ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 2, February 2017

Analysis of Distortion of Steel in Heat Treatment

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Abstract: The examination of this paper gives an outline to study the impact of warmth treatment on various metals by utilizing three diverse cooling media. Heat treatment is a complex process of multi physics. Heat transfer is the driving phenomenon because the other phenomena are accelerated by it. Heat treatment is an activity or arrangement of tasks including heating and cooling of a metal or a compound in the state so as to achieve the ideal change in the physical properties of a metal, Air, Water, and Oil. The examination was finished by programming Simufact. Forming for a chamber to anticipate heat treatment stress and bending. The examples of this examination are low, medium and high carbon steel. It has been seen from the investigation that volume diminishes and remaining stresses create because of warm angle. This paper will help to foresee the necessary remittance of disfigurement because of warmth treatment to accomplish wanted dimensioned object without machining.

Keywords: Heat treatment, Simulation, Cooling medium, Distortion, Residual stresses, Microstructure.

INTRODUCTION

Heat treatment is an operation or series of operations involving heating and cooling of a solid-state metal or alloy to achieve the desired change in a metal's physical properties. Complex thermal behaviors produce significant thermal, residual stresses that lead to cracking and distortion during heat treatment. Heat treatment is a complex process involving multi-physics. Heat transfer is the driving phenomenon as it accelerates the other phenomena. The key factor that engineers can change in many cases is heat transfer to the quenching medium**.** Heat transfer from the surface depends primarily on thermodynamic processes and fluid flow at the liquid-solid interface. Temperature variation is the main driving factor for phase transformations. Due to the change in thermodynamic stability of the initial phases, phase transformations occur on heating and cooling. Phase transformations change the temperature gradient due to the transformation's latent heat. Complex parts with different cross-sections will go through a non-uniform austhenization that is the main cause of distortion. Because non-uniform cooling causes non-uniform transformation of the liquid, during quenching it contributes to distortion. Due to the microstructure transformation during heat treatment, the dimensional change or deformation occurs [1] [2].

Simulation is a highly effective and useful tool for predicting the formation of stress and distortion during heat treatment. Simufact forming is known as the advanced software most widely used to solve stress heat treatment and distortion problems. Application of this study highlights the laws of mechanical and metallurgical behavior. The failure of heat-treated steel is calculated using parameters such as stress, stress and volume. Comparison was made between the predicted results and the measured results. The simulated and experimental values that prove the validity of the simulation tool used almost

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ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
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coincide. Thermal stresses are created by the variation of mechanical properties with low and high temperature gradients in the heat-treated component. Various cooling rates lead to differing thermal contractions at different points. This contraction is balanced by an internal stress state. Cooperation and competition between thermal and phase transformation strains results in a variable internal stress field that can cause cracking under certain conditions. The material properties depend significantly on the percentage of carbon. Heat treatment causes the outer surface to deform more than the core [3].

During the heat treatment of metals, cracking and distortion are considered the most vital issues. While the relative cost of compensating heat treatment problems per component depends mostly on the history of manufacture, specifications and material used, the cost of losses due to heat treatment is usually quite high. Usually, extreme cracking and distortion are irredeemable and pre-heat treatment losses include production costs. In addition, heat treatment requires relatively large amounts of energy, longer processing times and higher emissions of CO_2 (carbon dioxide) compared to conventional production methods. Once again, demand for sustainable and green manufacturing requires manufacturers to think more about improving the heat treatment efficiency. If we need to achieve the desired mechanical properties and permissible residual stresses, efficient furnace management is not easy without this knowledge. Modeling heat treatment affects the discomfort of a casting that is hard to get.

