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Numerical Study And Optimization Of Heat Treatment Processing Annealing

GEETA
M.Tech Student in Department of Mechanical Engineering, PDA College of Engineering Kalburgi District, Karnataka, India.

Dr. M C NAVINDGI
Associate Professor, Department of Mechanical Engineering & Coordinator PG(TPE), PDA College of Engineering Kalburgi Karnataka, India.

Abstract: **In this project work the simulation of heat transfer and the temperature curve in the furnace is computed out using Fluent and fluent software. Comparison of temperature profiles of the material in the furnace using constant temperature heat source and linearly varying temperature of the heat source for unsteady state is done. Also the time for temperature to become steady is compared. The material used in the furnace is aluminum and conduction is the mode of heat transfer, the side walls are adiabatic and maintained at ambient temperature. Also the density variation and solidification-melting curve of material filled inside are compared for both conditions. The Pocess used is a heat treatment process most of the heat treatment process uses furnaces to perform the melting operation therefore we choosed annealing process to be used in this analysis process .**

FLUENT is a computational fluid dynamics (CFD) software package to simulate fluid problems. It uses the finite-volume method to solve the governing equations for a fluid. It provides the capability to use different physical models such as incompressible or compressible, in viscid or viscous, laminar or turbulent, etc. Geometry and MESH generation is done using FLUENT which is the preprocessor bundled with FLUENT.

I. THE MINIATURIZATION

HEAT UP processing is the basic step for the workload in melting and heattreatment for further processing. It is also an energy-intensive process. Thus, correct prediction of the temperature variation and distribution in the workload is of significance to ensure the final quality of the parts and to reduce energy consumption and time as well.

There are some studies about the optimization of heat treating process in furnace. FurnXpert'11 is developed to optimize furnace design and operation for many types of batch and continuous furnaces, such as the continuous belt furnace for sintering process in powder metallurgy. The program mainly focuses on the heat balance of the furnace, while, the load pattern of work pieces is just aligned load pattern in 2-dimention.

Han Xiaoliang [21 established mathematical model for the heating of workpiece in bogie hearth heat treatment furnace, while, the workpiece is assumed to be one dimensional and only single workpiece is considered.

Wan Nini [31 studied the heating up of steel tubes in continuous furnace annealing furnace. The influence of moving speed and thickness of steel tubes are studied. The heat transfer is also assumed to be one dimensional and the load pattern is simply aligned in the width direction. In the heat treatment of parts such as castings and forging, the load pattern is complicated with multi parts stacked in order or disorder and the shapes of work pieces are also irregular. Then it is necessary to model the heat transfer inside the workload.

In recent years, the computational fluid dynamics (CFD) based on conservation equations has become a viable technique for process simulation So in this work we are going to compute the temperature profile generated Using CFD and FLUENT for a given temperature source, it can help to Compute the energy required and to optimize it.

BASICS OF FURNACE:

A furnace is a device used for heating. The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through Induction heating in induction furnace

Industrial process furnaces: -

An industrial furnace or direct fired heater is equipment used to provide heat for a process or can serve as reactor which provides heats of reaction. Furnace designs vary as to its function, heating duty, type of fuel and method of introducing combustion air. However, most process furnaces have some common features.

Fuel flows into the burner and is burnt with air provided from an air blower. There can be more than one burner in a particular furnace which can be arranged in cells which heat a particular set of tubes. Burners can also be floor mounted, wall mounted or roof mounted depending on design. The flames heat up the tubes, which in turn heat the fluid inside in the first part of the furnace known as the radiant section or firebox. In this chamber where combustion takes place, the heat is transferred mainly by radiation to tubes around the fire in the chamber. The heating fluid passes through the tubes and is thus heated to the desired temperature. The gases from the combustion are known as flue gas.

After the flue gas leaves the firebox, most furnace designs include a convection section where more heat is recovered before venting to the atmosphere through the flue gas stack.

HEAT TREATMENT PROCESS

Annealing, in metallurgy and materials science, is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable. It involves heating a material to above its recrystallization temperature, maintaining a suitable temperature, and then cooling.

