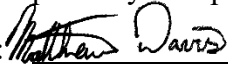


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Certification of Authorship: I certify that I am the author of this paper and that any assistance I received in its preparation is fully acknowledged and disclosed in the paper. I also have cited any sources from which I used data, ideas, or words, either quoted directly or paraphrased. I certify that this paper was prepared by me specifically for the purpose of this assignment, as directed.

Student's Signature:  _____

Creating a Way to Track Nonconforming Parts During the Heat Treatment Process

Matthew A. Davis

Concordia University Chicago

Abstract

The purpose of this project is to review and analyze current heat treatment industry quality control standards and systems to track nonconforming materials through the heat treatment process to better understand how an application might be created to identify and track nonconforming materials. Heat treatment process database management systems collect, categorize, and store data regarding a variety of the variables applied to finished materials undergoing the heat treatment process, such as: furnace temperature rate, carbon rate, RX gas rate, quench oil temperature, time tables in reference to each cycle within the heat treatment process, tempering furnace temperature rate, and washer water temperature rate. A composition and thorough analysis of this data in aggregation could potentially be utilized to create an algorithm to identify and detect when finished materials will not conform to quality control specifications after the heat treatment process. In order to create this algorithm, extensive research should be conducted concerning the heat treatment process, and the reasoning and rational behind the root causes of nonconforming finished materials conforming to quality control specifications must be identified. Once these variables have been identified and established then an algorithm utilizing the data already collected and stored within current heat treatment database systems can be created to track when finished materials do not conform to quality control specifications. Based on evidence, this piece utilizes archival and secondary data research to address concerns within the industry regarding nonconforming materials tracking through the heat treatment process and provides a proposed solution in the form of an algorithm and subsequent application to allow quality control technicians to interface with that algorithm.

Chapter 1 - Creating a Way to Track Nonconforming Materials

Heat treatment process data-acquisition systems and database management systems collect, categorize, and store all of the information related to materials undergoing the process. However, there has yet to be an algorithm written, or application designed to run and interface with that algorithm, that utilizes and comprehends the data collected by these database management systems in a way that is beneficial beyond the review of the data. Such an algorithm, and subsequent application would allow quality control technicians monitoring the process to know whether materials undergoing the process are suspect before quality control checks are conducted. This could potentially save the heat treatment industry millions of dollars a year spent on keeping, supplying, equipping, and maintaining quality control standards and practices within the industry; as well as reduce the number of scrap materials and materials required to undergo a rerun cycle through the process due to not meeting quality control specifications. Very little research studies have explored the aforementioned algorithm and subsequent application to access that algorithm outlined in this piece. Therefore, utilizing archival and secondary research, this piece outlines, and summarizes, research conducted by those within the heat treatment industry regarding quality control techniques, methods, and standards; the advancement of technology and software within the industry; and modeling and simulation of materials undergoing the process to ascertain whether an algorithm and application can be potentially created.

With rising costs of energy, slimmer profit margins and tighter specifications on product quality, the metals-processing industry continues to look for ways to increase productivity and reduce costs (Fotopoulos, 2007, para. 1). The ultimate goal of any company, small or large, within any industry is increasing productivity levels and reducing the costs of manufacturing a

product in order to create a larger profit margin. Quality control is an important aspect in any industry. In education quality control is ensuring that students understand and retain the concepts being taught during the duration of a course. Some examples of the quality control methods in this industry consist of student testing, class discussions, personal projects, and written assignments. In the food service industry quality control is certifying that food is stored and prepared to company, customer, and regulatory standards and specifications. Some examples of the quality control methods in this industry consist of regular visits from the local health inspector, regular maintenance and standard checks from employees regarding kitchen equipment and overall cleanliness of food preparation areas, as well as continually assessing customer satisfaction based on a number of factors. In the heat treatment industry quality control is guaranteeing that materials undergoing the process are consistent and uniform in attributes and characteristics. The quality control processes in the heat treatment industry can be subdivided into two different categories. The first is regarding the efficiency of equipment and the second is in regard to materials undergoing the process. Continual equipment testing, monitoring, analysis, and inspection is essential to producing quality materials undergoing the heat treatment process. Like the words to your favorite song playing over and over in your mind, the heat treater's repeating lyric is producing the best quality parts by controlling both equipment- and process-induced variability (Herring, 2016, para. 1). Quality control analysis, in terms of materials undergoing the heat treatment process, consist of surface hardness testing, internal hardness testing, stress testing, effective case depth testing, total case depth testing, retained austenite testing, microstructure testing, among others. This second category of quality is directly affected by the first category. If a heat treatment department's equipment is not functioning to quality control specifications then it stands to reason that the materials undergoing the process will not

meet the specified quality control specifications. This simple, undeniable fact will become a keynote concept described in greater detail later in this piece. Quality is free; low quality (or poor quality) always comes with a price (Beltz, 2017).

Advanced sensor, control and optimization technology has been used successfully to improve productivity and reduce costs in other areas, such as the refining and chemical industries, and can provide similar benefits in the metals-processing industry (Fotopoulos, 2007). There are many working mechanical systems in the heat treatment process including furnaces, quench tanks, washing systems, and tempering furnaces. And within each of these mechanical systems are a multitude of mechanisms that must operate in harmony with one another in order to ensure that the materials undergoing the heat treatment process meet specific quality control specifications. Each of these mechanisms, on each of these mechanical systems must contain an apparatus for quality control technicians monitoring the process to interface with in order to understand if the mechanism is operating and functioning properly. These apparatuses are called data-acquisition systems and according to an article written by Scott Johnstone no one piece of technology in the heat treatment process has seen more change since its inception (Johnstone, 2013). These apparatuses are an essential part of the quality control processes in the heat treatment industry, but how and where is the information collected from these apparatuses stored and utilized? The information collected from these apparatuses are then sent via a networked computer system to an information management system, or database management system. Information systems consolidate, organize, and manage the collection, storage, aggregation, manipulation, dissemination, and management of data (Stephens, 2009, p. 4). Database management systems allow end users, in this case quality control technicians, to access the stored data to be utilized for quality control purposes. Anith S. Larson states that “database

design is the process of translating facts about part of the real world into a logical model” (Larson, 2009). A database management system receives the information gathered by data-acquisition systems and then stores it, categorizes it, and allows quality control technicians monitoring the heat treatment process to access and utilize that information for quality control purposes. Technology has played a major role in nearly all aspects of achieving higher quality and greater efficiency in heat-treating processes (Johnstone, 2013). These two technologies in aggregation, data-acquisition systems and database management systems, have done more to further the goals of improving productivity and reducing costs than any other technology in the heat treatment industry. These technologies will be highlighted and become keynote concepts described later in this piece.

By combining advanced software with a sophisticated engineering background, induction heating professionals possess the unique ability to analyze, in few hours, complex technological problems... (Rudnev, 2011, para. 1). Modeling and simulation of materials undergoing the heat treatment process provide a deeper understanding of the microstructural changes that a material will undergo during the process, and therefore will help predict and ensure that materials meet quality control specifications. According to Dr. Rudnev, modeling and simulation provides the ability to predict how different, interrelated and nonlinear factors may impact the transitional and final thermal conditions, help to determine what must be accomplished to improve the effectiveness of the heat treatment process, and assist in choosing the most appropriate process recipes for materials undergoing the process (Rudnev, 2011). Basically, modeling and simulation of materials undergoing the heat treatment process can provide quality control technicians monitoring the heat treatment process a guide map of how materials should be treated before the process even begins. This type of predictive modeling simulation technology can save heat

treatment operations millions of dollars spent on testing, in scrap costs produced by the process, and in materials requiring a rerun through the process due to not meeting quality control specifications. Later in this piece, predictive modeling and simulation technology will be further highlighted and become keynote concept, as well as be described in greater detail. In a fast-paced global economy, the ability of induction heating manufacturers to minimize time between a customer's request for a quotation and a prepared quote based on efficient computer modeling is critical to their customer's success (Rudnev, Doyon, & Russell, 2013, para. 1).

In congregation, quality control techniques designed to monitor equipment efficiency and material specifications, technologies that have been designed to monitor and store information regarding the heat treatment process, and modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process will provide the basis for the research conducted in this piece. The goal of this piece is to discover whether an algorithm can be produced to track nonconforming materials undergoing the heat treatment process, as well as an application designed to run and interface with that algorithm. In this piece, a thorough study utilizing archival and secondary research of the previously mentioned techniques and technologies is conducted in order to understand whether such an algorithm and application can be created utilizing these techniques and technologies. If such an algorithm and application were designed it could potentially save the heat treatment industry millions of dollars a year spent on keeping, supplying, equipping, and maintaining quality control standards and practices within the industry. This potential solution could also reduce the number of scrap materials and materials required to undergo a rerun cycle through the process due to not meeting quality control specifications.