The computer simulation of heat treatment processes has proven over the past few years that it can be a powerful tool to achieve some heat treatment goals. Visual evidence, for the most part, cannot determine the presence of burning as well as overheating. The residual stresses generated cause cracking, distortion, and ultimately cause quenched parts to fail. To examine the service performance of the parts, the metallurgical laboratory is required. Therefore, during the heat treatment, machine designers and foundry engineers need to take into account the manufacturing problems and difficulties. Due to the increasing field demand of the subject in industry and academia, several attempts have been made in recent past to simulate heat treatments. Therefore, simulations of heat treatment can be very useful in addressing the needs of tool engineers, foundry engineers. Because they can design more efficient and innovative heat treatment systems that reduce trial and error processes and can make more economical use of heat treatment resources [4].

METHODOLOGY

Simulation Process:

Dimensions as shown in Fig.1 has been used for the simulation process. The simulation model used for the process is Simufact forming. The initial volume of the sample is 16076.86 mm^3.

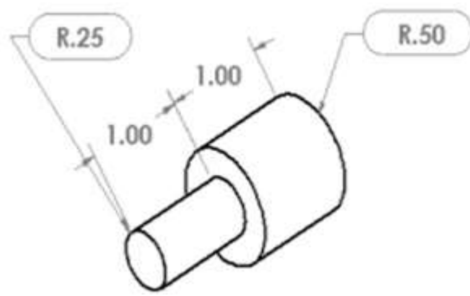

Fig.1: Model Dimension

The materials used in the simulation are given in the Table.1 with their composition.

Table.1: Percent Composition of Different Materials

Material	Composition%		
	AISI 1016	AISI 1070	AISI 1095
Fe	97.12-98.47	97.2-97.7	97.28-97.7
C	0.12-0.17	0.64-0.65	0.89-1.02
Mn	0.56-0.89	0.59-0.89	0.29-0.49
P	0.038	0.040	0.039
S	0.050	0.049	0.049

The heat treatment process is illustrated as shown in Fig.2. Initially, the specimen is heated to a temperature of 900 ° C for 1⁄2 hour, then isothermally held there for 1 hour and then cooled in mediums (air, water, and oil) at a temperature of 25 ° C for 3 hours. Thus the process of heat treatment is cyclically done. As shown in Fig.3, the representation of the

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heat treatment effect in this simulation can be observed [5].

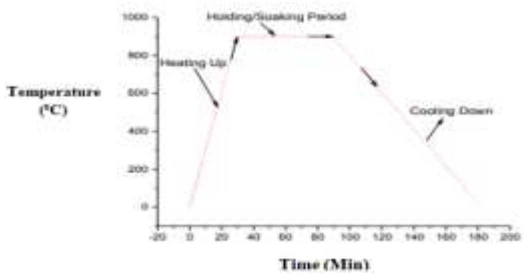

Fig.2: Heat Treatment Cycle of Process Model

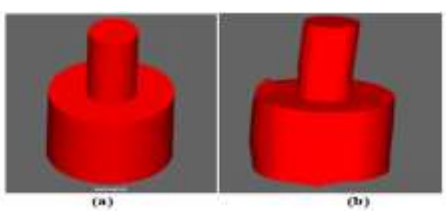

Fig.3: (a) Pictorial Diagram of the Object before Heat Treatment, (b) Pictorial Diagram of the Object after Heat Treatment

In this simulation, the finite element method (FEM) is used as shown in Fig.4. The material is attached to an FE-element in this process and as it deforms, the FE-element deforms with it. The precision of solutions in hexahedral meshes is the maximum for the same amount of cells. The mesh form used in this simulation is therefore Hexmesh with a minimum of 0.75 mm hexahedral components.

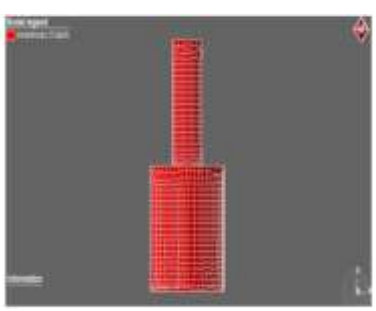

Fig.4: Finite Element Model Used to Simulate the Specimen Model

RESULTS ANALYSIS AND DISCUSSION

The outer surface will be cooled faster than the core during the immersion of a heated steel piece into a liquid quenching medium. If the surface cooling rate is higher than the Critical Cooling Rate (CCR), then marten site is formed in the surface and pearlite is formed due to the slower core cooling rate. Strong marten site forms on the surface due to the pressure expansion. Hot and ductile austenite should remain in the inner part. And then the remaining austenite transforms into a marten site that causes volumetric expansion. However, the outer hard layer obstructs volumetric expansion. Because of this limitation, the central portion of the surface is under compression. The normal expansion will be limited by the middle portion's compressive force. The effect is a decrease in the number.

