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Evolution of terminology related to tooth distress

Describing the tooth surface distress of gear tooth flanks calls for a closer look at how 'scoring' and 'scuffing' definitions have changed through the years.

Inspection of gears operating in the field requires the proper use of terms describing tooth distress. Written reports by field engineers on occasion have mislabeled the description of tooth distress on the tooth flanks. This error could be the result of reference publications and standards which, in the last 60 years, have redefined the terminology describing the reported findings, particularly the terms scoring and scuffing. Even at this time, there is some conflict in terminology with ANSI/AGMA 1010-F14 and ISO 10825-1 2022. This article describes the evolution of scoring vs. scuffing in the referenced period of time.

NOMENCLATURE: SCORING VS. SCUFFING

The history of these terms has created much confusion when describing tooth surface distress of gear tooth flanks.

In 1937, Dr. Harmon Blok published his theory about the relationship between contact temperature and scuffing, which was presented at the Second World Petroleum Congress held in Paris, June, 1937 [1]. At the time, the tooth distress arising with Dr. Blok's theory was referred to as scoring.

In the 1960s, MAAG formulated a procedure to assess scuffing risk. This method was published in 1963 in a MAAG handbook and applied the term scoring risk [2].

As a result of field experience, MAAG further developed an assessment of scuffing risk, published in 1990 in a newer updated handbook, continuing with the term reference as scoring.[3]

Until 1990, the term scoring was predominant in describing adhesive wear without a distinction with abrasive wear. This is a conflict in reporting examples of tooth distress of the gear tooth flanks. In order to separate the two, scuffing became the appropriate term for severe adhesive wear, and scoring referred to scratching or abrasive wear.

1 WEAR

Wear is a term describing change to a gear tooth surface involving the removal or displacement of material due to mechanical, chemical, or electrical action. Wear can be categorized as mild, moderate, or severe. In some applications, no wear is acceptable. However, in many other applications mild wear is considered normal. Moderate, and sometimes even severe, wear may be acceptable in some applications [4].

Tribology considers two main phenomena for wear, abrasive wear, and adhesive wear. These are the main causes found for wear in gearboxes.

1.1 ABRASION

Abrasive wear, also known as abrasion, is the removal of material

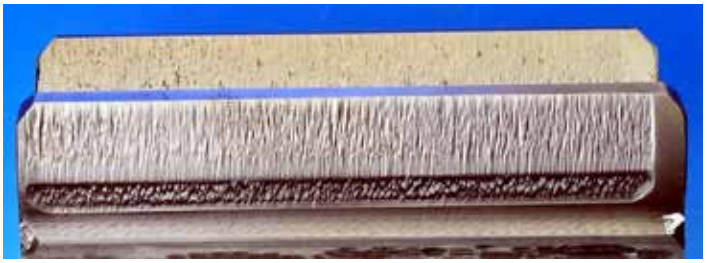

Figure 1: Severe abrasion. (Source: ANSI/AGMA 1010-F14)

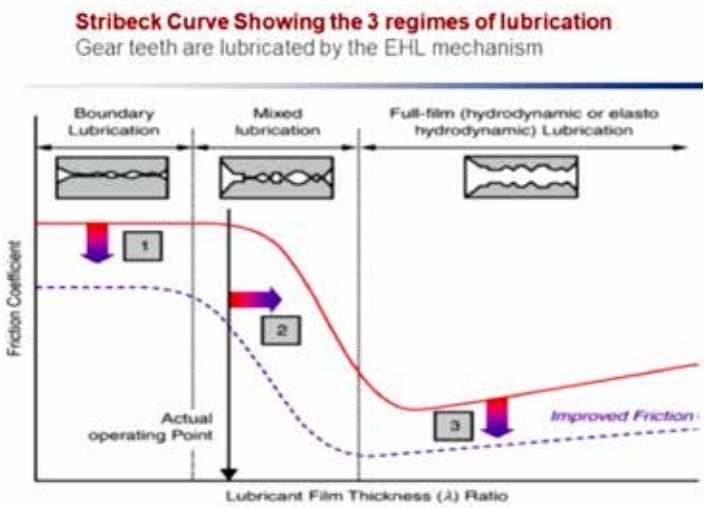

Figure 2: Stribeck Curve. (Source: Wang Q.J., Chung YW. Encyclopedia of Tribology. (2013) Springer, Boston, MA)

Figure 3: Scuffing. (Source: AGMA 19FTM24)

from the tooth flanks as a result of contamination of the lubricant with debris that could consist of hard elements such as metallic particles from bearings, rust, or sand, suspended and circulating in the lubricant.