Chapter 2 - Background

The heat treatment process, while simple by design and by definition, has a long and diverse history. Also, many uncommon terms and concepts are associated with this process. In order to fully understand the research conducted in this piece a thorough outline of its history, importance, procedures, definition, technology, and theory needs to be digested. The following portion of this piece encapsulates this information.

The heat treatment process is as old and ancient as civilization itself. In the *Odyssey of Homer*, written in the 8th century B.C., a passage speaks of a blacksmith tempering ancient weapons utilizing the method, “Just as a smith plunges into cold water some great axe-head or edge and it hisses angrily-for that is the treatment, and the strength of iron lies in its temper...,” (Homer, *Odyssey* 8.518-521). In the Old Testament Book of Daniel, the story of Shadrach, Meshach, and Abednego tells of the king of Babylon, Nebuchadnezzar, throwing them into the fiery furnace for not bowing down to worship the golden idol he had created (Daniel 3, New International Version). And in what is modern day Syria, Damascus Steel was produced with wootz steel imported from India from the 3rd century to the 17th century and was sought the world over for its distinctive pattern, its tough resistance to shattering, as well as its ability to be honed to a sharp, resilient edge (Helmenstine, 2018). Today, the world would not turn without the aid and assistance of the heat treatment process. Without this process the railway and automobile industries would not have proliferated and changed the face of the world, planes would have never taken flight, man would have never gone to space and visited other celestial bodies, and land would have never been cleared to create the great cities and highways that have spread across the globe. Without this process skyscrapers would have never been built, and

computers could not store and access the information utilized in modern society every single day. Without this process food delivered across the world to local grocery stores would be waiting in unharvested fields and pasture lands. And without this process the lifesaving technologies that medical professionals utilize to diagnose and treat the ills of society would not exist. The heat treatment industry has had and continues to have, a significant role to play in the development of modern society.

Since its inception, the heat treatment process has changed a great deal. In a bygone era, blacksmiths utilized the color of the steel they were working with to gauge the temperature of the product, as well as to add the qualities and distinctive characteristics customers buying and using the product required (History of blacksmithing, 2011). Historically, metal workers in the Middle East steel hardened their weapons by barbarically plunging their red-hot swords through the bodies of living livestock to create a hard, tough, and reliable product (Sullivan, 1981). And the medieval tradition in England was that journeymen going into the trade were preferred to have blond hair because it was believed that a blond man's urine when mixed with water for process quenching baths created superior results in the finished product materials (Jayanti, n.d.). There certainly were some strange rituals and creeds during the early inception of the heat treatment industry, but it wasn't until the early 19th century that the art of metallurgy started to become a science. Since then the industry has transformed from craft, tradition, experience, and raw ability into an industry based on well founded and factual knowledge.

Today, the modern heat treatment process utilizes mechanical processing systems, digital computer network systems, data-acquisition systems, and database management systems to control, track, and record information regarding the heat treatment process. In an industrial setting, materials undergo the heat treatment process to acquire the required company, and

customer, specifications to fulfill their intended purposes, and to attain longevity of utilization. This process begins when materials undergoing the process are assembled into groups of types, and characteristics, onto a tray. These groups of parts assembled onto a tray in congregation are what are called a load. Once a load is assembled it is then given a unique numerical and/or alphabetical identifier called a load number. Before the load undergoes the heat treatment process its load number is entered into an database management system that is specifically designed to manage, and keep track of – production planning, scheduling, and inventory controls as materials move through the process. This database management system can also be described as a materials requirements planning (MRP) system, and is used to call for loads needing to be heat treated, schedule which load needs to be loaded in what furnace, and track loads of parts throughout the entire heat treating process, and on into other processes. This database management system also stores recipes for each part number a company produces. Once the load number is entered into this system a recipe is assigned to a load number based on the part number that the load is comprised of. After the load number is in the database management system the load is ready to go through the process.

There are three main stages to the heat treatment process, which include heating, soaking, and cooling; as well as a potential fourth and fifth steps, washing and tempering (Foster, 2011). All five of the stages will be described as follows. After the load number has been entered into the information management system the load is then loaded into a furnace where it is gradually heated to a specified temperature. Then, once the load has reached the specified temperature, the load is held at the specified temperature for a prescribed period of time to allow the load to soak and the substructures of the parts on the load to change and reform based on the characteristics of the final product. Then, the material is cooled utilizing a variety of methods and solutions. These

cooling methods include quenching the material in gases, liquids, solids, or a combination of them to achieve the desired affects and properties. Then, the load is washed, which serves two purposes. The first purpose is to clean the load and the second is to allow the load to cool down gradually to prevent the parts from developing stress cracks. And finally, the load is tempered in order to allow the parts to regain some of their elasticity. As the load is going through the heat treatment process the database management system is sent information from data-acquisition systems via a computer networking system. These apparatuses are designed to allow quality control technicians to understand if a mechanism is operating and functioning properly. These apparatuses, data-acquisition systems, keep track of all the variables associated with the load while in the furnace, the quench tank, the washer, and the tempering furnace. It records this data as simple unquantifiable data. The database management system then stores this information that is sent to it from the data-acquisition systems. Currently, the only way to access this data is to export it as a file, pull it up as a chart or graph within the database management system, or watch the data on the database management system as it recorded.

So, what is the heat treatment process exactly and what does it do? By definition, it is a metallurgical process utilized to customize the physical and chemical properties of a specified material. The manipulation of a material undergoing this process will attain, and then retain, certain aspects during and after the process including hardness, strength, toughness, ductility, and elasticity. There are a variety of methods utilized to attain the required aspects and specifications within materials undergoing the heat treatment process and they are as follows: annealing, surface hardening, normalizing, hardening, and tempering. Each method imparts a unique attribute upon a material undergoing the process. Annealing is used to remove the internal stresses within a material's substructure as well as to toughen the material to prevent wear

(Foster, 2011). Surface hardening, or case hardening, chemically changes and hardens the surface of a material while the core remains chemically unaffected which prevents the material from wear on the surface and allowing the core of the material to remain soft and flexible (Foster, 2011). There are three types of surface hardening: carburizing, cyaniding, and nitriding. In carburizing carbon molecules are infused into the outer case of a material, during cyaniding a material is repeatedly dipped and removed from a cyanide bath, and nitriding is a process by which materials undergo the heat treatment process before being reheat treated in a furnace that has an atmosphere of ammonia gas (Foster, 2011). Normalizing is a process by which a material is heated past its critical temperature for a specified period of time and then air cooled which allows the carbon atoms within the material to disperse and reform into a more uniform pattern and allows internal stresses to be released (Foster, 2011). Hardening is a process by which a material is not only hardened, as the name implies, but is also strengthened by a controlled heating and rapid cooling of a material (Foster, 2011). And lastly, tempering is a process by which heat treated parts are reheated to a specified temperature to relieve brittleness and internal stressing acquired during the process of other methods (Foster, 2011). Some of these methods are utilized in concert with one another to help achieve the perfect balance of form and function.

Basically, the modern heat treatment process is a process by which a material is heated to a specified temperature, the material is then allowed to soak at the specified temperature, and the material is cooled in order to attain certain characteristics and properties within the material. There are multiple methods that can be conducted in order to heat treat a material to attain these certain characteristics. Modern heating treatment systems have facilitated the collection and storage of data throughout the entire process via means of data-acquisition systems and database management systems. This data, however, is currently not being utilized to its full potential.

Right now, the data being collected and stored by database management systems during the heat treatment process is utilized when the materials undergoing the heat treatment process do not conform to company, or customer, specifications. This information is only accessed after materials do not conform quality control specifications. However, this information, along with other factors researched in this piece, could potentially be utilized in congregation to create an algorithm that can track nonconforming materials undergoing the heat treatment process, as well as an application designed to run and interface with that algorithm. If such an algorithm and application were designed it could potentially save the heat treatment industry millions of dollars a year spent on quality control process; as well as reduce the number of scrap materials and materials required to undergo a rerun cycle through the process due to not meeting quality control specifications.

Chapter 3 - Senior Project Process/Method of Investigation

By definition, research is defined as the search for knowledge, and knowledge is further defined as the theoretical or practical understanding of a subject or topic. A research project, such as this one, is written as a mechanism to acquire knowledge to systematically answer or solve the question or problem posed in the hypothesis of such a project. The purpose of this piece is to understand if an algorithm, as well as an application to run and interface with that algorithm, can potentially be created to track nonconforming materials through the heat treatment process for quality control purposes. Such a system has yet to be created, therefore, this piece is written utilizing the qualitative research methodology in conjuncture with archival and secondary research methodologies. Utilizing these research methodologies, the piece stitches together fragments of knowledge obtained from multiple articles written by leading experts in the field and published in a premier industry magazine, reports and symposiums given by noteworthy professionals and conducted by key organizations at multiple conferences held by a preeminent society within the industry, and articles obtain from a reputable online digital archive service pertaining to the hypothesis posed in this piece.

