

Technology Breakthrough Achieves Objectives for SAE Preload Targets in Heavy Duty Wheel Ends

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ABSTRACT

Patents granted recently to Mr. Rode have changed the industry capability to adjust and verify wheel-end bearings on trucks. Until now it was believed¹ that there was nothing available to confirm or verify the most desirable settings of preload on these bearings. The new, breakthrough invention is a tool and spindle-locking nut that permit quick and accurate wheel bearing adjustment by utilizing direct reading force measurement. Bearings can be set to either SAE recommended preloads or specific endplay settings. The author has been working on bearing adjustment methods for industrial applications for over forty years, and considers these inventions to be his most important breakthrough for solving this elusive bearing adjustment problem. Consistent wheel bearing preload adjustment was not possible before, even though it was widely known to achieve the best wheel performance as noted in SAE specification J2535 and re-affirmed in 2006 by the SAE Truck and Bus Wheel Subcommittee. Initial commercialization of the new technology with a field ready tool has been accomplished. The associated lock nut is a premium product with a special relief on the back face that permits direct preload force application onto the wheel bearings. This nut is in current production.

INTRODUCTION

The ideal engineering solution to the problem of adjusting heavy-duty truck wheel end tapered roller bearings has eluded engineers and inventors for decades. The conceptual solution, however, is quite simple. Certainly, an optimal condition would be achieved if one could capture an accurately loaded bearing set in its exact preloaded position. The absence of a direct and verifiable method to construct wheel ends with preload has been documented by at least one of the leading bearing manufacturers. The subject technology has solved this elusive problem.

The author's perspective was honed by years of experience studying many customer challenges to find better solutions for efficient and accurate production assembly of bearings in all kinds of industrial mechanical assemblies. His work has resulted in patented methods and arrangements for bearing assemblies in a diverse array of products manufactured by customers worldwide. Tools and machines for adjusting bearings are also described in many of the author's previous patents. It is this cumulative body of knowledge that led to the two inventions that became the problem solution.

Truck wheel end roller bearing adjustment procedures that have been formally recommended by the industry's technical organizations as well as various component manufacturers are all based on similar approaches. In every case, a locking nut is engaged by a torque wrench

fitted with an appropriately sized socket. Torque applied to a nut translates to force applied to the bearings and a procedure is followed to seat the rollers. Achievement of a target setting requires that this process be repeated multiple times. In all such cases the accuracy depends on the relationship of applied torque to the expected axial force transmitted through the bearings. That accuracy is always diminished by the usual variations in efficacy of lubrication, surface roughness of axle and nut threads and the accuracy of the device applying the torque. Results typically vary by about five thousandths of an inch when endplay is targeted. Excessive preloads can sometimes result as well.

EARLIER PRODUCT DEVELOPMENT

The author's early work on truck wheel end adjustment involved integration of heavy-duty collapsible spacers between the inner and outer bearings using a portable hydraulic tool to apply and control preload. The author's patented technology that included the installation of collapsible cone spacers was effective in producing quick and accurate settings. It showed good promise with performance on the highway in test vehicles. However, commercial barriers were the net addition of weight and cost which ultimately blocked widespread adoption. It was this work that led the author to consider manufacture of a premium spindle locking nut as a product to complement his company's offerings in adjustable spacers. This in turn set the stage for invention of the new technology.

BREAKTHROUGH DEVELOPMENTS

The author recognized that a hand tightened capture nut effectively secures the correct position of the bearings and captures a small preload, if that preload can be externally created, and not created by the nut. This can be achieved if there is space around the nut to access the outer bearing cone and still not interfere with tightening the nut. When the nut is secured it does not impart any meaningful additional axial force. Securing the nut brings it into position so that the release of a separately imparted axial force is transferred to the secured nut.

