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Scuffing Resistance of Vehicle Transmission Gears

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TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

In many transmission types, the lubricant fulfills other functions apart from lubricating the gearing, for example in friction elements (synchronizer unit, clutch) in vehicle transmissions, or as a hydraulic fluid (torque converter, retarder, steering system). The modern trends are now high contact ratio gearing as well as the use of low viscosity lubricants to reduce churning losses.

Therefore, at the gear design and lubricant additive stages, compromises are now necessary which require the most precise information possible on scuffing resistance of the gearing and lubricant.

It will be demonstrated that the normal test procedures for determining scuffing resistance are not suitable for lubricant classification for vehicle transmissions (GL 4 and GL 5). By reducing the tooth width as well as doubling the speed, the scuffing test to DIN 51354 standards was increased in severity to such an extent, that the parameters necessary for transmission dimensioning could be determined for even higher scuffing resistant oils.

The oil data necessary for sufficient scuffing resistance will be shown for different transmission design types. Within the scope of lifetime oil fills, attention should be paid to oil aging processes.

The profile and tooth trace of gears on modern transmissions are nowadays corrected, almost without exception, to compensate for load-related deformation and production discrepancies. In the current calculation procedures these corrections, which tend to increase scuffing resistance, are not considered to an adequate extent.

A process is being presented, in which scuffing resistance is calculated for every point on the tooth flank, based on the "flash temperature method", and taking all variations and corrections into account. It will be demonstrated with practical examples, that, as early as the design stage, this method can be used to detect flank areas at risk, and to eliminate them with a specific correction design.

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SCUFFING RESISTANCE OF VEHICLE TRANSMISSION GEARS

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1 Introduction

The following essay describes new test and calculation procedures for defining the scuffing load capacity of gears in vehicle transmissions.

The standard test for defining the scuffing load capacity of lubricants as per DIN 51354 /8/ only allows differentiation between uninhibited (without anti wear additives) and lowly-inhibited oils (API-GL 2 and GL3) up to damage load level 12. More highly-inhibited lubricants as per API-GL-4 and GL-5, which are also used in vehicle transmissions, reach damage load levels above 12 and can therefore no longer be differentiated. To enable classification of such lubricants also, proposals were put forward to make the tests more severe as part of internal investigations. Based on these investigations, the FVA (Forschungsvereinigung Antriebstechnik = German Research Association of Transmission Technology) developed a more severe scuffing test as part of a research program. The differences between this and the standard tests will be outlined and explained. Generally, procedures as per DIN 3990 /1/ and ISO TR 13989 are used for checking scuffing load capacity calculations. As a supplement to this, a procedure which also considers profile and tooth trace corrections will be outlined.

2 Requirements for transmission lubricants

The lubricant is an important design component and must be considered as early as the transmission configuration and design phase. The main functions of the lubricant are to minimize friction and wear on sliding and rolling components, dissipate heat and protect against corrosion.

Using an automatic transmission from a passenger car as an example, Fig. 1 shows the numerous transmission components whose function and lifetime directly depend on the lubricant. In such cases, there has to be compromise in order to fulfill often contradictory criteria such as load-bearing capacity, resistance to temperature and ageing, cold-

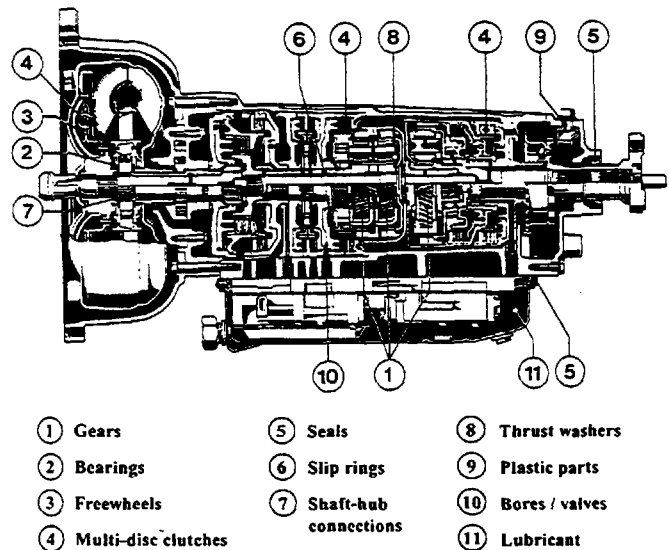


Fig. 1: Lubricant influenced components in an automatic transmission

shift characteristics, efficiency, friction characteristics, costs, availability, etc. The "lubricant-transmission component" matrix outlines the main failure criteria, Table 1.

Possible tooth flank damages such as scuffing, pitting, micropitting and wear are substantially influenced by the properties of the lubricant. Viscosity, molecular structure and additives determine either the lubricant film thickness or the friction factor and, consequently, the surface stress. A particularly important factor with regard to scuffing load capacity is the chemical-physical interaction between the lubricant and the surface, which influences the material properties around marginal zone Fig. 2.