Abrasion appears as scratches or gouges on the tooth surface in the direction of sliding and is visible over the entire tooth flank. Abrasion is not limited to gear teeth; it also can severely degrade bearings, seals, and other components. Abrasion of bearings can promote failures of gear teeth by causing misalignment [4].

Clean oil is absolutely essential to prevent abrasive wear.

Not all abrasion is bad. Polishing is fine-scale abrasion. But too much polishing can be detrimental to the intended gear tooth accuracy.

1.2 ADHESION

Adhesion is caused by transfer of material from one tooth surface to another due to micro-welding and tearing. Adhesion is categorized as mild, moderate, or severe [4].

1.2.1 SCUFFING

Scuffing is severe adhesion where transfer of metal from one surface to the other occurs due to welding and subsequent tearing of material.

This can occur in gear teeth when they operate in the boundary lubrication regime. To better understand it, it may be best to reference the Stribeck Curve shown as Figure 2.

Scuffing is influenced by a combination of the film thickness and the coefficient of friction dependent on surface pressure and sliding velocity [5].

When calculating the total contact temperature, the tooth flank temperature is as significant as the flash temperature:

ϑ total contact max = ϑ flash max + ϑ tooth flank temp

Scuffing is likely to occur when: θ total contact max $\geq \theta s$

Where: θs = the mean scuffing temperature

This means scuffing will occur if the total contact temperature raises the lubricant temperature above the lubricant's ability to maintain its viscosity.

2 DISCUSSION

Figure 3 displays a classic example of scuffing. Note the difference with Figure 1.

Abrasion occurs over the entire tooth profile, whereas scuffing occurs where there is relative sliding of the mating surfaces. So, near the pitch line where there is minimal sliding, there is no tooth distress.

It is evident the surface distress is functionally developed quite differently. Terminology needs to be clear for investigative work when composing a report by field service technicians.

ANSI/AGMA 1010-F14 Table 1 lists correct nomenclature and lists references to historic improper terminology. Terms such as cold scuffing and hot scuffing are rejected in Table 1, but terms such as cold scoring — found in ISO 10825-1 1996 [6] — and hot scoring — found in the MAAG handbook 1990 [3], — are not referenced.

Recognizing this problem, ISO has updated ISO 10825-1 2022 and makes clear the difference in nomenclature. ISO admits the error in terminology and now defines the term scoring, which was incorrectly used in earlier gear nomenclature for scuffing, is in reality scratching and is now classified as a form of abrasive wear. [7]

NOMENCLATURE

For observational reporting it is recommended to follow the ISO nomenclature:

SCUFFING

Mild to moderate scuffing resulting from severe adhesion in the boundary lubrication regime producing high tooth contact temperatures.

HOT SCUFFING

Severe scuffing where the surfaces are markedly distressed all the way to the pitch line but oriented in the sliding direction.

COLD SCUFFING

Also operating in the boundary regime but with lower sliding velocities, which is often found more where greases are the lubricant.

ABRASION

Furrows or gauges usually the result of contaminated lubrication.

SCRATCHING

Scoring abrasion resulting from metal-to-metal contact nearly void of lubrication.

REFERENCES

[1] Blok, H., Les Températures de Surface dans les Conditions de Graissage sans Pression Extrême, Second World Petroleum Congress, Paris, June, 1937.

[2] MAAG Gear Wheel company Ltd, 1963 pages 128-130.

[3] MAAG Gear Wheel Company Ltd 1983, pages 150, 153-155, 166 – 168. January, 1990

[4] ANSI/AGMA 1010-F14, pages 2, 7. February, 2020

[5] Amendola, Amendola, Errichello, Calculating Scuffing Risk AGMA 19FTM24, page 3-4, 2019

[6] ISO 10825-1 page 9, 1995

[7] ISO 10825-1, pages 2, 9. 2022

ABOUT THE AUTHOR

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