Qualitative research is a research methodology in which a researcher conducts research based on nonnumerical exploratory factors of data, such as: through simple observation and keeping a record of those observations, by conducting one-on-one interviews, by conducting surveys on a given research topic, by sampling answers to questions given in a focus group, through reading about and discussing the oral history of a topic, and through a thorough content analysis of visual and textual data already composed and presented on a given topic. The key point in qualitative research is that the data being researched on any given topic is nonnumerical. Basically, qualitative research is a method of researching what others have to say and discern

based on their own personal research about a given topic. Furthermore, archival research is a specific subset of the qualitative research methodology. During archival research, a researcher combs through articles, records, documents, and materials held within a repository of information in search of evidence to prove or disprove their hypothesis.

Moreover, secondary research is another subset of the qualitative research methodology which involves the accumulation, comparison, and summation of research that has been conducted on a specific topic. Secondary research is a process which involves taking the data that others, preferably experts, have already generated and subsequently collected to prove or disprove a hypothesis. In this piece, an amalgamation of articles, studies, presentations, and symposiums written, presented, and published by innovators and experts in the heat treatment industry have been gathered to support and give credence to the assumptions made in this piece. Through the use of qualitative, archival, and secondary research methodologies this piece hopes to support the hypothesis outlined here by virtue of the aforementioned research materials.

Industrial Heating is the world's largest and most comprehensive integrated-media resource focusing on high-temperature thermal-processing technology, heat treatment, and metallurgy (“Contact Us”, 2019). The topics the *Industrial Heating* magazine cover include: heat treating, ceramics and refractories/insulation, combustion and burners, heat-resistant and corrosion-resistant composites/materials, induction heat treating, industrial gases and atmospheres, materials characterization and testing, melting/forming/joining, process control and instrumentation, sintering/powder metallurgy, and vacuum/surface treatments (“Contact Us”, 2019). The *Industrial Heating* magazine is a product of BNP Media, which was founded in 1926 and is one of the country’s leading business-to business media companies and provides services for over fifty different industries (“Contact Us”, 2019). This piece utilizes numerous articles

from the *Industrial Heating* magazine as research material. The industry professionals who have written the articles utilized in this piece for research purposes for this publication are innovators and experts in the heat treatment industry. For example, Daniel H. Herring, whose work is referenced multiple times in this piece, is nicknamed “The Heat Treat Doctor” (“Biography – Dan Herring”, 2016). Mr. Herring’s credentials include a Research Associate Professorship at the Illinois Institute of Technology/Thermal Processing Technology Center, has spent over twenty-five years working for several furnace equipment manufacturers, owns his own heat treatment business, has authored over five hundred papers on heat treatment process, and has published four books on the topic (“Biography – Dan Herring”, 2016). Another contributor and author for the *Industrial Heating* magazine that has been referenced multiple times in this piece is Dr. Valery Rudnev, his nickname is “Professor Induction” (“News Room”, 2018). Dr. Rudnev’s credentials include being elected as Fellow of ASM International in recognition for his distinguished contributions to materials science and engineering, being elected as Fellow by the International Federation for Heat Treatment and Surface Engineering in recognition of his outstanding and globally recognized and significant contributions to the development of heat treatment and surface engineering, is the director of Science and Technology at Inductoheat Inc., has written ten books and over two hundred fifty articles on the topic of heat treatment process, and has obtained over fifty patents (“News Room”, 2018). These are just two of the authors of articles from the *Industrial Heating* magazine referenced as research material for this piece, and the other authors of articles referenced in this piece from this publication have just as prestigious credentials, although maybe not as cool of nicknames.

The Heat Treatment Society is an affiliate society of the ASM International and is a professional organization comprised of metallurgists and engineers. ASM International was

founded in 1913, but by 1969 with the growth and expansion of a diverse group of industry experts and professionals it became clear that technical divisions within the organization needed to be drawn in order to focus on the specific subjects of expertise within the metallurgy industry (“About HTS”, 2019). This was when the Heat Treatment Society was founded. The mission of the Heat Treatment Society is to bring heat treaters together to discuss heat treating challenges; providing the technical information, knowledge, and education needed by all heat treaters; serving as a central clearinghouse for information of value to heat treaters; and interfacing with all organizations that serve heat treaters (“About HTS”, 2019). Each year the Heat Treatment Society conducts multiple international conferences to bring heat treatment professionals together to present presentations and symposiums on the issues and challenges that are faced within the heat treatment industry. During each of these international conferences, a book of the proceedings held during these conferences is comprised and submitted to the attendees. In each of the books, an amalgamation of the presentations and symposiums presented during these conferences are compiled together. This piece references multiple presentations and symposiums given at these conferences as compiled in these books of proceeding as subjects of research and reference material within the piece. Each presentation, or symposium, referenced in this piece was presented by industry professionals, or by organizations that are held in high regards in within the heat treatment industry, at these conferences. One such presentation referenced in this piece, titled “Heat Treatment Simulation of Highly Alloyed Tool Steels,” was presented by Böhler Edelstahl GmbH & Co. headquartered in Kommanditgesellschaft, Austria and their foundations in the metallurgies industry predates the formation of the United States. From a beginning rooted in a hammer works situated and established in Kapfenberg, Austria in 1446, Böhler Edelstahl GmbH & Co. was founded in Vienna, Austria in 1870 (“History”, 2019). This

company has a history entrenched in the early days of the industrial revolution and is still creating innovative and ground-breaking technology for the heat treatment industry. This is just one example of the multiple experienced organizations and industry professionals whose presentations presented at a Heat Treatment Society conference are referenced as research material in this piece.

EBSCO Information Services was founded in 1944 and EBSCOhost is a trusted academic online database management system product of theirs utilized by students, teachers, and professional researchers to obtain research pertaining to academic, quantitative, medical, theology, business, communication, mass media, education, and environmental research. This piece utilizes research, along with the aforementioned gathered research materials, found via means of EBSCO Information Service's EBSCOhost product in order to obtain and supplement the research materials utilized to prove the hypothesis outlined in this piece. With these fully grounded and thorough research materials in congregation, utilizing the outlined qualitative research methodologies, this piece hopes to prove that an algorithm, and subsequent application to run and interface with that algorithm, can be created to track nonconforming materials through the heat treatment process.

Chapter 4 - Literature Review/List of Resources

1. Source

Beltz, R. (2017, August 3). The cost of quality: above and below the surface. *Industrial Heating*, (2017 August). Retrieved from <https://www.industrialheating.com/articles/93660-the-cost-of-quality-above-and-below-the-surface>

Summary

This article is an eye-opening analysis of industrial heat treatment quality-management systems. It explains that as an organization produces a substandard product it is not technically saving any money on that product. In fact, it is losing money that could have been spent on improving upon its manufacturing quality control processes.

The article further explains that the average buyer of an organization's product does not care how much an organization spends on quality. In fact, the average consumer assumes they can purchase the same quality product from an organization's competitor. It is only when quality issues with a product arise that a buyer will turn to an organization's competitor. Therefore organizations will prosper by instating a thorough and effective quality-management system.

Relevance

This article supports the position that quality control measures, such as the ones outlined in this piece, are not only valuable, but can eventually bolster an organization's reputation and therefore its worth. This article further supports the solution proposed in this piece by stating that in reducing the costs related with nonconforming materials the overall costs associated with quality control systems will also be reduced.

2. Source

Forrest, D. R., Miller, T., Diachin, L., Fisher, A., Waters, D., Zhou, C., Silaen, A., & Okosun, T. (2017, November 9). Modeling, simulation and visualization capability for steel manufacturing. *Industrial Heating*, (2017 November). Retrieved from <https://www.industrialheating.com/articles/93860-modeling-simulation-and-visualization-capability-for-steel-manufacturing>

Summary

The case study conducted in this article was organized to optimize blast furnace system's energy consumption and to reduce emissions. The research conducted within this case study consists of the modeling, simulation, and subsequent data analysis of blast furnace systems. The benefits of modeling blast furnace systems include improving energy efficiency, reducing waste, and boosting competitiveness within the industry.

This case study took quite a bit of time and effort to conduct. Overall this case study took two years to conduct but has yielded new insights about blast-furnace operations, which will hopefully translate into major and significant changes regarding blast furnace operations in the United States.

Relevance

This case study is very similar to the case study that will need to be conducted before the solution proposed in this piece can be created and implemented. While the solution outlined in this piece does not directly correlate to the research conducted on blast furnaces in this case study the technologies are very similar. Furthermore, a thorough review of this piece shows that the utilization of modeling and visualization technology can translate directly into savings.