The new, patented technology uses a specially designed tool, known as Doctor Preload®, which imparts a known axial preload force directly on the bearings through load arms that engage the outer bearing cone. A nut, that is specially relieved, allows the load arms to engage the bearing while the nut is against the bearing. Thus, the force is applied at the same time as the nut is secured.

This breakthrough approach to wheel-end bearing adjustment provides a simplified, more effective process and achieves consistency and accuracy with significant timesavings for the mechanics.

CURRENT WHEEL END BEARING ADJUSTMENT PROCEDURES

In order to reduce the occurrences of "wheel-off" situations on America's highways, the Technology and Maintenance Council (TMC) issued a Recommended Practice in 1993 entitled "Wheel Bearing Adjustment Procedures". Document RP618, incorporating the best practices of the time, delineates procedures having an objective of establishing endplay on every completed wheel end.² The acceptable range was from .001" to .005" endplay. Although light preload was known to provide better wheel life, a condition of endplay in this range was known to provide adequate bearing life, when correctly applied. Since there was no way of verifying preload force values or zero endplay, the standards settled for a larger than ideal endplay setting. However, accuracy limitations imposed by torque-force variables did not eliminate some out-of-limit endplay results.

In 2001, the Society of Automotive Engineers (SAE) issued a Surface Vehicle Recommended Practice J2535 entitled "Setting Preload in Heavy-Duty Wheel Bearings" through its Truck and Bus Wheel Subcommittee of the Truck and Bus Brake Committee³. Confirmation was made that "*Bearing and seal life can be maximized when the bearings are adjusted to a light, controlled preload setting*". The document also cautioned that the risk of catastrophic failure of the bearings and entire wheel-end was great if preload was excessive. "*A light preload bearing setting should only be attempted if the entire bearing setting process is accurate and repeatable*". The SAE J2535 standard calls for 500 pounds of preload on drive and trailer axle bearings and 250 pounds on steer axle bearings. In spite of this long-standing specification there has not been a way to quickly and accurately achieve preload settings. Commonplace variations in axle and nut threads and the resulting wide variations in actual preloads prevented the acceptance of an accurate preloading practice.

PRELOAD VS ENDPLAY

Figure 1 TYPICAL BEARING LIFE VERSUS WHEEL END SETTING⁴

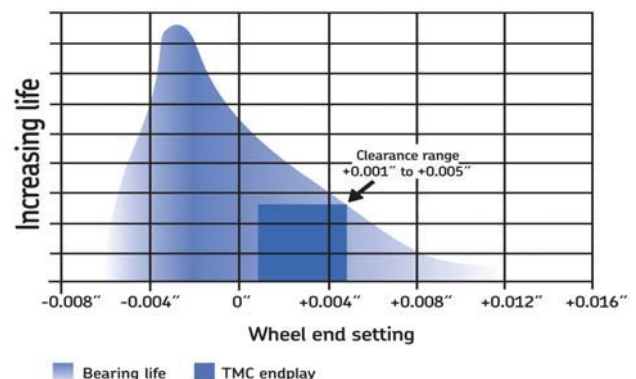
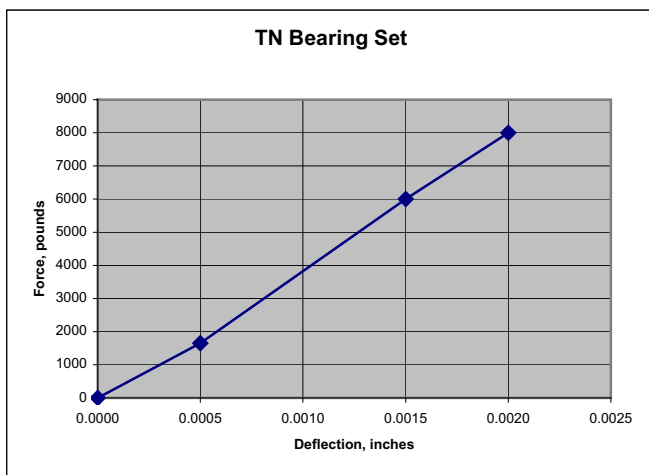


