

Scuffing Resistance of Surface Treated 8625 Alloy Steels

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ABSTRACT

Scuffing is a common source of failure for many mechanical components in automobiles. 8625 alloy steel is commonly used in camshafts, gears, piston pins, shafts, and splines. The purpose of the research is to study the scuffing resistance of non-treated, carburized, nitrocarburized, and carbonitrided 8625 alloy steels. The scuffing resistance of the 8625 alloy steels was determined through pin-on-disk tests. The hardness and microstructure of the disks were analyzed using electron microscopy to determine wear mechanisms for each surface treated steel. The wear mechanisms were then related to the scuff resistance of the various materials.

INTRODUCTION

Scuffing is a common cause of failure for drive train components. Scuffing is the sudden failure of mechanical components resulting in noise, vibration, seizure, sharp increase in coefficient of friction, and increased temperature [1]. Causes of scuffing include adhesive wear, accumulation of wear debris, plastic deformation, formation of a hard surface layer, break down of oil film, and break down of oxide layers [1].

The surface properties of alloy steel can be improved through different case hardening treatments. Carburizing is a case hardening process in which carbon is interstitially diffused into the outer layer of the steel. Gaseous carburization is accomplished by heating the steel to its austenitic state, usually in the temperature range of 840 to 950°C, in an atmosphere of sufficient carbon potential to cause carbon diffusion into the steel [2]. The carbon source usually consists of vaporized hydrocarbons. After the carbon diffuses into the

case, the steel is quenched to form a martensitic layer, then tempered to achieve desired properties [3].

Carbonitriding is a case hardening process similar to carburizing except the case of carbonitrided steel contains interstitial carbon and nitrogen and the process is completed at lower temperatures and in less time. Gaseous carbonitriding is accomplished by heating the steel to its austenitic state, usually in the temperature range of 740 to 820°C, in a carbon and nitrogen rich furnace. The carbon source is usually vaporized hydrocarbons and the nitrogen source is ammonia gas [2]. After the carbon and nitrogen diffuse into the case, the steel is quenched to form a martensitic layer, then tempered to achieve desired properties. Because carbonitriding is performed for a shorter duration and at a lower temperature than carburizing, a more shallow case results [3]. Karamis, Ipek, and Selcuk [4][5] have shown that carbonitrided steels have improved tribological properties as compared to carburized steels, even with a more shallow effective case.

Ferriticnitrocarburizing is a case hardening process that produces a case consisting of an outer compound layer of iron nitride (white layer) with an underlying diffusion layer containing interstitial carbon and nitrogen. The outer compound layer consists of two phases of iron nitride, ϵ ($\text{Fe}_{2.3}\text{N}$) and γ' (Fe_4N). The ϵ layer is the external layer and the γ' lies beneath the ϵ layer. The compound layer can be up to 20 μm thick and the diffusion layer can reach a thickness of 0.8 mm [6]. The compound layer improves wear and scuffing resistance [6]. Unlike carburizing and carbonitriding, which require the steel to be in the austenitic state, gaseous ferriticnitrocarburizing is accomplished by heating the steel to its ferritic state, usually below 675°C, in a carbon and

nitrogen rich atmosphere [2]. Krishnaraj, Iyer, and Sundaresan [7] have shown that nitrocarburized steels have excellent scuffing resistance and are superior to martensitic hardened steels.

The purpose of this study is to determine the scuffing resistance of non-treated, carburized, nitrocarburized, and carbonitrided 8625 alloy steels, which are commonly used in automotive drive trains, through pin-on-disk tests. The hardness and microstructure of the disks were analyzed using an electron microscopy to determine wear mechanisms for each surface treated steels. The wear mechanisms will be then related to the scuff resistance of the various materials.

EXPERIMENTAL DETAILS

TRIBOMETER

In this research a pin-on-disk tribometer (POD) was used to determine scuffing resistance as shown in Figure 1. The POD consists of a variable speed motor, rotating cup, pin, pin mount, and steel weights. The motor can drive the rotating cup to spin at a maximum speed of 1800 rpm. The rotational speed of the cup is monitored with an optical tachometer. The disks are mounted in the cup with four machine screws. The pin is a 7.94 mm diameter E52100 alloy steel ball (60 to 67 HRC). The coefficient of friction between the pin and disk can be determined knowing the normal load and the frictional force which is measured using strain gages attached to the pin mount.

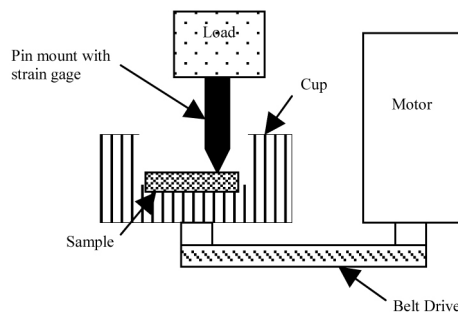


Figure 1. Schematic of pin-on-disk (POD) tribometer

TEST SAMPLES

All disk specimens are made from AISI 8625 alloy steel. The disks are machined to 9.5 mm thick and 67.5 mm in diameter. Among the disks, there are three different hardening treatments, carburization, carbonitration, and nitrocarburization. The carburized and nitrocarburized disks are treated in an environment with 0.9 carbon potential. Among the carburized and carbonitrided disks, there are three different hardness levels achieved through tempering. The disks are tempered in a furnace for one hour at 260, 290, or 315 °C respectively.

TEST PROCEDURE

For the scuffing resistance test, the disk is mounted in the cup. The pin is adjusted to be a specified distance from the center of the disk to achieve the desired linear velocity. Scuffing resistance is tested at five different linear velocities: 1.40, 1.28, 1.16, 0.93, and 0.81 m/s. Three to four milliliters of light mineral oil is initially added to the cup so that an oil film is maintained on the disk. The motor speed is adjusted so the cup is rotating at 700 rpm. After the strain gage is zeroed, the pin is loaded with 22.25 N and timing starts. The load on the pin is increased from 22.25 N with a 22.25 N increment for every two minutes. The frictional force is recorded one minute after every load increase. During testing, the oil level in the cup is monitored so that an oil film is maintained on the surface of the disk. The test is stopped when the coefficient of friction between the pin and the disk suddenly increases, as indicated by a large spike in frictional force. The load at this moment is referred as the scuffing load.

After test the samples are cut radially and tangentially to the scuffing track. The samples are mounted in Transoptic mounting resin, polished, and etched with nital. Microscopy is then used to determine the microstructure of the samples at the core, surface, and scuffing track. The microhardness of the carburized and nitrocarburized samples is measured. The effective case depth of the carburized and nitrocarburized samples is determined from the measured microhardness. Effective case depth is defined as the perpendicular distance from the surface where the hardness level is 50 HRC or less [2]. The total case depth of the nitrocarburized sample is determined from the microstructure of the sample. Total case depth is defined as the perpendicular distance from the surface where the case and core can no longer be distinguished from one another based on chemical or structural properties [2]. The surface roughness of the scuffing tracks are measured in the radial and tangential directions. A scanning electron microscope is then used to view the surface characteristics and wear mechanisms of the scuffing path.

RESULTS AND DISCUSSION

SAMPLE PROPERTIES

The microstructure of each sample was examined. The microstructure of the carburized and carbonitrided samples is tempered martensite and retained austenite, as shown in Fig. 2 and 3. The microstructure of the untreated samples is Widmanstatten needle-like ferrite (forged microstructure), as shown in Fig. 4. The nitrocarburized layer on Fig. 5 is $\epsilon(Fe_{2-3}N)$ and $\gamma'(Fe_4N)$ compound layer (white layer).