3. Source

Fotopoulos, J. (2007, April 3). Developing an advanced control strategy to optimize heat-treating processes. *Industrial Heating*, (2007 April). Retrieved from <https://www.industrialheating.com/articles/87204-developing-an-advanced-control-strategy-to-optimize-heat-treating-processes>

Summary

This article discusses various technologies that can be utilized to improve upon the heat treatment process. “Due to the rising costs of energy, slimmer profit margins, and tighter specifications on product quality manufacturers need to increase their awareness of the potential solutions that are now available” (Fotopoulos, 2007, para. 1 & 2). The solutions outlined in this article are technologies utilized to track and measure heat treatment systems.

Furthermore, this article outlines a five-step system utilized to optimize processes within a manufacturing facility, and could also be used to optimize heat treatment processes. This five-step process includes awareness and education of new and preexisting processing control technologies, overall facility objectives regarding processing control technologies, assessment of manufacturing processes, implementation of technologies, and measurement of results.

Relevance

The five-step plan in this article can be utilized to implement the outlined algorithm in this piece. This article also discusses some of the technologies that could be utilized in order to make the algorithm outlined in this piece feasible. Also, this article describes how these technologies can be utilized in order to increase productivity, improve efficiency, and reduce the costs associated with the heat treatment process.

4. Source

Herring, D. H. (2017, November 8). Industry 4.0 and the 7 key considerations in heat treating.

Industrial Heating, (2017 November). Retrieved from

<https://www.industrialheating.com/articles/93858-industry-40-and-the-7-key-considerations-in-heat-treating>

Summary

This article outlines seven key considerations to “getting the job done right, the first time, and every time.” It then associates these considerations with the term ‘Industry 4.0,’ a term used to describe the retrofitting of processes with automation technology to improve efficiency and quality control processes. Moreover, this article states that “humans create many of the issues that prevent true process control and repeatability” (Herring, 2017, para. 3).

This article also talks a great deal about predictive and preventive maintenance and the importance it has within the heat treatment process. The article states that utilizing Industry 4.0 technology to predict and prevent maintenance issues within the heat treatment process can save organizations costs incurred due to equipment breakdowns, failures, and the lost time associated with these issues.

Relevance

The several key considerations outlined in this article directly reflect the considerations taken into account in the hypothesis of this piece. Also, this article shows the importance that predictive and preventive maintenance measures have in the creation of quality materials undergoing the heat treatment processes which directly supports the assumptions made in the introduction of this piece.

5. Source

Herring, D. H. (2016, June 6). The influence of process- and equipment- induced variability on product quality. *Industrial Heating*, (2016 June). Retrieved from <https://www.industrialheating.com/articles/92911-the-influence-of-process--and-equipment-induced-variability-on-product-quality>

Summary

This is a case study conducted about a furnace known for processing consistently quality materials and then all of a sudden it started to process consistently nonconforming quality materials. This article describes all of the variables that lead to this particular furnace producing nonconforming materials. Many of the variables had to do with poor maintenance and upkeep, while others had to do with substandard simulations in regard to over production.

The purpose of this article is to show how a detailed case study to track nonconforming materials through the heat treatment process can be conducted. It also shows the direct effects of poor maintenance and upkeep within the heat treatment process, as well as the direct effects of not properly modeling and simulating materials undergoing the heat treatment process.

Relevance

This case study shows the significance of proper predictive and preventative maintenance techniques in direct correlation to the quality of materials undergoing the heat treatment process. It also proves the assumption stated in the introduction of this piece that proper modeling and simulation of materials undergoing the heat treatment process will save organizations capital in the long run by ensuring that materials going undergoing the heat treatment process will conform to quality control specifications.

6. Source

Johnstone, S. (2012, May 6). Maximizing your data acquisition system investment. *Industrial Heating*, (2012 May). Retrieved from <https://www.industrialheating.com/articles/90618-maximizing-your-data-acquisition-system-investment>

Summary

This article relates the importance of data-acquisition systems concerning the heat treatment process. It further outlines the often-overlooked potential uses of data-acquisition systems within the process. By monitoring these often-overlooked variables, as well as the variables that are commonly monitored, capital regarding maintenance issues can be saved.

Furthermore, the article states that the data-acquisition technology discussed within the article can also be utilized to monitor quality control mechanisms within the heat treatment process. The article goes on to state that this data-acquisition technology can gather data from whatever system it is designed to hook up to, but that this data needs to be properly assessed in order to make an impactful affect. “Data can be gathered and points can be added to a system, but proper analysis of the data is vital” (Johnstone, 2012, para. 16).

Relevance

This article proves the assumption made in this piece that data-acquisition systems help to prevent maintenance related issues when processing materials through the heat treatment process. It also supports the claim made in this piece that data-acquisition systems are currently not being fully utilized to their full potential. And finally, this article supports the assumption made in this piece that fully utilizing data-acquisition systems to their full potential can increase profitability within the heat treatment industry.

7. Source

Ma, S., Varde, A. S., Takahashi, M., Rondeau, D. K., Maniruzzaman, M., & Sisson, R. D. (2003, May 20). Quenching-understanding, controlling and optimizing the process. *4th International Conference on Quenching and the Control of Distortion Conference Proceedings* (187-192). Beijing, China: Chinese Heat Treatment Society.

Summary

This presentation is a summary of the findings from four different case studies conducted by the Center for Heat Treating Excellence regarding the heat treatment quenching process. This presentation addresses the issues associated with the quenching process, as well as mechanical variations within the process, which cause the distortion and cracking of materials undergoing the heat treatment process and result in millions of dollars a year lost in potential gains in the heat treatment industry. The main mechanisms for the research conducted in these case studies as presented in this presentation are various data-acquisition systems connected to and monitoring the quenching process. Each case study presented in this presentation was conducted under the same set of conditions, in the same quenching tank, and utilizing the same quenchant.

This presentation also outlines the utilization of a database management system to collect, store, organize, and utilize the data acquired during the case studies conducted for this presentation.

Relevance

This presentation shows the importance of data-acquisition systems in concert with database management systems to interpret information regarding the quenching process to prevent quality control issues within materials undergoing the heat treatment process.

8. Source

Oakes, J. & Merritt J. R. (2014, August 5). Automated control of heat-treating processes: technology, data acquisition, maintenance and productivity gains. *Industrial Heating*, (2014 August). Retrieved from <https://www.industrialheating.com/articles/91800-automated-control-of-heat-treating-processes-technology-data-acquisition-maintenance-and-productivity-gains>

Summary

This article outlines the different applications of the heat treatment industry and claims that all of these applications, even though they require different variables to achieve a quality material, can be subdivided into two categories: traditional and automated. The article goes on to explain the pros and cons of each of these categories and concludes that the automated category of heat treatment operations is better because of the fundamental reason that human error is taken out of the equation.

Furthermore, the article states that “technology has played a major role in nearly all aspects of achieving higher quality and greater efficiency in the heat treating processes” (Oakes, & Merritt, 2014, para. 7). In turn, the higher the quality and greater the efficiency of the processes customer demand is driven higher, as is the need for faster delivery; which translates to higher profit margins. Moreover, the article explains the exponential gains the industry has acquired due to the emergence of data-acquisition systems in terms of quality and maintenance.

Relevance

This article highlights the importance of automated heat treatment systems, data-acquisition systems, and the production of quality products in the eyes of the customer.

9. Source

Rudnev, V., Doyon, G., & Russell, C. (2013, September 11). Computer modeling, induction heat treating are here to stay. *Industrial Heating*, (2013 September). Retrieved from <https://www.industrialheating.com/articles/91278-computer-modeling-induction-heat-treating-are-here-to-stay>

Summary

This article highlights the importance of computer simulation and modeling within the heat treatment industry. It goes on to explain that these kinds of techniques allow heat treatment operations to remain competitive and stand out from the competition. Furthermore, it explains that these kinds of techniques can be utilized in the design of new recipes to take the guess work out of predicting the outcomes of materials undergoing the heat treatment process.

Moreover, this article outlines some of the multiple types of computer simulation and modeling software within the heat treatment industry and their specific uses. These are as follows: scan induction hardening, which is a two-step modeling process involving both the heating and quenching of materials; localized heating, which is a modeling process of only a certain area of a material; FEA computer simulation, which models both optimal and maximum temperatures; and 3-D simulation, which takes all of the geometrical features of heat treating a material into consideration.

Relevance

This article helps to prove the assumption made in the introduction of this piece that modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process are a relevant area of research for the solution posed in the piece.

10. Source

Rednev, V. (2011, May 2). Computer modeling of induction heating: things to be aware of, things to avoid. *Industrial Heating*, (2011 May). Retrieved from <https://www.industrialheating.com/articles/90111-computer-modeling-of-induction-heating-things-to-be-aware-of-things-to-avoid>

Summary

This article communicates the significance of combining advanced modeling and simulation software with knowledgeable engineering techniques to predict the potential results of materials undergoing the heat treatment process. Furthermore, this article outlines the drawbacks of antiquated process design technologies and highlights the advancements made in this field. Moreover, this article summarizes a case study of a standard scan hardening simulation.

