

STRESSTECH BULLETIN 9

Distortion and Residual Stresses

Distortion is the unexpected, uneven change in size or shape caused by dissimilarities in manufacturing and heat treatment processes. Distortion is affected by material properties, part geometry, the size of the component and the most importantly the residual stress state of the component.

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Residual stresses can be strong enough to exceed the yield strength of the material. Once the yield strength is exceeded, plastic deformation as a shape change will occur. Heat treatment is one of the most common methods which is applied to relieve the residual stresses. However, it is not always possible to reduce them below the yield strength of the material which will cause the distortion.

The volume changes due to phase transformations may also create strong residual stresses which may exceed the yield strength and cause distortion. When the part is heated then rapidly cooled, austenite which has a densely packed, face-centered cubic (fcc) structure

transforms into martensite which has a loosely packed, body-centered tetragonal (bct) structure.

The transformation causes an expansion in the volume of the material which creates more space for carbon atoms to fill. A structure with high carbon percentage forms residual stresses and becomes a distorted lattice structure.

In their article, Prof. Dr.-Ing. H.-W. Zoch and Dr.-Ing. Thomas Lübben described the factors which contribute the distortion problem on a manufacturing process of a typical component for the transmission industry. Their study gives examples of distortion potential of individual processes and factors such as part geometry,

microstructure, residual stresses, history of machining and heat treatment.

The causes of distortion during manufacturing and heat treatment processes can be investigated in few categories.

- 1. Before heat treatment:** Material properties such as the composition, homogeneity and strength affect the mechanisms of distortion. The magnitude and the distribution of residual stresses also affect the distortion prior the heat treatment. Stress raisers such as sharp corners also contribute the distortion, so the design and geometry of the part are also important parameters. Fillets should be used in the design to distribute the stresses to a wider area. When stress raisers are combined with residual stresses, distortion and warpage may become stronger. Buckling is also a form of distortion that is caused by residual stress.
- 2. During preheating for heat treatment:** In this step, shape changes occur due to relief of thermal stresses. Any volume change due to phase transformation can contribute to distortion formation.
- 3. During surface hardening:** Any volume change due to phase transformation can again contribute to distortion formation when the temperature is high and constant for a long time. Depending on the creep strength and the geometry of the material, high temperatures especially the elevated temperatures may cause metal creep. Distortion due to creep is common in long and flat parts.

4. During quenching and cooling: Cooling characteristics such as the type of quench media, non-uniform cooling gradients, cooling rate affect the distortion characteristics. Surface roughness is another parameter which has a connection with distortion during quenching and cooling period. Surface roughness contributes the crack formation due to distortion.

5. During post-quenching processing: Straightening by flexing or peening of the part may be necessary to reduce the distortion. Distortion often occurs when the part is cooled down; straightening can even reduce the crack formation when the part is still hot. Reheating the part may also reduce the distortion by increasing the dimension stability.

As it can be found in several studies, residual stresses are one of the main contributors of distortion problem together with many other factors. Measurement and evaluation of residual stresses are beneficial to understand the root causes of distortion problem.

Stresstech is a research oriented company with more than 30 years' experience in residual stress engineering and stress evaluation. Feel free to contact us to learn more about residual stresses and their evaluation.

www.stresstech.com

Sources

“Distortion of Heat-Treated Components”, Michiharu Narazaki and George E. Totten

“Distortion Engineering - a New Concept to Control Distortion Problems”, H.- W. Zoch, Th. Luebben, Stiftung Institut fuer Werkstofftechnik, Bremen, Germany. Proceedings from the 6th International Quenching and Control of Distortion Conference

“Residual Stress and its Measurement Techniques”, Murat Deveci