In annealing, atoms migrate in the crystal lattice and the number of dislocations decreases, leading to the change in ductility and hardness.

In the cases of copper, steel, silver, and brass, this process is performed by heating the material (generally until glowing) for a while and then slowly letting it cool to room temperature in still air. Copper, silver[1] and brass can be cooled slowly in air, or quickly by quenching in water, unlike ferrous metals, such as steel, which must be cooled slowly to anneal. In this fashion, the metal is softened and prepared for further work—such as shaping, stamping, or forming.

Thermodynamics

Annealing occurs by the diffusion of atoms within a solid material, so that the material progresses towards its equilibrium state. Heat increases the rate of diffusion by providing the energy needed to break bonds. The movement of atoms has the effect of redistributing and eradicating the dislocations in metals and (to a lesser extent) in ceramics. This alteration to existing dislocations allows a metal object to deform more easily, increasing its ductility.[citation needed]

The amount of process-initiating Gibbs free energy in a deformed metal is also reduced by the annealing process. In practice and industry, this reduction of Gibbs free energy is termed stress relief.[citation needed]

The relief of internal stresses is a thermodynamically spontaneous process; however, at room temperatures, it is a very slow process. The high temperatures at which annealing occurs serve to accelerate this process.[citation needed]

The reaction that facilitates returning the cold-worked metal to its stress-free state has many reaction pathways, mostly involving the elimination of lattice vacancy gradients within the body of the metal. The creation of lattice vacancies is governed by the Arrhenius equation, and the migration/ diffusion of lattice vacancies are governed by Fick’s laws of diffusion.[2]

In steel, there is a decarburation mechanism that can be described as three distinct events: the reaction at the steel surface, the interstitial diffusion of carbon atoms and the dissolution of carbides within the steel.[3]

Stages

The three stages of the annealing process that proceed as the temperature of the material is increased are: recovery, recrystallization, and grain growth. The first stage is recovery, and it results in softening of the metal through removal of primarily linear defects called dislocations and the internal stresses they cause. Recovery occurs at the lower temperature stage of all annealing processes and before the appearance of new strain-free grains. The grain size and shape do not change.[4] The second stage is recrystallization, where new strain-free grains nucleate and grow to replace those deformed by internal stresses.[4] If annealing is allowed to continue once recrystallization has completed, then grain growth (the third stage) occurs. In grain growth, the microstructure starts to coarsen and may cause the metal to lose a substantial part of its original strength. This can however be regained with hardening.[citation needed]

Controlled atmospheres

The high temperature of annealing may result in oxidation of the metal’s surface, resulting in scale. If scale must be avoided, annealing is carried out in a special atmosphere, such as with endothermic gas (a mixture of carbon monoxide, hydrogen gas, and nitrogen gas). Annealing is also done in forming gas, a mixture of hydrogen and nitrogen.The magnetic properties of mu-metal (Espey cores) are introduced by annealing the alloy in a hydrogen atmosphere.

Setup and equipment

Typically, large ovens are used for the annealing process. The inside of the oven is large enough to place the workpiece in a position to receive maximum exposure to the circulating heated air. For high volume process annealing, gas fired conveyor furnaces are often used. For large workpieces or high quantity parts, car-bottom furnaces are used so workers can easily move the parts in and out. Once the annealing process is successfully completed, workpieces are sometimes left in the oven so the parts cool in a controllable way. While some workpieces are left in the oven to cool in a controlled fashion, other materials and alloys are removed from the oven. Once removed from the oven, the workpieces are often quickly cooled off in a process known as quench hardening. Typical methods of quench hardening materials involve media such as air, water, oil, or salt. Salt is used as a medium for quenching usually in the form of brine (salt water). Brine provides faster cooling rates than water. This is because when an object is quenched

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in water air bubbles form on the surface of the object reducing the surface area the water is in contact with. The salt in the brine reduces the formation of air bubbles on the object's surface, meaning there is a larger surface area of the object in contact with the water, providing faster cooling rates.[citation needed] Quench hardening is generally applicable to some ferrous alloys, but not copper alloys.

