HOT SEAT

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DEEP NITRIDING FOR GEAR APPLICATIONS AND THEIR PARTIAL TREATMENTS

Plasma/ion nitriding meets demanding gear applications by offering increased load capacity of gears and increased fatigue strength of components as well as less complicated masking treatments.

STRESS CONDITIONS INSIDE GEAR TEETH ARE COMPLEX and require a careful examination by the designer before any specific surface treatment of the gears should be recommended [1]. As a result of those examinations, nitriding applications, specifically plasma/ion nitriding, for the surface engineering of gears have been growing steady in recent years because of the many benefits offered by this technology. This applies to low-modulus gears requiring a lesser deep case as well as higher-modulus gears with a deep case.

Nitriding has been known for its effectiveness in resisting shear stresses due to friction and prevention of the tooth flank subsurface fatigue failure that can occur in any application of highly loaded case-hardened gears. The nitrided layer increases various surface and volume properties of the component. The load capacity of gears can be significantly increased by the nitriding process if it produces a sufficient depth of the layer. Fatigue strength and durability of the nitrided components increase with increasing nitriding depth. Gears with tooth modulus of 15-20 mm require a case depth of about 0.7 to 1 mm [2, 3]. The nitrided layer has not only high hardness but also a very high thermal stability, and it is under compressive residual stress. Therefore, nitriding is extremely valuable in many demanding gear applications including dry running, lack of lubrication, and use at temperatures above a typical tempering temperature of the case-carburized gears.

In these situations where a superior-quality nitrided layer is essential, selection of a proper steel for the gear to assure a good hardness of its surface for increasing tribological and contact fatigue properties has to be considered. Well-nitridable steels contain nitride-forming elements including 1-3 percent chromium, 0.2-0.5 percent molybdenum as well as smaller amounts of vanadium or niobium [2]. Typical examples include DIN 39 CrMoV13.9 (similar to UNS K33585), 31CrMoV9, as well as 4340 or 4140. Those steels also have superior mechanical properties such as yield strength and toughness. Nitriding carried out at a temperature of 530-570°C (986-1058°F) can produce a layer of 1 mm in a long process of a few hundred hours [2, 3]. Hardness distribution in such a deep layer is shown in Figure 1. Deep nitriding results in a significant increase in the capacity of the nitrided medium- and large-size gearings, specifically a better bearing capacity compared to conventionally nitrided gears [3].

Keep in mind that the long nitriding time may have a detrimental effect on mechanical properties of the steel. Therefore, processing temperature should be carefully selected to avoid an over-tempering effect of the steel itself as well as softening of the nitrided layer because of over-aging of the nitrides. Structure of the nitrided layer has a paramount importance and determines its properties. Therefore, it has to be well controlled. Modern gas nitriding processes are typically potential-controlled nitriding, allowing for avoidance of the structure with an overly thick compound layer of $Fe_{2-3}N$ and Fe_4N type iron nitrides. The plasma nitriding process is, by nature, a low-nitriding potential process, therefore, it allows for easy control of the layer's structure.

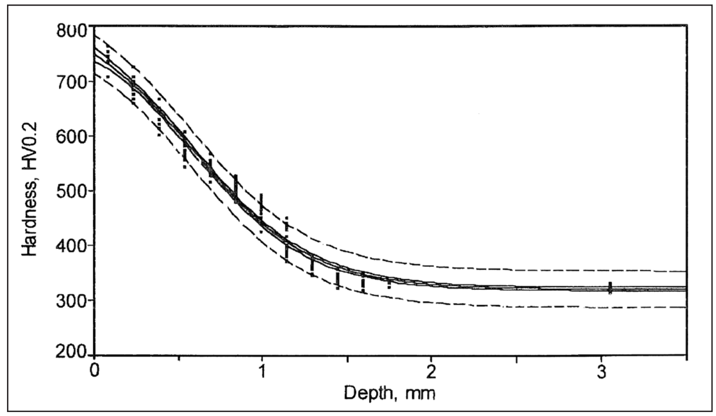

Figure 1: Microhardness profile in 3%Cr-Mo-V steel gear nitrided at 538°C. Confidence and prediction intervals represent normal distribution and standard error (small internal) at 95 percent. Figure adopted from Reference [2].

