care should be taken to run the parts in a “forward drive” torque and speed configuration.

All NEW test samples shall have a break-in performed before being tested for efficiency.

The half shaft is mounted in the test stand in such a way that the joint to be measured can be articulated about its centerline at defined angles during the test. It must be ensured that the other joint is not articulated (remains at 0-degree angle). For the plunging/stroking joints, the joint must be mounted at the center of the joint pivot or at the design stroke position in the vehicle.

A sample size of six pieces to be tested for PPAP type submissions unless agreed otherwise between the supplier and customer.

7. PRE-TEST CONDITIONING OF TEST SAMPLES

7.1 Grease Distribution Schedule

Prior to initiating a break-in cycle, a grease distribution step shall be performed as follows below. The objective is to distribute and warm up the grease and the joint before the efficiency test.

Torque: 20 Nm

Speed: 1200 rpm

Angle: 16 degrees

Stroke: For stroking type joints, mid-stroke or a position representative of the intended application should be used.

Temperature: Room temperature (~18 to 25 °C)

Time: 3 minutes

7.2 Break-In Schedule

Break-in or running-in are defined in this document as the time or cycles it would take a new CVJ to reach relatively constant friction properties during operation. This schedule may be omitted for joints that have been previously tested following the procedure described in subsequent sections. For new CVJs or CVJs not tested before per this procedure, the break-in portion of the test shall be performed as follows:

Torque: Maximum forward driving test torque used for mechanical efficiency characterization

600 Nm by default

If the CVJ is too small and temperature cannot be stabilized to 80 °C max (e.g., overheating even when applying cooling air), the forward driving torque shall be reduced to 400 Nm. If temperature cannot be stabilized at 400 Nm, reduce to 200 Nm. If temperature cannot be stabilized at 200 Nm, abort the test.

The applied torque must follow the pattern shown in Figure 2, which consists of applying the forward driving torque for 30 seconds, then “releasing” it by shifting to -80 Nm for 10 seconds, to allow re-lubrication, then re-applying the forward driving torque. The time to ramp-down must be 5 seconds minimum. The time to ramp-up must be 5 seconds minimum.

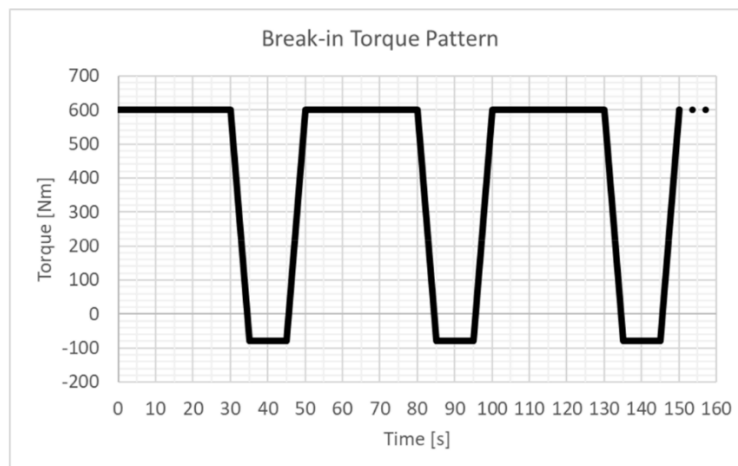


Figure 2 - Break-in torque pattern, forward driving direction, three cycles shown
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Speed: 200 rpm (forward / drive direction)

Angle: Maximum test angle used for mechanical efficiency characterization, plus 1 degree

Stroke: For stroking type joints, mid-stroke or a position representative of the intended application should be used.

Temperature*: Initiate at room temperature (~18 to 25 °C). Temperature will increase during the test. Temperature shall be maintained not to exceed 80 °C throughout the break-in testing period. Cooling air flow shall initiate when the break-in starts and may be increased as needed to not exceed the temperature limit. CVJ outer body temperature (by IR pyrometer) shall be recorded during the break-in time.

Time: Total break-in time is 60 torque cycles x 50 seconds/cycle = 50 minutes.

Actual time under break-in torque is 30 minutes.

Time may be longer if the time required by the test-bench to ramp-up or ramp-down torque, per the pattern in Figure 2, is longer than 5 seconds.

Repeat the break-in schedule in the opposite direction (backward). CVJs can be used in either RH or LH side of the vehicle. Thus, both flanks of the tracks need to be characterized for efficiency.