Diffusion annealing of semiconductors

In the semiconductor industry, silicon wafers are annealed, so that dopant atoms, usually boron, phosphorus or arsenic, can diffuse into substitutional positions in the crystal lattice, resulting in drastic changes in the electrical properties of the semiconducting material.

II. LITERATURE REVIEW

This chapter provide a literature reviews with relations to the past research effort such as journals or articles related to combustion process, effect of air/fuel ratio on combustion efficiency of LPG fuel and computational fluid dynamics (CFD) analysis whether on two dimension and three-dimension modelling. Moreover, reviews on other relevant studies are made in order to relate to our project.

Mathematical Modelling of NOx Emission from High Temperature Air with Nitrous Oxide Mechanism

Previous studies show that the modelling of NOx emission in term of excess air ratio and temperature distribution. Figure 2.1 depicts the results from experimental measurement and simulation prediction. The experimental results were taken at the burner outlet and the chimney of the furnace. The graph is based on effect of excess air ratio which consists of actual measured results, predicted simulation result with N_2O route and predicted simulation result without N_2O route. The simulation result without the N_2O route is lower than both of measured and prediction with N_2O route. The reason is that when the N_2O route is not present, the simulation assumed that mixing rate was considered complete at excess air ratio equal to 1.04 which allows no formation of NO. As the excess air ratio increases, the temperature increases to which point it allow the simulation to predict the value of NO emission. The simulation with N_2O route shows that NO was formed at lower excess air which corresponds to the measured experimental result which shows NO formation at every excess air ratio. When comparing with experimental data, the model with N_2O route shows a very good agreement when excess air ratio is equal or less than 1.15. On the other hand, when excess air ratio is equal to 1.25, NO emission is almost two times higher than experimental data. [9]

The result is related to Figure 2.2 which shows the experimental data on the effect of excess air ratio o the maximum temperature, the graph shows that with increasing amount of excess air ratio will increase the maximum temperature of the furnace. It is in fact that oxygen concentration in reaction zone increases as excess air ratio increase which results in a higher flame temperature [9]. It is worth to note that the furnace model used was semi industrial furnace with HiTAC system compared to the one used in this study. Nonetheless, the parameter applies to furnace and combustion chamber in general. Therefore, the results from the literature can be used as base for this project.

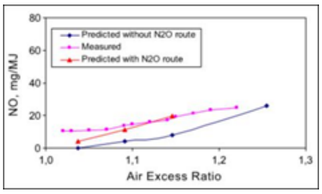


Figure 2.1: Effects of excess air ratio on NO emission.

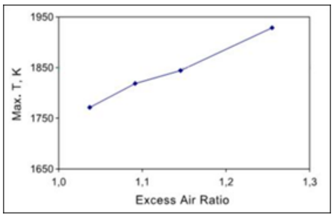


Figure 2.2: Effect of excess air ratio on maximum temperature.

Effects of NO Model on the NO Formations

In order to further understand the effects of the NO model on NO formation and destruction inside furnace or combustion chamber is by investigating temperature profiles as shown in Figure 2.3 which the cross section of the furnace at different excess air ratio. There is usually large chemical reaction zone in all case which can be verified by experimental studies. The highest temperature usually occurs at the middle of the furnace which is where the flame situated. This literature uses HiTAC burner which mix the fuel and combustion air at initial stage of the combustion which also the sameOperationfor the C492 gas burner that is used in this study. The combustion product is entrained into the root of flame because of high injection momentum which reduces the oxygen availability in the primary combustion zone. The unburnt fuel that escaped the primary combustion zone gradually mixed with air to complete the combustion, resulting in more uniform temperature profile. So that, the production rate of NO is lowered. [9]

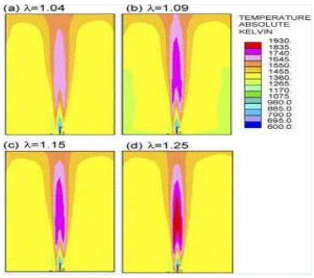
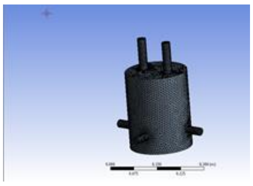


Figure 2.3: Temperature distribution at the cross section through fuel and one airnozzle in the test furnace at different excess air ratio (λ).