This article also outlines a three-step process to be used by organizations who utilize the heat treatment process in order to pre-prepare the materials, and subsequent additional information regarding those materials, being studied before a modeling and simulation study is conducted. This article stresses that if all of the parameters of a modeling and simulation study are not contemplated, recorded, and communicated to the party conducting the study the test results may come back incorrect. And finally, this article stresses the potential gains a heat treatment operation can gain from utilizing modeling and simulation software.

Relevance

This article supports the assumption made in the introduction of this piece that modeling and simulation of materials undergoing the heat treatment process can predict materials conformity, but also notes that all parameters of testing must be calculated and communicated.

11. Source

Schützenhöfer, W., Wieser, V. Schweiger, H., Kaiser, E., & Schneider, R. (2003, May 20). Heat treatment simulation of highly alloyed tool steels. *4th International Conference on Quenching and the Control of Distortion Conference Proceedings* (125-129). Beijing, China: Chinese Heat Treatment Society.

Summary

This presentation describes the simulation of the different phase transformations of materials undergoing the heat treatment process and the influence each phase transformation has regarding unanticipated distortions in those materials. It also discusses the effects that cooling rate, tempering temperature, and timing components have in the formation and retention of microstructures within a material. This presentation also thoroughly chronicles the methods utilized in the creation of the modeling and simulation processes utilized in this presentation.

The results of this presentation show that the results of the simulations conducted in this study are more or less in keeping with general and practical heat treatment knowledge and understanding, other than minute variations in material size. This piece also outlines the technology utilized to conduct this study regarding quality control measurement processes.

Relevance

This presentation shows the importance of modeling and simulation techniques in the heat treatment process, which supports the assumptions made in the introduction of this piece. Also, this presentation supports the assumptions made about the various stresses different materials undergo during phase transformations in the heat treatment process within the introduction of this piece.

12. Source

Zha, X. F. (2007). A web-enabled open database system for design and manufacturing of micro-electro-mechanical systems (MEMS). *International Journal of Advanced Manufacturing Technology*, 32(3/4), 378–392. Retrieve from <https://doi.org/10.1007/s00170-005-0336-y>

Summary

This article is a synopsis of a database management system designed to gather, store, and interface with information regarding the design and manufacturing of micro-electro-mechanical systems created to be accessible over the Internet. In it the benefits of utilizing such as a system is outlined. Such as the means of communicating globally, strategic collaboration in regard to the manufacturing of products, and the resource management advantages that such a system can exert.

This article also outlines, in great detail, the process of creating a database management system such as the one described in the piece. This description includes all of the specific tasks to be undertaken in order to create the outlined database management system, the steps take in the creation of a relational database management system, the rational behind choosing the software to create the system, the objectives of the system, the logistics of the system in regard to structure, the advantages of this type of system, and descriptions of any other additional technologies utilized in the creation of this system.

Relevance

This article is a great resource of research material because while the database management system outlined in this article is does not keep track of the same sort of data as the solution outlined in this piece the methodology to construct each system is exactly the same.

Literature Review: How Sources are Related

As outlined in the introduction of this piece the research conducted for this senior research project is based on three factors within the heat treatment industry to prove or disprove the solution postulated in this piece. Those three factors are as follows: quality control techniques designed to monitor equipment efficiency and material specifications, technologies that have been designed to monitor and store information regarding the heat treatment process, and modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process. Each piece of research material that was chosen to be referenced in this piece supports the underlining claim in the hypothesis of this piece that in fact an algorithm to track nonconforming materials through the heat treatment process, and subsequent application to run and interface with that algorithm, can be constructed and integrated into the heat treating process.

The first component requiring research in order to support and promote the proposed solution within this piece is that of quality control techniques designed to monitor equipment efficiency and material specifications during the heat treatment process. The research conducted in this piece summarized multiple articles published within a distinguished industry publication and written by heat treatment industry innovators and experts regarding this component. The following is a summation of the research conducted in this piece regarding this component and its relevance regarding the hypothesis of this piece.

The first article referenced as research material in this piece is called “The Cost of Quality: Above and Below the Surface.” In this article the author, Ron Beltz, supports the concept portrayed throughout this piece that quality control processes within the heat treatment industry are essential to manufacturing long lasting and quality materials for companies and

customers. The author also states that by producing quality materials through their first processing run of the heat treatment process organizations will save capital by not having to rerun materials through the processes a second or third time in order to meet quality control standards.

The cost of quality isn't the price of creating a quality product or service. It's the cost of NOT creating a quality product or service. Every time work is redone, the cost of quality increases. An obvious example would be the reworking of a heat-treating service or something simpler, such as the replacement (rework) of a food order in a restaurant (Beltz, 2017, para. 10).

This statement by Mr. Beltz directly correlates to the seven key considerations to “getting the job done right, the first time and every time” in another article used as research material in this piece by Daniel H. Herring (Herring, 2017, para. 3). These seven key considerations are as follows:

1. To know, metallurgically, what you want to accomplish.
2. To be able to predict the outcome of a heat-treatment operation.
3. To have repeatability built into the process.
4. To get the most out of the equipment we have and to use state-of-the art heat-treating equipment whenever possible.
5. To be aware of how changes to our manufacturing operations influence the outcome of a given heat-treatment process or series of processes.
6. To not compromise on quality.
7. To know our costs and predict our profitability. (Herring, 2017, para. 3).

Within Mr. Herring's seven key considerations he outlines in consideration number three that repeatability must be built into the heat treating process, which further supports the aforementioned claim made by Mr. Beltz; as well as the assumption made in the introduction of this piece that materials undergo the heat treatment process to acquire the required company and customer specifications to fulfill their intended purposes. Furthermore, in both Mr. Beltz's and Mr. Herring's articles they stress the fact that quality is the guide post on the road to success in the heat treatment industry. Mr. Beltz states this very eloquently in the conclusion of his article by stating the following:

“Highest quality is lowest cost” is a Japanese manufacturing aphorism based on the premise that the highest-quality manufacturer will earn a reputation that makes buyers prefer (price being reasonably similar) to buy its goods. This means that the company will produce more than its competitors, with higher quality and lower production costs, and outperform competitors (Beltz, 2017, para. 31).

The second component requiring research in order to support and promote the proposed solution within this piece is that of technologies that have been designed to monitor and store information regarding the heat treatment process. The research conducted in this piece summarized multiple articles published within a distinguished heat treatment industry publication and obtained from a reputable scholarly online information repository and written by heat treatment industry professionals and information systems experts regarding this component. The following is a summation of the research conducted in this piece regarding this component and its relevance regarding the hypothesis of this piece.

In the introduction portion of this piece two specific technologies are mentioned that have been designed to monitor and store information regarding the heat treatment process. Those

technologies are data-acquisition systems and database management systems. These two systems in congregation will comprise the heart and soul, the extremities and brain, or the branches and root of the solution proposed in the form of an algorithm to track nonconforming materials through the heat treatment process, and subsequent application to run and interface with this algorithm, in this piece. This unrealized technology can potentially monitor, measure, gather, store, predict, and analyze prospective problems that can occur during the heat treatment process. The research conducted in this piece supports the position stated in this piece that these technologies currently exist but have yet to be fully utilized in congregation to realize the solution outlined in this piece.

Mr. Herring (2017) states that data-acquisition systems can certainly be utilized to fulfill the goals of the solution proposed in this piece.

Industry 4.0 is...a catchy name coined from the software industry, it is intended to represent the focus on factory automation and data exchange in a manufacturing environment... Industry 4.0 tools include things such as a “cyber” interface with physical systems (i.e., where a physical device is monitored or controlled by computer systems integrated with the Internet), the Internet of Things (IoT), cloud-based computing and even cognitive computing (i.e., the simulation of human thought by computer modeling) (Herring, 2017, para. 4 & 5).

Furthermore, Jake Fotopoulos (2007) further supports the assumption made in this piece that data-acquisition technology can reduce the variability within the heat treatment process and therefore reduce the costs associated with materials requiring a rerun through the process due to not conforming to quality control standards, or scrap caused by the process. “Advanced sensor, control and optimization technology has been used successfully to improve productivity and

reduce costs in other areas, such as the refining and chemical industries, and can provide similar benefits in the metals-processing industry” (Fotopoulos, 2007, para. 3). Scott Johnstone (2013) further supports this assumption in his work and expands on another assumption made in the introduction in this piece, which is that data-acquisition systems can bolster the preventative and predictive maintenance programs that save heat treatment operations capital in regard to nonconforming materials and scrap materials. “Proper use of a data-acquisition system can minimize equipment downtime and maximize per-load margins, resulting in a positive outcome no matter what the application” (Johnstone, 2013, para. 17). Mr. Johnstone (2013) further supports this assumption by articulating that “...an effective data-acquisition system helps prevent troublesome incidents before they arise and is more beneficial for handling those that do occur” (Johnstone, 2013, para. 3). Lastly, Mr. Johnstone (2013) states that the acquisition of data can be further extrapolated and utilized as key heat treatment performance indicators, but that this data needs to be properly compiled in order for it to be utilized properly.