In many situations for various reasons, hardening of the gears is limited to the teeth only. Therefore, protection of the other surfaces from the treatment must be assured. Such protection in the long gas nitriding process is somewhat complicated and labor intensive, but it can be done by using electrolytic copper plating. However, after the treatment, the copper layer has to be removed and the gear has to be annealed at a low temperature to avoid hydrogen embrittlement. Much simpler solutions are available in the ion/plasma nitriding process where the masking with mechanical fixtures is commonly used. This type of masking is also 100-percent effective. Figure 2 illustrates a large-size gear for power-generation applications being loaded into the ion nitriding vessel. All of the surfaces requiring protection from nitriding are covered with masking elements made of a plain carbon steel. The purpose of the fixturing plates and components is to interrupt direct contact of the plasma with the surface requiring protection from the treatment. Ions of nitrogen and of NH_x radicals coming from the plasma cannot penetrate the small gap between the masking fixture and protected surface of the part, therefore, there is no nitriding in this area.

Additionally, nitriding is an extremely valuable technology in gear applications because it is carried out at a comparatively low temperature not exceeding tempering or stress-relieving temperatures of the steel. As a result, there is very little or no distortion of the treated gear. Existing plasma nitriding furnaces allow for treating gears of 150" in diameter. One such equipment operated by Advanced Heat Treat Corp. in Monroe, Michigan, can accommodate 45,000-pound gears.

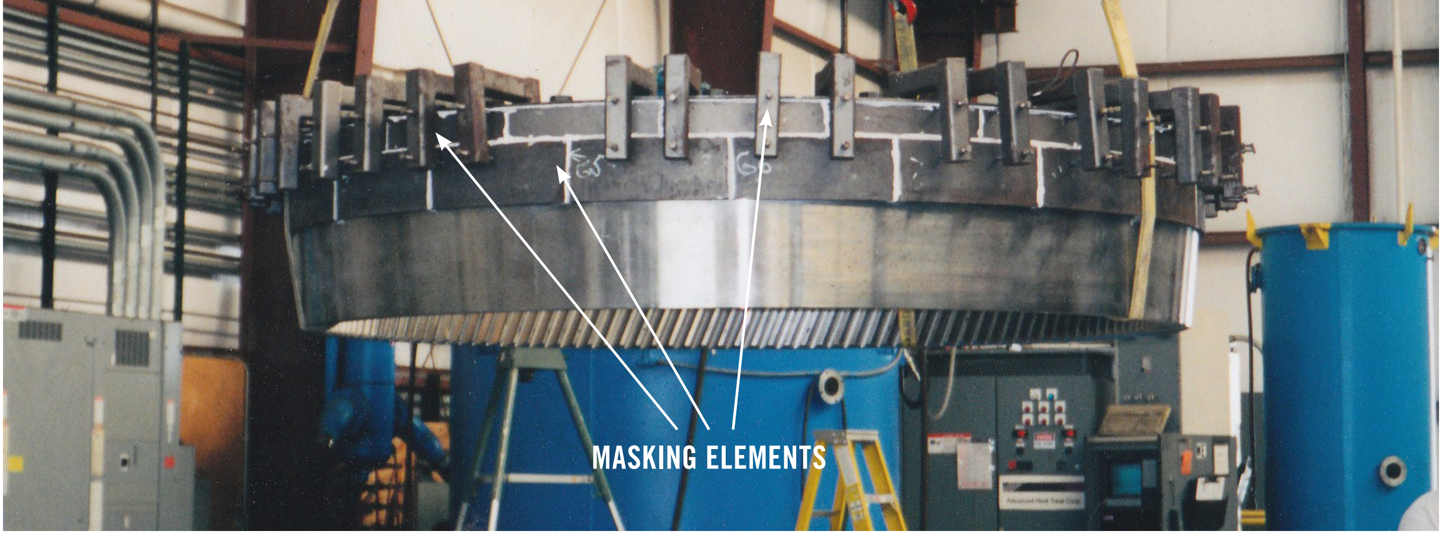

Figure 2: Plasma nitriding of the 4340 steel gear used in the power-generating industry requiring selective hardening. Mechanical masking/segmented fixturing covers a portion of the outside diameter of the gear. Photo courtesy of Advanced Heat Treat Corp., Monroe, Michigan.

REFERENCES

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