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Analysis of Residual Stress and Distortion for the Manufacturing of Axle Drive Shaft

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Abstract: **-- This paper analyses the effect of residual stress in the distortion of the axle drive shaft. Residual stress is the stresses that remain in a solid material after the original cause of the stress has been removed. An axle drive shaft of 20MnCr5 material is been analyzed. Research is carried out on two axle drive shaft. In one shaft, after the last manufacturing step was sent through residual stress relief process by shot peening process. And both shafts after going through heat treatment process showed variation in distortion. The shaft with stress relief treatment showed less amount of distortion compared to the other shaft. Therefore a stress relief shot peening process is recommended for reducing the distortion in axle drive shaft.**

Keywords: Residual stress, axle drive shaft, heat treatment.

I. INTRODUCTION

In automotive industry, heat treatment of components is implicitly related to distortion. This phenomenon is particularly obvious in the case of gearbox parts because of their typical geometry and precise requirements. Even if distortion can be anticipated to an extent by experience, it remains complex to comprehend. Scientific literature and industrial experience show that the whole manufacturing process chain has an influence on final heat treatment distortions. This paper presents an approach to estimate the influence of some factors on the distortion, based on the idea of a distortion potential taking into account not only geometry but also the manufacturing process history. Then the idea is developed through experiments on an industrial manufacturing process to understand the impact of residual stress due to machining on shaft bending and teeth distortion during heat treatment. Instead of being measured, residual stress is being neutralized. By comparing lots between each other, connections between gear teeth geometry and manufacturing steps before heat treatment are obtained. As a consequence, geometrical nonconformities roots can be determined more easily thanks to this diagnosis tool, and corrective actions can be applied. Secondly, the influence of product geometry on bending is experimentally considered. Moreover, metallurgical observations enable to explain the influence of work pieces geometry on shaft bending. Residual stresses are the stresses that remain in a solid material after the original cause of the stress has been removed. Residual stress is the internal stress distribution locked into a material that are presents even after all external loading have been removed. Distortion is the error seen in the cylindricity of the shaft. The shaft that is being produced shows a certain amount of distortion in the material after it has been sent it to the material testing process. The shaft that has been used is axle drive shaft. The material that in which it is being used to manufacture of shaft is 20MnCr5.

1.1 The manufacturing process of axle drive shaft:

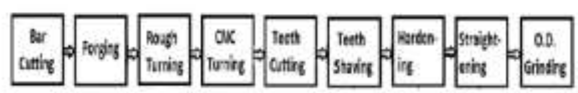

Fig 1: Manufacturing process of axle drive shaft

1.2 Root cause of residual stress:

There are several root because which leads into the formation of the residual stress Hence residual stress can be formed due to this several reasons.

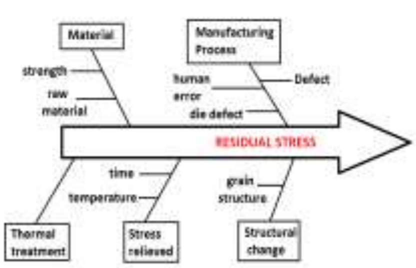

Fig.2 : Fishbone diagram of residual stress (Ref. 1)

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1.3 Root causes of distortion:

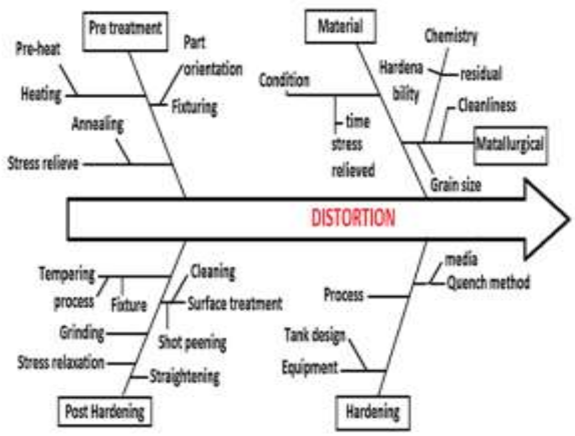

Fig.3 : Fishbone diagram of distortion (Ref.1)

Processing can have a large influence on properties and the resulting residual stresses. Typically, this is related to wrong procedures or improperly specified procedures. Ambiguous processes or specifications can also contribute to failures due to interpretation or application. Simple things like improper selection of processing sequences or procedures or specifications that were not followed can also contribute to failure. Cold forming, such as stretching or deep drawing, can develop highly localized residual stresses. Local changes in microstructure can occur. Because of the changes in reduction, a large anisotropy in material properties also results. Due to the drawing operation, cracks or micro cracking can occur. This could be due to improper lubrication or improper die design. The localized changes in ductility can also con- tribute to failure.