By logging the status of equipment, the gathered data can be turned into key performance indicators addressing a specific stakeholder such as production manager, sales/estimating, maintenance, etc. With many DAQ systems, a considerable amount of data is compiled without a proper summary, and the task becomes overwhelming and underutilized (Johnstone, 2013, para. 15).

This is where the next piece of the puzzle comes into play regarding technologies that have been designed to monitor and store information during the heat treatment process. While data-acquisition systems monitor and gather data from mechanical processes during the heat treatment process, database management systems store that information as well as execute a whole host of other tasks. Mr. Johnstone claims that database management systems take the

information gathered and monitored by data-acquisition systems and "...improves the analysis of data by presenting it in a functional, organized format." (Johnstone, 2013, para. 3). Oakes and Merritt (2014) describe how these two technologies, data-acquisition systems and database management systems, can potentially be utilized and work in tandem with one another.

If the controller detects a process deviation or a condition likely to result in one, it can make adjustments or generate a process alarm if operator intervention is needed.

Information is delivered through mobile devices to operators, supervisors or even maintenance based on an escalation and profile of the alarm and recipient. Data logging is electronic, and logged data points can be accessed at any point in the future (Oakes & Merritt, 2014, para. 4).

This description of these two technologies in concert with one another is describing a precursor technology to the solution outlined in this piece. This article further describes this precursor technology being utilized in the field at the Phoenix Heat Treating company located in Phoenix, Arizona.

"The furnaces now talk back to us and create a functional communication link with the entire operation. When combined with our wireless system, the operators are in touch with the operation regardless of their location," Hushek added. "From process modeling to process control and on to communication, our controls and SCADA package have given us the command, control and communication we feel we need to maintain cost-effective processing without losing any aspect of quality control" (Oakes & Merritt, 2014, para. 12).

This article by Oakes and Merritt (2014) certainly proves the assumption made both in the hypothesis of this piece, and introduction of this piece that an algorithm to track nonconforming materials through the heat treatment process, and subsequent application to run and interface with that algorithm, is not only viable but is currently well on the road to being developed.

One last piece of research material referenced in this piece needs to be thoroughly discussed in terms of technologies that have been designed to monitor and store information regarding the heat treatment process and that is Xuan F. Zha's (2007) article regarding the creation of a database management system for the micro-electro-mechanical systems industry. In this section of this piece it has already been discussed how data-acquisition systems and database management systems work in tandem with one another to monitor and store information regarding the heat treatment process, as well as the importance of data-acquisition systems technology being utilized in heat treatment process. However, the importance of database management systems within the heat treatment process has yet to be fully examined. In Mr. Zha's (2007) article he discusses how data can be stored and accessed by end users of a database management system.

The user can define what data will be stored in the database, the type of data (e.g. numbers or characters), and how the data are related. In some cases, it can also be defined how the data should be formatted and how they should be validated (Zha, 2007, 10).

Furthermore, Mr. Zha (2007) discusses how data can be manipulated by end users within a database management system.

Data can be worked with in many ways. The user can select which data fields are required, filter the data, and sort them. The user can also join data with other related

information and summarize the total data as well as select a set of information and ask the RDBMS to operate (update, delete, copy) them (Zha, 2007, 10).

And finally, Mr. Zha. (2007) discusses how end users of a database management system can control the data stored there. “The user can define who is allowed to read, update, or insert data. In many cases, how data can be shared and updated by multiple users can be defined as well” (Zha, 2007, 10). This is a significant piece of research material to reference in this piece as it describes how the end users of a database management system can define, manipulate, and control the data stored within the system. This is crucial information regarding this piece as the entire purpose of this piece is to determine the viability of an algorithm to track nonconforming parts through the heat treatment process, as well as a subsequent application to run and interface with that algorithm. It has also been stated numerous times throughout this piece that quality control technicians monitoring the heat treatment process need to be able to access, monitor, and diagnose the problems that arise during the heat treatment process. Mr. Zha’s article supports this assumption.

The third, and final, component requiring research in order to support and promote the proposed solution within this piece is that of modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process. The research conducted in this piece summarized multiple articles published within a renowned heat treatment industry publication and obtained from multiple presentations given at a distinguished industry association’s international conference as compiled in those conferences proceeding regarding this component. The following is a summation of the research conducted in this piece regarding this component and its relevance regarding the hypothesis of this piece.

In the introduction of this piece the assumption is made that predictive modeling and simulation technology can save heat treatment operations millions of dollars spent on testing, in scrap costs produced by the process, and in materials requiring a rerun through the process due to not meeting quality control specifications. This assumption is supported by multiple sources referenced as research material for this piece. For example, in a case study referenced in this piece it is states that “Each year millions of dollars are lost as a result of distortion, cracking, and mechanical property variations due to unexpected problems in the quenching process” (Ma, Varde, Takahashi, Rondeau, Maniruzzaman, & Sisson, 2003, para. 1). This assumption is also supported by another article utilized as research material for this piece “Computer simulation allows induction heating specialists to determine the details of a process that could be costly, time consuming and, in some instances, difficult or impossible to resolve experimentally” (Rudnev, Doyon, & Russell, 2013, para. 3). And is further supported by a case study utilized as research material in this piece “...a smart manufacturing system could be developed to provide optimized, stable and safe operations, along with superior energy efficiency, product quality and productivity” (Forrest, Miller, Diachin, Fisher, Waters, Zhou, Silaen, & Okosun, 2017, para. 16). Furthermore, another assumption is directly supported by the research materials referenced in this piece. This assumption is that the modeling and simulation of materials undergoing the heat treatment process can potentially provide a deeper understanding of the microstructural changes that a material will undergo during the process. This assumption is also supported by multiple research materials referenced in this piece. For example, Dr. Valery Rudnev (2011) describes the advantages of utilizing simulation software within the heat treatment industry.

Simulation provides the ability to predict how different, interrelated and nonlinear factors may impact the transitional and final thermal conditions. Simulation also helps to

determine what must be accomplished to improve the effectiveness of the process, choose the most appropriate process recipes and serve as a comfort factor when designing new systems (Rednev, 2011, para. 1).

Another item of research material referenced in this piece further supports this assumption "...a deeper understanding of the microstructural mechanisms, which can be gained by numerical simulation, can help in finding optimized heat treatment parameters" (Schützenhöfer, Wieser, Schweiger, Kaiser, & Schneider, 2003, p. 125, para. 1). Lastly, another assumption made in the introduction of this piece is that the modeling and simulation of materials undergoing the heat treatment process can provide quality control technicians monitoring the heat treatment process a guide map of how materials should be treated before the process even begins. This assumption is also supported by referencing the research material utilized in this piece "[Computer simulation] provides the ability to predict how different, interrelated and nonlinear factors may impact the transitional and final thermal conditions of the heated component" (Rudnev, Doyon, & Russell, 2013, para. 3).

In summary, the research conducted in this piece is based on three factors within the heat treatment industry to prove or disprove the solution postulated in this piece. Those three factors are as follows: quality control techniques designed to monitor equipment efficiency and material specifications, technologies that have been designed to monitor and store information regarding the heat treatment process, and modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process. Each piece of research material referenced in this piece supports the underlining claims in the hypothesis of this piece, as well as the assumptions made in the introduction of this piece.

Chapter 5 – Summary of Findings

The primary objective of this research project was to review and analyze preexisting research regarding quality control mechanisms within the heat treatment industry to better understand if an algorithm, and application to run and interface with that algorithm, could be created to identify and track nonconforming materials through the heat treatment process. This potential solution could conceivably reduce the number of scrap materials and nonconforming materials requiring a rerun cycle through the process, which would save organizations in this industry millions of dollars a year. This piece was written utilizing the qualitative research methodology in conjuncture with archival and secondary research methodologies to stitch together fragments of knowledge obtained from multiple articles published in a premier industry magazine, reports given at conferences held by a preeminent society within the industry, and articles obtained from a reputable online digital archive service. The volume of research gathered for this project was based on three determining factors regarding quality control within the heat treatment process to prove or disprove the solution postulated in this project. Those three factors include: quality control techniques designed to monitor equipment efficiency and material specifications, technologies that have been designed to monitor and store information regarding the heat treatment process, and modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process.

In the introduction of this piece, one of the keynote assumptions that was made is that the matter of quality control is an essential part in the processing of materials through the heat treatment process. Dr. Armand Reigenbaum defined ten crucial benchmarks for total quality success in the manufacturing of products in one of the articles referenced as research material in this piece. One of those benchmarks states that “quality is the most cost-effective, least capital-

intensive route to productivity” (Beltz, 2017). Additionally, quality control is a way to verify that the materials undergoing the heat treatment process meet the outlined company and customer specifications, which in turn bolsters the image of a company’s reputation to the customers within its given market. Beltz states that “‘Highest quality is lowest cost’ is a Japanese manufacturing aphorism based on the premise that the highest-quality manufacturer will earn a reputation that makes buyers prefer (price being reasonably similar) to buy its goods” (Beltz, 2017, para. 29).

