



SURFACE VEHICLE RECOMMENDED PRACTICE

J2817™

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(R) Definition and Measurement of Torque Biasing Differentials

RATIONALE

This document is being updated to include all types of differentials and to include lessons learned from recent test developments completed in late 2014.

SAE J2817 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This SAE Recommended Practice covers passive torque biasing axle and center differentials used in passenger car and light truck applications. Differentials are of the bevel gear, helical gear, and planetary types, although other configurations are possible.

1.1 Purpose

To provide a common means to define, measure, and quantify the operating characteristics of torque biasing for all differentials.

2. REFERENCES

There are no referenced publications specified herein.

3. DEFINITIONS

3.1 TORQUE BIAS RATIO

Given a differential where one full turn of a first output shaft results in one full turn in the opposite direction of a second output shaft (1:-1 ratio across outputs):

Torque bias ratio is defined as the ratio of the output torques when differentiating under load.

$$\text{Torque Bias Ratio (TBR)} = \text{Torque High/Torque Low} \quad (\text{Eq. 1})$$

(Expressed as N:1)

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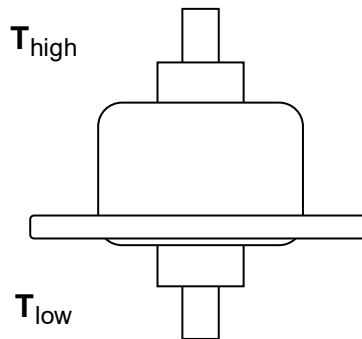


Figure 1 - Differential outputs showing high and low torque

3.2 LOCKING EFFECT

Locking effect (LE) is an alternate means of expressing torque imbalance supported by the differential. It is the relationship between torque difference and input (total) torque. It is useful when defining the performance of a torque split differential (ratio across outputs other than 1:-1). The relationship between locking effect and bias ratio is shown in Figure 2.

$$\% \text{ Locking Effect} = 100 \times \Delta T / T_{\text{total}} \quad (\text{Eq. 2})$$

$$\% \text{ LE} = 100 \times (\text{Torque High} - \text{Torque Low}) / (\text{Torque High} + \text{Torque Low})$$