Figure 1 shows an example for a wheel-end that has an ideal setting at about three thousandths of an inch of preload. In practice, such a measured definition is not possible without a force-measuring device. Preload is a force not a dimension. The term “.003” preload” refers to the condition where the combined deflection of two bearings and perhaps some wheel end compressive deflection under axial load is .003”. The target preloads specified in SAE J2535 are force values, not deflections. Charts like Figure 1 may have very different equivalent dimensional preloads depending upon the characteristics of each different wheel end construction. For each bearing design there is a characteristic curve of the amount that the bearing will deflect axially in relation to the axial force applied to that bearing. This is evaluated as the force-deflection characteristic of the bearing. When axial force is applied to a tapered roller bearing, the bearing becomes slightly compressed due to expansion of the bearing cup, plus contribution from contact stresses between the cup, cone and rollers.

Figure 2 shows the stiffness characteristic for the pair of bearings of a TN trailer wheel-end. Bearing load ratings are specified as the load under which 90% of bearings will survive for 3000 hours at a speed of 500 RPM. The smaller of the two bearings of a TN set is rated at 7030 pounds axial thrust force. The SAE recommended preload of 500 pounds will only deflect this bearing pair about 0.0004 inches, and is only about seven percent of the smaller bearing’s life rating. Clearly, when observing the life chart of Figure 1 and the stiffness chart of Figure 2 it is seen that an accurate application of force will produce far better adjustment accuracy and bearing life than can be obtained by any other method. Even the 2000-pound force chosen as a starting point for wheel end setting verification will only impose .001” deflection on a TN bearing set, and will be less preload than Figure 1 shows for maximum life.

Figure 2 FORCE-DEFLECTION CHARACTERISTICS FOR A SERIES TN BEARING SET⁵



SEATING THE BEARINGS

Correct assembly of the tapered roller bearings used to support wheel ends requires a procedure to cause the individual rollers to become aligned in the bearing. Otherwise, the rollers will be “skewed”, which means that they are not in correct alignment and therefore will not roll smoothly. Even in cases where bearings are initially set without bearing skew, if the setting allows too much endplay or clearance in the rollers, the bearing life will be foreshortened because the rollers will not always stay in perfect alignment. Loading the bearings with a torque wrench, followed by rolling the wheel, sometimes will not prevent skewing of the bearing rollers. All of the procedures currently in use require repetition of the torque and rolling process multiple times in order to decrease the possibility that the bearings remain skewed. When fully loaded, the pattern of radial load distribution on a bearing is primarily on the lowest third of the roller set and the rollers on the top portion of the bearing are essentially not loaded. When a light preload is established, the portion of the roller set at the top of the bearing is always kept in alignment.

REASONS FOR WHEEL END VARIATIONS

Currently accepted practices of using torque wrenches for wheel end bearing adjustment have inherent issues that require exceptional vigilance to obtain the best possible results.

Tools

Torque wrenches in a maintenance shop environment are notorious for facing a number of difficulties. They can fall victim to neglected preventative maintenance and recalibration. They can lose calibration, especially when they are used for other operations in a shop that may exceed their ratings. The biggest problem with torque wrench use, as specified in the TMC RP procedures, is that at least two values of torque must be employed. It is a great rarity to find a mechanic supplied with two torque wrenches to eliminate the need for multiple torque adjustments for each wheel adjustment. This leads to greater possibility of errors in setting plus the added time needed to make these frequent adjustments.

Torque - Axial Preload Relationship

The most accurate application of torque will translate into a wide variation of applied axial force. The actual load applied is at the mercy of variable friction coefficients at best. This, in turn, depends on thread surface qualities, freedom from minor thread damage, and type and amount of lubricant present. The variation can be worsened by minor thread damage to either axle or nut that can easily escape notice.