1.4 Application of axle drive shaft

The axle drive shaft is coupled with the rear differential to transmit the power to the rear wheels.

Fig.4 : Application of axle drive shaft (Ref.3)

II. LITERATURE REVIEW

Remi Husson et al.[1] proposed that during the manufacturing of the shaft at each and every stage there is a rise in residual stress, due to which distortion is seen after the heat treatment process. So to avoid the distortion, neutralisation of residual stress at each and every stage is done. 2 separate lots are experimented, one without neutralising the residual stress and one with neutralizing the stress. The result shown that the lot which was gone through neutralising, showed less distortion. S.H.Khan et al.[2] identified that the chemical inhomogeneity at micro-scale gave rise to undesirable multiphase structure, which is responsible for bending during machining stage. From the initial stage of the manufacturing process there was a certain amount of austenite present as a impurity. When machining was done on the shaft, due to this austenite present, the stress was generated which is the major cause of distortion. A.I. Zyubrik et al.[3] identified here that annealing as a process parameter has been changed and results were verified accordingly. It was seen that as the annealing temperature is increased the formation of crack growth is reduced. The chemical inhomogeneity at micro- scale gave rise to undesirable multiphase structure, which is responsible for bending during machining stage. A.H. Mahmoudi et al.[4] observed that shot peening is carried out to postpone the crack initiation or reduce the propagation rate. In shot peening, a target is peppered using small spherical shots with a velocity of 20-100m/s. The outcome is a compressive residual stress field beneath the surface of metallic components. Shot peening is the most effective treatment of reducing the residual stress. MiroslavNeslusam et al.[5] The bainite structure gave the least distortion compared to the martensite structure. The stress formed in the bainite structure is less compared to the martensite structure. Bainite structure gave 11% less deviation compared to the martensite structure during heat treatment. Compressive stress is formed more in the bainite structure in comparision to the martensite structure.

Abdul muttalib et al.[6] observed that Two lots were classified, one lot was given the relief treatment, named as ND; and other lot was not given the relief treatment, named as D. With the help of X-ray diffractometry method, the distortion was calculated in both the lots. And the result showed that the distortion seen in ND shafts are less compared to D shaft.He recommended that give a stress relief heat treatment to the hot rolled bars to reduce the level of residual stress to reduce risk of distortion. R. Atraszkiewicz, et al. [7] Helium compared to gas quenching and oil quenching gives better results and preserves the features. Measurement of gear distortion after heat treatment, made of 16Mncr5 steel, the average out of roundness value is equal to 0.0013mm for nitrogen and 0.0011 mm. For helium For flatness the helium quenching did not show any distortion (0.004 mm), while for nitrogen the value was 0.015mm. A.Gariepy, et al. [8] Beneficial compressive surface residual stress are introduced by projecting small, hard particles at high velocity onto a metallic part. Small diameter shot gives better result

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compared to big diameter shot in the formation of the compressive stress. Rajesh Purohit et al.[9] proposed that By applying the shot peening process, the compressive stress are induced in the shaft, which reduces the formation of the crack growth. With the help of the shot peening process, the residual stress can be reduced to a greater extent. ViniciusWaechter et al.[10] observed that several parameters like drawing angle, cutting method, hardening process and grinding are responsible for the distortion. Every parameters are given input in the DOE method .Although the intentional parameters were varied, the uncontrollable variables also showed significance in the distortion process.

III. MODEL OF THE AXLE DRIVE SHAFT

Fig.5: Model of the axle drive shaft

IV. EXPERIMENTAL PROCEDURE:

In order to observe the influence of a carrier of potential distortion, this carrier is neutralized before heat treatment as presented in Fig.after manufacturing step k, both lots A and B have the same geometry GA (k) and GB (k). Then, lot A goes directly to heat treatment and finally obtains geometry GA (HT) while lot B is being "neutralized." At last, lot B is heat treated. Its geometry after heat treatment is GB (HT). Finally, to observe the influence of the carrier of distortion on heat treatment distortion, a comparison is made between both geometries after heat treatment GA (HT) and GB (HT).

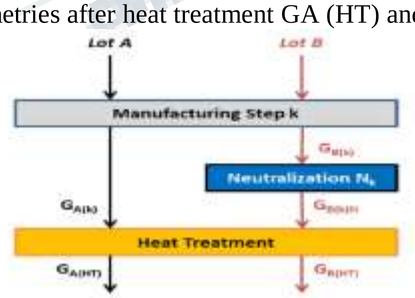


Fig.6 : Experimental principle: two different lots (A, B) are set up after manufacturing step k. Contrary to lot B, lotA is not neutralized.