$$\% \text{ LE} = 100 \times (\text{TBR} - 1) / (\text{TBR} + 1)$$

$$\text{TBR} = (1 + \% \text{LE}) / (1 - \% \text{LE}) \quad (\text{Eq. 3})$$

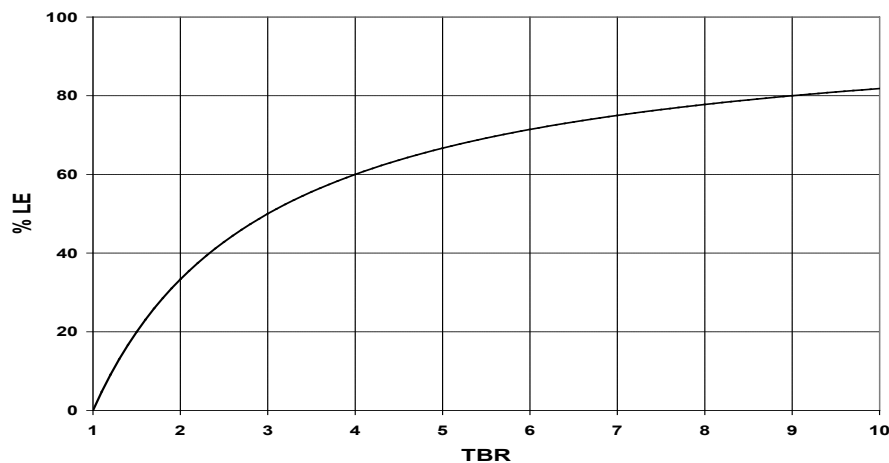


Figure 2 - Plot of locking effect versus torque bias ratio

3.3 TORQUE SPLITTER

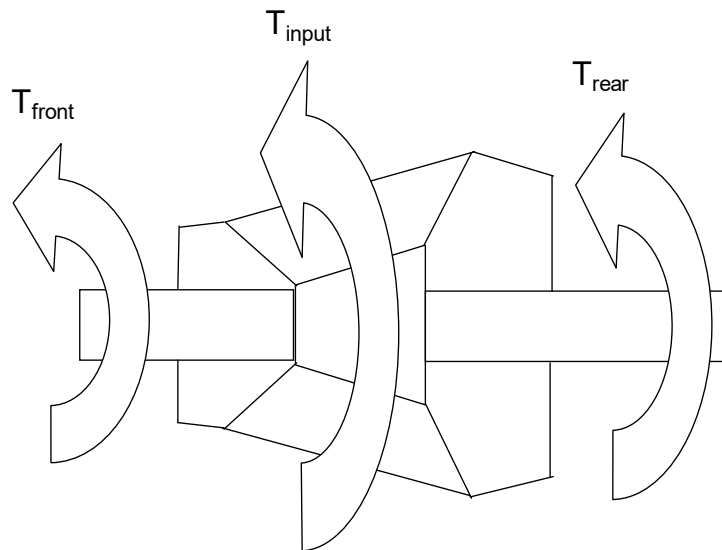


Figure 3 - Diagram of torque splitter

$$T_{Input} = T_{Front} + T_{Rear} \quad (\text{Eq. 4})$$

Torque split ratio (TSR) is the gear ratio of the two output shafts.

where:

N_f = number of teeth on front output gear

N_r = number of teeth on rear output gear

$$TSR = N_f/N_r \quad (\text{Eq. 5})$$

Example:

12 teeth on front output gear.

18 teeth on rear output gear.

$$TSR = N_f/N_r = 12/18 = 0.667$$

Torque distribution (front:rear) assuming a “frictionless” open differential is always fixed at a certain ratio determined as follows:

$$\% \text{ Torque to front output: } T_f = 100 \times N_f/(N_f + N_r)$$

$$\% \text{ Torque to rear output: } T_r = 100 \times N_r/(N_f + N_r)$$

Example #1:

12 teeth on front output gear.

18 teeth on rear output gear.

$$\%T_f = 100 \times 12 / (12 + 18) = 40\%$$

$$\%T_r = 100 \times 18 / (12 + 18) = 60\%$$

This is normally expressed as a 40/60 (front/rear) nominal torque split.

When biasing capability is added, torque is distributed over a range around the nominal split ratio. Torque distribution ratio (TDR) is the ratio of the output torques when biasing. It is expressed as the ratio of the high torque output to the low torque output and may also be shown as percent torque to front and rear. It is a combined effect of TSR and TBR.

When biasing to the front, $TDR = TBR \times TSR$

When biasing to the rear, $TDR = TBR / TSR$

Example #2: 12/18 tooth combination gearing, 30% locking effect:

$$TSR = N_f / N_r = 12 / 18 = 0.667$$

$$LE = 0.3$$

$$TBR = (1 + 0.3) / (1 - 0.3) = 1.86$$

When biasing to front, $TDR = 1.86 \times 0.667 = 1.24$ (1.24:1 ratio front to rear).

$$\%T_f = 100 \times TDR / (TDR + 1)$$

$$\%T_f = 100 \times 1.24 / (1.24 + 1) = 55.4\% \text{ (55\% front, 45\% rear)}$$

When biasing to rear, $TDR = 1.86 / 0.667 = 2.78$ (2.78:1 ratio rear to front).

$$\%T_r = 100 \times TDR / (TDR + 1)$$

$$\%T_r = 100 \times 2.78 / (2.78 + 1) = 73.5\% \text{ (74\% rear, 26\% front)}$$

In Example #2, the nominal 40:60 torque split will send up to 55% of the torque to the front or 74% to the rear due to the biasing capability. Within the defined limits of torque distribution, differential gearing remains static relative to the differential housing in a vehicle application. When torque distribution reaches either the bias to front or bias to rear limit, differentiation will occur with torque distributed at the limit. Torque distribution is shown graphically in Figure 4.

