The formation of non-transformation products and grinder burn on heat-treated steel gears is a serious problem for John Deere. These defects reduce hardness, residual compressive stresses and fatigue life, increasing scrap costs. John Deere has suggested shot peening as a possible way to restore mechanical properties. Shot peening induces compressive residual stress into the gears, potentially undoing the damage caused by grinder burn. Residual stress, metallography and microhardness measurements were conducted on gear samples provided by John Deere in order to recommend whether or not John Deere should pursue the shot peening approach.

Non-Transformation Products

Optical microscopy and residual stress and hardness measurements were performed on a set of non-shot peened and non-shot peened microstructure gears. As shown in Fig. 8, the greatest amount of NTP was found near the 2° offset location (Fig. 7).

Grinder Burn

A severe grinder burn region was selected by visual inspection and measurements were taken along the burned area. The average surface hardness of a shot peened tooth was shown to be higher than a non-shot peened. Figure 13 shows a greater surface hardness difference between shot peened and non-shot peened tooth. The greatest post-peen hardness difference was found in the burned zone. This shows that shot peening cannot fully recover lost surface hardness in the grinder burn region.

Results & Discussion

Application of shot peening was able to improve the internal stress state and recover some of the hardness lost due to NTP layer formation at the surface. The application of shot peening introduced up to 1400 MPa of compressive residual stress into the surface of the gear. This effect of shot peening on residual stress and hardness decreases as depth increases, and it is negligible beyond a depth of 220 µm.

Future Work

Further work should be performed to verify the efficacy of shot peening in residual stress recovery. An increased and varied sample volume in XRD residual stress testing and subsequent fatigue testing should be performed to verify the applicability of results to all products subject to grinding. Analysis can be used to provide more quality assurance.

Recommendations

Our team recommends that John Deere further pursue shot peening as a countermeasure to offset the negative effects of excessive surface NTP and grinder burn. Additionally, we suggest more testing to be done to establish a correlation between residual stress recovery and a non-destructive testing method such as Barkhausen Noise.

Project Background

This work provides an analysis and evaluation of the non-transformation products, intermediate products, and grinder burn issues that John Deere is experiencing as a result of current heat treatment and finish machining. A carburizing heat treatment is applied to the 8620 steel gears in order to create a hard outer martensitic surface while retaining a tough pearlitic core (Fig. 1). Quenching after carburizing produces a compressive residual stress profile that improves fatigue life and minimizes crack propagation.

During the carburizing heat treatment process, softer non-transformation products (NTP) are sometimes formed on the gear surface. The NTP layer is thought to result from de-alloying during propagation. The formation of non-transformation products and grinder burn on heat-treated gears increases the costs. John Deere has suggested shot peening as a possible way to restore mechanical properties. Shot peening induces compressive residual stress into the gears, potentially undoing the damage caused by grinder burn. Residual stress, metallography and microhardness measurements were conducted on gear samples provided by John Deere in order to recommend whether or not John Deere should pursue the shot peening approach.

Experimental Procedure

A depth profile was taken from 0-200 µm depth at the 30° offset location (Fig. 7) of the NTP and subsequently shot peened part. Vickers hardness and optical microscopy were used to verify levels of NTP and grinder burn. Cross-sections were cut to measure the depth and hardness at each area. Surface hardness was also measured along the surface of the burn part.

Gears affected by NTP development and grinder burn were sectioned and prepared for X-ray diffraction testing, optical microscopy, and Vickers hardness measurements. An audit part with previous residual stress measurement history was used to verify XRD machine capability. A surface profile along the length of the grinder burn (red line in Fig. 12) was created on both the base grinder burn part and the subsequently shot peened part. A depth profile was taken from 0-200 µm depth at the middle of the burn.