4.1 Results of experimental procedure:

By comparing shafts from lot Aand Bin Fig., it can be seen that the amplitude of bending after heat treatment is lower for lot Bthat has been stress-relieved between shaving and heat treatment. Actually, shaft bending is almost the same all along the machining process for both lots and even during stress relief for lot B. But after both the lots were sending to the heat treatment process, the variation was observed in the distortion of both the shafts. The lot which was given stress relief treatment showed less amount of distortion compared to the other lot in which there was no stress relief treatment given. Hence at the last step the variation was seen. Thereby the stress relief treatment viz. Shot peening process is recommended before the heat treatment process in the manufacturing cycle.

4.2 Methodology used to reduce residual stress:

Shot peening is a cold-working process used for finishing treatment to produce a compressive residual stress layer and modify mechanical properties of metals. In this process, the surface of a component is bombarded with a multitude of small hard spherical shots moving at high velocity. As a result of the collision of the shot with the surface of the component, an indentation is created which is surrounded by a plastic region followed by an elastic zone. Upon the rebound of the shot, the recovery of the elastic zone creates a large compressive residual stress in the surface. The magnitude of these residual stresses and the depth of the layer containing these stresses are a function of the process parameters set for the operation.

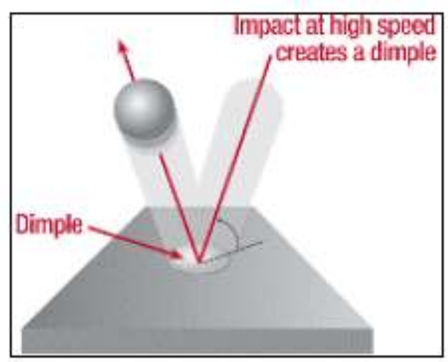


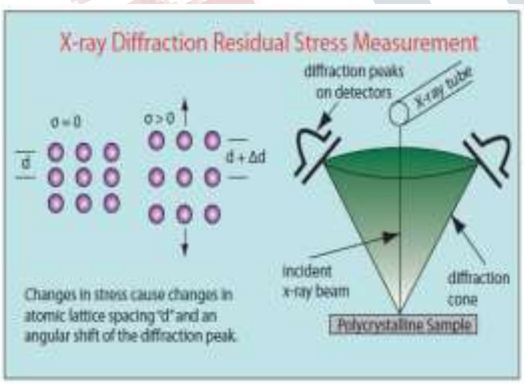
Fig.7: Shot peening process

Shot peening is one of the most effective mechanical surface treatments generally applied to improve fatigue life of engineering components. Shot peening is carried out to postpone the crack initiation or reduce the propagation rate. In shot peening, a target is peppered using small spherical shots with a velocity of 20–100 m/s. The outcome is a compressive residual stress field beneath the surface of metallic components.

In order for the dimple to be created, the surface fibers of the material must be yielded in tension. Below the surface, the fibers try to restore the surface to its original shape, thereby producing below the dimple, a hemisphere of cold-worked material highly stressed in compression. Overlapping dimples develop an even layer of metal in residual compressive stress. It is well known that cracks will not initiate or propagate in a compressively stressed zone. Since nearly all fatigue and stress corrosion failures originate at the surface of a part, compressive stresses induced by shot peening provide considerable increases in part life. The maximum compressive residual stress produced at or under the surface of a part by shot peening is at least as great as half the yield strength of the material being peened. Many materials will also increase in surface hardness due to the cold-working effect of shot peening.

4.3. X-Ray diffraction method to calculate the residual stress:

X-ray diffraction can be used to measure residual stress using the distance between crystallographic planes, i.e., d-spacing, as a strain gage. When the material is in tension, the d-spacing increases and, when under compression the d-spacing decreases. Stresses can be determined from the measured d-spacing. X-rays diffract from crystalline materials at known angles 2☐ according to Bragg's Law: $n\lambda = 2d\sin\Theta$



Where: n = order of diffraction
λ= wavelength of the x-ray beam
d = distance between lattice
planes inside the material
Θ= angle of the diffracted beam

V. CONCLUSION

The stress relief process by shot peening appears as a manufacturingstep which does not affect shaft bending directly but enables to decrease bending during heat treatment. Thus, applying a stress relief decreases the level of residual stress that has been stored into the material all along the process. Moreover, it does not lead to shaft bending but decreases the future bending due to heat treatment. In other words, shaft bending has an advantageous influence on the distortion potential regarding the carrier "residual stress". Hence shot peening process before the heat treatment process is recommended, which results in reducing the residual stress and there by leads into less deformation of axle drive shaft.

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