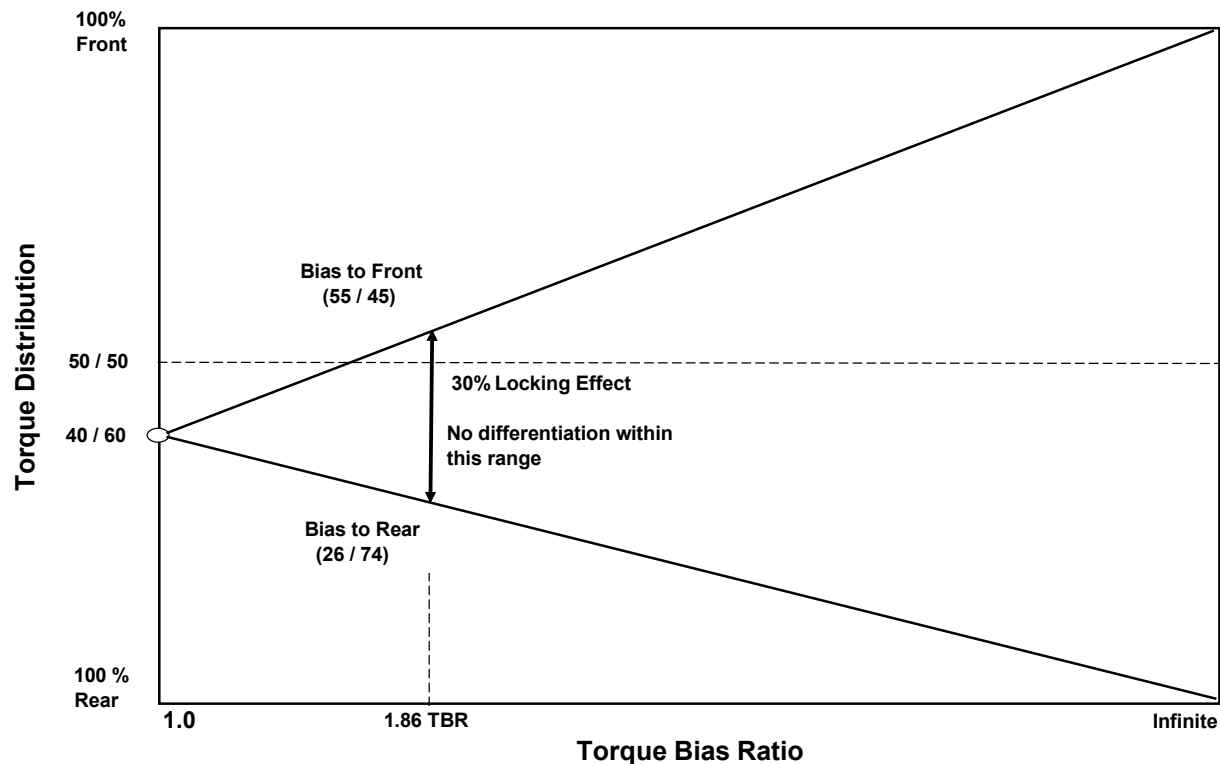


Figure 4 - Torque distribution at 30% LE

Example #3: 18/12 tooth combination gearing, 30% locking effect.

$$\text{TSR} = N_f/N_r = 18/12 = 1.50$$

$$\text{LE} = 0.3$$

$$\text{TBR} = (1 + 0.3)/(1 - 0.3) = 1.86$$

When biasing to front, $\text{TDR} = 1.86 \times 1.50 = 2.78$ (2.78:1 ratio front to rear).

$$\%T_f = 100 \times \text{TDR}/(\text{TDR} + 1)$$

$$\%T_f = 100 \times 2.78/(2.78 + 1) = 73.5\% \text{ (74\% front, 26\% rear)}$$

When biasing to rear, $\text{TDR} = 1.86/1.50 = 1.24$ (1.24:1 ratio rear to front).

$$\%T_r = 100 \times \text{TDR}/(\text{TDR} + 1)$$

$$\%T_r = 100 \times 1.24/(1.24 + 1) = 55.4\% \text{ (55\% rear, 45\% front)}.$$

3.4 Preload

Torque biasing properties of bevel, helical, and planetary gear differentials are commonly achieved by using gear thrust forces to generate friction within the differential, and thereby resistance to differentiation. Spring thrust may also be added to generate additional friction.

Without the addition of spring thrust, there is generally negligible resistance to differentiation when input torque is equal to zero. With the addition of spring thrust, an initial preload is generated which creates resistance to differentiation when input torque is equal to zero.

The effect of preload can be seen in Figure 5 by examining Δ torque versus total torque.