The literature concludes that they developed the N_2O route in order to predict the NO formation and emission inside combustion chamber. The results show that the NO emission formed by N_2O intermediate mechanism is important in furnaces that have low peak temperature. Moreover, the increasing excess air ratio leads to increasing NO emission under high temperature air combustion condition.

III. METHODOLOGY

In order to create a suitable model to run in FLUENT software, pre-design geometry must be created to match with the needs of FLUENT. Therefore, FLUENT which is a geometric modelling and grid generation tool is provided along with the FLUENT technology. FLUENT allows the user to import geometry from other designing software or computer-aided design (CAD) software or create own geometry entirely based on FLUENT itself. In addition, FLUENT can automatically mesh surfaces and volume while allowing the user to manipulate the mesh through size functions and boundary layer meshing.



RESULTS

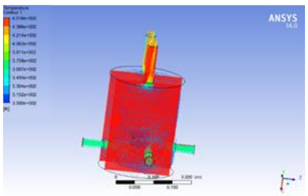


Fig 4.2: Contours of the temperature

As u can observe From the above picture the temperature inside the furnace is at maximum The coloured representation of the model is known as contour the bar left side of the picture is called legend From blue to red Blue colour indicates minimum temperature and red colour indicates maximum temperature.

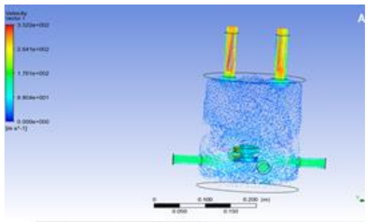


Fig 4.3: Contours of the velocity

The above Figure is the vector Representation the Velocity Distribution inside the Furnace From the legend We can Say that the blue colour indicates the minimum Velocity and the Red Colour indicates the maximum velocity and transition of colours play according role as per the value

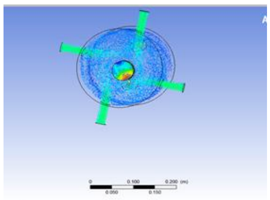
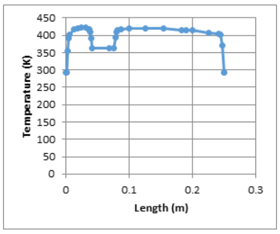


Fig 4.4: Velocity vector representation

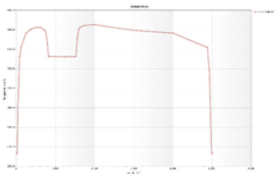
From the Bottom view of the Furnace we can say that the Vortex is formed At the Work piece area when the gas is sent through the inlets due to these vortices the flow is irregular and turbulent through out the process

Graphs and Plots



Graph 4.7.1:Temperature along axis of the furnace at time moment 100s

The above plot represents the length in x-axis and the Temperature in y axis The behaviour of the curve is technically explained as the sudden drop and sudden raise in temperatures noted in the graph is for the workpiece at 100 sec during the annealing process the heat treatment process is slowed down at this frame of time to due solidity of workpiece



Graph 4.7.2 Temperature along the axis of the furnace at time moment 900s

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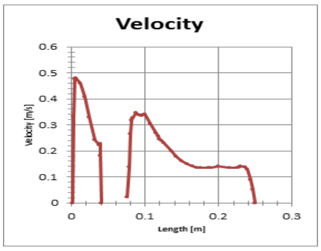
The above plot represents the length in x-axis and the Temperature in y axis The behaviour of the curve is technically explained as the sudden drop and sudden raise in temperatures noted in the graph is for the workpiece at 900 sec during the annealing at this time frame the temperature is absorbed by the work piece and the lower temperature gas is sent out of the outlet