Due to thermal gradients and volume contraction, residual stress is produced at the end of the cooling. Even though the material hits a balance of power. This retained stress also increases due to the increase in thermal gradient with the increase in the thickness of the component. The major impacts of residual stress, as shown in Table 2, cause dimensional changes. Typically, dimensional changes occur when a body's retained tension is removed. In terms of crack initiation, residual stresses may be permitted depending on the nature of the force. When an external force is applied to a heat-treated component, residual stresses algebraically sum up the stresses developed. The residual compressive stresses developed in the surface are usually helpful because the compressive stresses can reduce the effects of the tensile stresses applied which can cause cracking or failure [6].

Resist the cracking of stress-corrosion in the component. Residual tensile stresses effectively increase the surface stress level. Thanks to the combined effect of stress and environment, it can be a source of stress-corrosion cracking. If the residual stress exceeds the stress of yield, then there will be plastic deformation. If the local ultimate tensile strength is surpassed by this stress, cracking may occur. If the total value of the strain exceeds the true strain at the value of the fracture, the strain will cause fracture. Table 3 shows the total pressure. Cracks are actually formed when the localized strain exceeds the material failure strain [3] [7].

Table.2: Volume Reduction (%) and Residual Stress from Simulated Data

Material	Cooling Medium	Final Volume (mm^3)(Simulated)	Percentage of Volume reduction	Simulated Residual Stress (MPa)
AISI 1016	Air	16031.6	0.2764	5276.14
	Water	16018.2	0.327	65170.9
	Oil	16015.7	0.370	6548.62
AISI 1070	Air	15889.67	1.165	11207.6
	Water	15805.23	1.640	12281
	Oil	15820.35	1.50	12118.9
AISI 1095	Air	15717.27	1.581	15207.5
	Water	15688.29	1.765	16286.62
	Oil	15672.35	1.605	17127.8

Table.3: Total Strain for Material in Different Quenching Medium

Material	Cooling Medium	Total Strain
AISI 1016	Air	0.435
	Water	0.56
	Oil	0.93
AISI 1070	Air	1.88
	Water	2.23
	Oil	2.64
AISI 1095	Air	1.70
	Water	2.87
	Oil	2.81

From the fig. 5 it is seen that the importance of the str ain is also increased with the rise in carbon content [8].

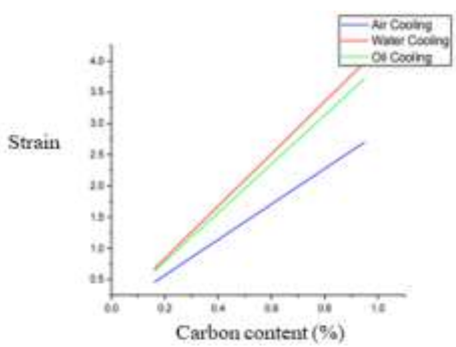

Fig.5: Variation of Strain with the Increase of C Content in Percentage (%)

CONCLUSION

The analysis gives the result due to the phase transformation of the complexities associated with the formation of residual stresses. From the analysis, volume decreases due to heat treatment was observed. Other parameters have also changed effectively, such as residual stress, strain, shear stress. Comparisons have been made for various cooling media and materials. A straight line that synchronizes the theoretical curve is the curve observed from the simulated data obtained. This research should help to improve the accuracy of the critical shaped model. We can predict the load power, cracking and distortion of the heat treated specimen by analyzing results and optimizing them.

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International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
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