Moreover, in the heat treatment industry quality control is proving that materials undergoing the process are consistent and uniform in properties and characteristics. Herring outlined seven key considerations to “Getting the job done right, the first time and every time” (Herring, 2017, para. 3). One of those seven key considerations is “to be able to predict the outcome of a heat-treatment operation” (Herring, 2017, para. 3). Furthermore, quality control processes within the heat treatment industry are subdivided into two different categories. The first is regarding the efficiency of equipment and the second is in regard to materials undergoing the process. The first directly affects the second. Another of Herring’s seven key considerations is “to be aware of how changes to manufacturing operations influence the outcome of a given heat-treatment process or series of processes” (Herring, 2017, para. 3). Basically, this is another way of saying that if the equipment is not functioning to quality control specifications, then it stands to reason that the materials undergoing the process will not meet the specified quality control specifications. “A technique of mitigating risk is by performing regularly scheduled maintenance” (Herring, 2017, para. 11).

Another keynote presupposition made in the introduction of this piece is that heat treatment process data-acquisition systems and database management systems collect,

categorize, and store all of the information related to materials undergoing the process. Oakes and Merritt state that “Today’s technology is more reliable than ever before. This reliability extends to the parts of a sensor [data-acquisition system] used to monitor atmosphere or temperature and to the computer system [database management system] that drives an operation...” (Oakes & Merritt, 2014, para. 8). Data-acquisition systems allow quality control technicians monitoring the heat treatment process to understand if the equipment being utilized to conduct the process is operating and functioning properly. “Smart sensors [data-acquisition systems] will...help determine the condition of any part of the system or the entire furnace, predict breakdowns...and pinpoint the most cost-effective time and method for maintenance without loss of productivity” (Herring, 2017, para. 10). Database management systems then allow quality control technicians monitoring the heat treatment process to access the data gathered from data-acquisition systems and to manipulate and manage that data for quality control purposes. “[Database management systems] ...provide data definition, data manipulation, and data control features needed to manage large volumes of data” (Zha, 2007, para. 8). These two technologies in aggregation have done more to further the goals of improving productivity and reducing costs than any other technology in the heat treatment industry. “By utilizing specialized process controllers [data-acquisition systems] and software [database management systems], automated control systems [the two technologies working in aggregation] help enhance productivity through real-time monitoring and control, leading to reduced waste and freeing up operators for other tasks” (Oakes & Merritt, 2014, para. 22).

The final keynote postulation made in the introduction of this piece is that the modeling and simulation of materials undergoing the heat treatment process will provide a deeper understanding of the microstructural changes that a material will undergo during the heat

treatment process. A case study conducted by Böhler Edelstahl GmbH & Co. stated that "...a deeper understanding of the microstructural mechanisms, which can be gained by numerical simulation, can help in finding optimized heat treatment parameters" (Schützenhöfer, Wieser, Schweiger, Kaiser, & Schneider, 2003, p. 125, para. 1). The modeling and simulation of materials before undergoing the heat treatment process will also help to predict the result of a material's quality regarding predetermined specifications and ensure that materials meet these quality control specifications. "[Computer simulation] provides the ability to predict how different, interrelated and nonlinear factors may impact the transitional and final thermal conditions of the heated component" (Rudnev, Doyon, & Russell, 2013, para. 3). Furthermore, every year millions of dollars are lost in the heat treatment industry due to organizations not properly utilizing this technology in predicting the outcomes of materials undergoing the heat treatment process. "Each year millions of dollars are lost as a result of distortion, cracking, and mechanical property variations due to unexpected problems in the quenching process" (Ma, Varde, Takahashi, Rondeau, Maniruzzaman, & Sisson, 2003, para. 1). Proper use of predictive modeling and simulation technology can save the heat treatment industry millions of dollars spent on testing, in scrap costs produced by the process, and in materials requiring a rerun through the process due to not meeting quality control specifications. "...recent advancements in high-performance computers have improved the cost-effectiveness of the development stage for induction heating equipment by shortening the learning curve, reducing development time and allowing quick and reliable feasibility estimates of novel processes" (Rudnev, Doyon, & Russell, 2013, para. 26).

Overall, the research gathered for this project as reference material supports the solution postulated in the hypothesis of this project that in fact an algorithm to track nonconforming parts

through the heat treatment process, and subsequent application to run and interface with that algorithm, can be produced. In this project three determining factors regarding quality control mechanisms within the heat treatment process were researched to prove or disprove the solution postulated in the hypothesis of this project. The first factor was quality control techniques designed to monitor equipment efficiency and material specifications. The research conducted in this project proved that these techniques have been instated within the heat treatment process to produce materials that conform to quality control specifications. Also, research proved that these techniques can be bolstered by the creation and instigation of the solution postulated within the hypothesis of this project. The second factor was technologies that have been designed to monitor and store information regarding the heat treatment process. The research conducted in this project proved that data-acquisition systems and database management systems are technologies that in congregation gather, store, and manage data regarding the heat treatment process and can be utilized to monitor the quality of materials undergoing the process. Research has also proved that these technologies in convocation can support the creation of the solution postulated in the hypothesis of this project. Lastly, the third factor was based on modeling and simulation technologies designed to predict the outcomes of materials undergoing the heat treatment process. The research conducted in this project proved that modeling and simulation technologies can predict the effects of materials undergoing the heat treatment process. It also proved that utilizing these technologies can ensure that materials conform to quality control specifications and that by properly utilizing these technologies organizations within the heat treatment industry can save millions of dollars a year spent on scrap materials and nonconforming materials as a result of the heat treatment process.

Chapter 6 – Conclusion

Private First Class William A. Foster, a United States Marine who received the Medal of Honor for his actions and bravery above and beyond the call of duty during the Battle of Okinawa in World War II, once said that, “Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction and skillful execution; it represents the wise choice of many alternatives” (Mason, 2001). Quality control is a purposeful apparatus in the manufacturing and production of a commodity in any trade. This is true of the service industry, retail industry, agriculture industry, education industry, fashion industry, pharmaceuticals industry, and entertainment industry among many others; but is especially true of the manufacturing industry. Machined parts utilized in precision computing systems, airplane control systems, heavy vehicle mechanisms, and space craft operating systems are all manufactured to exacting and rigorous tolerances. These specialized machined parts are crucial to the sustained operation and enduring performance of complex systems in the various esoteric machines that aid society in its continual functioning every single day. These specialized machined parts require the attainment of certain qualities in order to assist these complex machines in their continued operation; including hardness, strength, toughness, ductility, and elasticity. The way these specialized machined parts attain these specific qualities is through the induction of these materials to the heat treatment process. This research project was conducted in order to prove or disprove the theory that by utilizing preexisting technologies already employed as quality control mechanisms in the heat treatment process that a system to track materials that do not conform to quality control specifications through that process could be conceivably created. The research conducted in this project has supported this theory and proved that these preexisting technologies

in congregation have laid a solid and unyielding foundation for the solution proposed and summarized in this project.

The research conducted in this project supports the theory postulated in the introduction of this piece that quality control technologies and techniques have been designed to monitor the efficiency of heat treatment equipment and materials emerging from the process. Specifically, the research conducted in this project has proved that continual equipment testing, monitoring, analysis, and inspection is essential to producing materials emanating from the heat treatment process that meet and maintain company and customer quality control specifications. If the machinery and systems within the heat treatment process intended to impart particular and exacting properties into materials subjected to the process is not functioning properly then materials derived from the process will therefore not meet quality control specifications. It is essential that heat treatment equipment perform to optimal standards. Research has proved that this simple fact is paramount to the success of the heat treatment process.

Moreover, research has also suggested that technologies designed to test, monitor, analyze, and inspect heat treatment processing machinery and systems is evolving and advancing by leaps and bounds every year. These new technological developments will further the cause of producing materials that meet quality control standards emanating from the process and will help lay the foundation for the solution postulated and discussed in this project. Furthermore, the research conducted in this project has supported the belief that the universal goal of quality control in the heat treatment process is to guarantee that materials undergoing the process are consistent and uniform in attributes and characteristics. The aforementioned technologies designed to monitor heat treatment equipment will help to reduce the capital spent on ensuring

that materials emerging from the process meet quality control specifications before testing is even conducted.