Graph 4.7.3 Velocity along the axis of the furnace At time moment 900s

The above graph represents the Velocity Distribution of the Gas inside the Furnace in the plot X-axis represents the Length in (m) and in y axis the Velocity in m/s Non linearity in the graph is because of the Solidity in Work piece

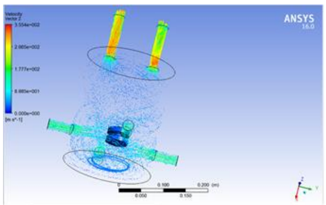


Fig4.7.14: Velocity stream line profiles

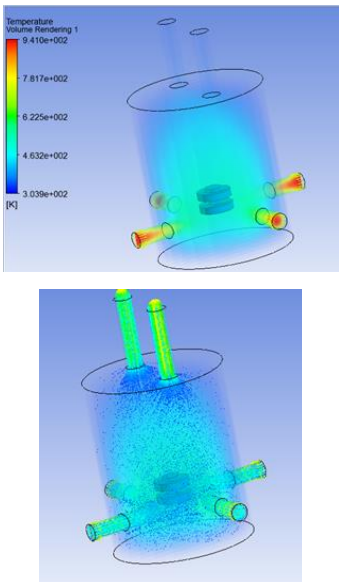


Fig4.8.15: Flame propagation and heating fluid flow patter around the work piece

The flame propagation and the Heating Fluid flow pattren is the key to observe the behaviour of the Fluid The uniform distribution of the flow in the pipes results in the distribution of uniform velocity to the work piece.

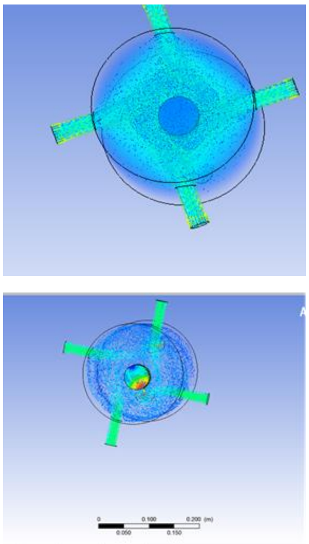
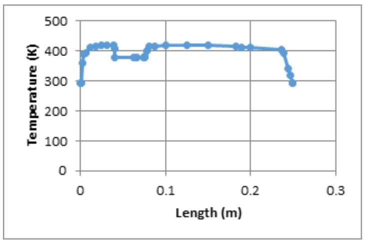


Fig4.8.16: Heating fluid flow pattern at the bottom of the work piece.



X-y Plot of temperatureat 900 sec

The above plot represents the Length Vs temperature Plot at the particular time frame therefore the Temperature at out let is recorded to be high in this case due to more vorticity in the Flow

IV. CONCLUSION

The results obtained by simulation are documented as above. The heating profile was reasonably predicted by the simulation. Through the CFD simulation, not only the surface temperature could be properly predicted, but also the temperature within the metal components could be simulated. The latter is crucial for the heat treatment process, but is not possible to measure directly in practice. The results obtained by us are found to be in acceptable limit (+ 5%). This indicates and extremely accurate range. Hence it is proved that method of analysis used for the current paper is accurate and can now be applied to an industrial annealing furnace.

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AUTHOR BIOGRAPHY

GEETA was born in Kalaburagi District, Karnataka, India in 1990. She received the B.E degree in mechanical Engineering from Basaveshwar engineering collage Bagalkot . Pursuing M.Tech degree in Thermal Power Engineering from PDA College of Engineering Kalaburagi, Karnataka, India

Dr. M C Navindgi: Received the PhD degree from JNTU. Currently working as Associate Professor in Department of Mechanical Engineering, and Coordinator PG (Thermal Power Engineering) in PDA College of Engineering, Kalburgi, Karnataka, India. He has published many research papers in national and international journals. Paper