The research conducted in this project also supports the proposition suggested in the introduction of this piece that data-acquisition systems and database management systems designed to monitor, store, access, and analyze information regarding the heat treatment process supports and maintains the previously mentioned quality control techniques. Research has proved that data-acquisition systems have been designed to monitor and gather data regarding the performance of machinery utilized to perform the heat treatment process. It has also suggested that new data-acquisition systems are being developed that can monitor even the most minute of variables in the process. Such as monitoring the water temperatures of inlet and outlet cooling components for equipment overheating, the vibration of motor shafts and fans for misalignment, and the heat of bearings in pumping systems for lack of lubrication. Or monitoring the strain on pulley systems to determine if a belt needs to be replaced before it breaks, as well as energy consumption of machinery to determine if it is working correctly among many other variables that were previously unmonitored. These newly designed data-acquisition systems in fellowship with preexisting data-acquisition systems designed to monitor the critical mechanisms within machinery utilized to conduct the heat treatment process can be employed to construct the substructure of the solution proposed in this project.

Furthermore, research has proved that database management systems utilized in the heat treatment process have been designed to store, access, and analyze the information gathered by data-acquisition systems during the process. Research also suggests that database management systems technology is already progressing towards the solution proposed in this project, but that this technology has yet to reach the cognitive computing capabilities outlined in the hypothesis

of this piece. These newly designed and implemented technologies can assist in furthering the construction of the framework of the postulated solution outlined in this piece, but current technology has a long way to go before reaching the goals stated in this project.

The research conducted in this project additionally supports the concept suggested in the introduction of this piece that proper utilization of modeling and simulation technologies can assist in predicting the results of materials undergoing the heat treatment process. Research suggests that this type of technology is a major benefit and asset to heat treatment operations and that it should be utilized before a material undergoes the heat treatment process. These technologies ensure that materials undergoing the heat treatment process meet and maintain quality control specifications. Therefore, this technology can be utilized as the foundation upon which quality control operations within the heat treatment process are founded as well as the basis upon which the proposed system can stand.

In conclusion, the research conducted in this project supports the hypothesis stated in the abstract of this piece and also supports the keynote assumptions made in this introduction of this piece. However, there are additional projects and research studies that need to be conducted before the solution postulated in this project can be fully realized. Each of these additional projects and research studies would be conducted utilizing the action research methodology. As the name suggests, action research is comprised of two components: action and research; which in tandem are utilized to improve a practice or to take action to deal with a problem or an issue. First and foremost, a heat treatment facility would need to be located that would be able and willing to assist in the following research. Then, a research study would need to be conducted regarding different types of alloy steels utilizing modeling and simulation technologies in order to determine how and why materials potentially do not meet quality control specifications. This

information will lay the foundation for further research to pinpoint exactly where materials start to deviate from quality control specification. Also, studies such as this one could have already been conducted and could potentially be utilized as reference material for this study. Second, a project to add supplementary data-acquisition systems on tertiary, but key, mechanisms within machinery and connected to the heat treatment database management system needs to be organized. Third, a meticulous testing project needs to be conducted of materials undergoing the heat treatment process. In this testing project data will be gathered and stored over the period of six months in all types of weather conditions to assess whether humidity and climate is a contributing factor in the heat treatment process, as well as to gather a significant amount of data for further testing. Fourth, sampling research will be required on each load going through the process and materials need to be sampled, cut, and then a series of laboratory tests will be conducted. Some example of these laboratory tests would include total case depth, effective case depth, retained austenite testing, bainite testing, core hardness, surface hardness, and so on. This information would also be recorded and charted for further research. And finally, a meticulous assessment of the data gathered from secondary and tertiary data-acquisition systems concerning critical mechanical mechanisms stored within the database management system in congregation with the data obtained from the quality control sampling process will be assessed in order to determine the root causes of nonconforming materials. After all of this information has been assessed a trend should start to appear where parts going through the heat treatment process begin to vary from established quality control standards. All of the variables that are associated with nonconforming materials will be noted and utilized in the creation of the aforementioned algorithm to be constructed once the research project concludes.

Chapter 7 – Reflection

The idea for this research project came about during a previous semester over a year ago in a course called Research Design and Methodology. In this particular course students were set upon the path of reading and learning about the various forms of research methodologies. Then were trained in the fine art of gathering and assessing assorted research materials available from the abundant and innumerable sources available on the World Wide Web and in text form. And were ultimately charged with developing a research proposal based on their previous work experiences and chosen field of study. This research proposal would eventually, after some extended discussion with the professor managing the course, lay the ground work for what would become for many a Senior Research Project. This project is one such project.

Years of experience in the manufacturing and heat treatment industries coupled with an Associate's Degree in Industrial Technology as an educational background lead me to the topic of discussion explored within this Senior Research Project. I thought it perfectly melded my previous work experiences, prior education, and current educational path. Information technology was a foreign and mysterious topic of discussion before I started taking courses at Concordia University Chicago. Through the last two and a half years while enrolled at this institution I have obtained a great deal of knowledge regarding the information technology industry, how the technology within that industry is implemented and utilized, as well as various and assorted forms of management styles and aspects concerning this particular field of study. In this project I really wanted to strive to go above and beyond in the melding of my previous and newly acquired knowledge bases and show that I had learned and applied the knowledge that I have been given during my time at Concorida.

This Senior Research Project during its genesis seemed more than a little daunting to me. Most of the final projects and essays I had had during my time at Concordia were limited to ten to fifteen pages in length maximum. These always seemed to come naturally to me and almost seemed to write themselves, but when I was presented with a thirty to fifty plus page project I honestly felt a bit like a deer in an oncoming car's headlights. Not to mention the fact that this project was purported to be a summation of the accumulation of knowledge I had obtained during my time in this institution. On top of these worries I also had numerous walls blocking my path while conducting research for and composing this project. The first obstacle to overcome was the amount of time that had elapsed between the Research Design and Methodology course and the Senior Project course, which was well over a year and a half. I had of course utilized the knowledge acquired in the Research Design and Methodology course in every paper written for every course after the grades had been handed out in that course, but I honestly still did not feel ready to complete this project. The second obstacle I had to overcome was the lack of research I had conducted on this project between the two courses. I really went after the research for this project for about a month after the Research Design and Methodology course, but then life got in the way. I got married, bought a new house, moved, went on a honeymoon, started a business, and had to juggle full time school and a full time work on top of all of that. These are not excuses in any way mind you, I am just stating the circumstances surrounding this project. The third obstacle I had to overcome was the overall lack of research materials that had been conducted regarding the topic I chose to highlight and discuss in this project. The technology that is the centerpiece of this project has yet to be created and therefore it was difficult to find research materials to support or disprove the hypothesis of this project. And lastly, even though I have years of experience in the manufacturing and heat treatment

industries I am by no means an expert on the topic. Also, the reason I am enrolled at Concordia is to learn about the information technology industry in order to obtain employment in the field, which means that while I have learned a great deal about this field of expertise I do not think that I will consider myself to be an expert in this industry until I have obtained numerous years of work experience in this field.

In summation, I felt overwhelmed, I was underprepared, I identified myself as underqualified to write about the topics presented in this project, and there was little to no research that I could find to supplement my argument for this project. I honestly felt like starting over and finding a completely new, easier, topic to research and discuss for this project. In spite of these mental and conceptual stumbling blocks I decided to carry on bravely and conduct my original research topic. I overcame my feeling of being overwhelmed by dissecting this project into weldable implements. The way the Senior Project course is constructed certainly helped considerably in this process. I also sought the advice and comfort from my wife, who is my rock, and my father, who graduated with a Master's Degree in Healthcare Management from this institution last year. I became prepared for this project by working and researching for it nonstop during its formation. Seriously, I spent over fifty hours a week writing, rewriting, re-rewriting, and conducting research for this project. Through all of that research I read over seventy articles, skimmed through five books of reference materials, read and reread presentations given at conferences on the topics highlighted in this piece, combed through digital archives for hours in search of research materials, and came out the other side feeling not quite like an expert on the topics of heat treating and information technology but certainly feeling like a more than knowledgeable arbitrator on both topics. The biggest boon to this project though came from my manager who has a Bachelor's Degree, Master's Degree, and PhD in Metallurgy Sciences. He

loaned me several massive volumes of his collection of articles, presentations, and writings regarding the heat treatment process that he has been collecting since 1991. In all there were fourteen large binders of materials spanning the last thirty years of the heat treatment industry. It really was a blessing bestowed onto me by God and I am very grateful to him for his contribution. Ultimately, this collection along with a subscription to the *Industrial Heating* magazine permitted me to conduct the research required in order to complete this project.

In conclusion, all throughout the process of conducting research for this project and during the composition of this project I felt that I had made a terrible mistake and that I should have chosen a different topic. However, having read and reread this piece multiple times I am glad that I stuck with my original topic. I am also proud of the work that I have done in this project and feel that my prior knowledge base and new knowledge base have melded together quite seamlessly. The algorithm, and application to run and interface with that algorithm, to track nonconforming materials through the heat treatment process discussed in this project has yet to be fully realized. I hope that this project can be utilized to make this technology a real and tangible reality someday. I also hope that this project is a meaningful, insightful, deliberate piece of research material that can be referenced in other research projects in the future. Thank you for joining me on this adventure.

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