Design, Functionality And The Development Of A Coreless Induction Furnace

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Introduction

The main aim of the paper Design, Functionality and the Development of a Coreless Induction Furnace is to describe the design, functionality and development of a coreless induction furnace. In administering the task, much focus has been given to analyzing the coreless inductor to emphasize the advantages over channel-type inductors. The difference between the two types is the consideration of the technical information to identify the new benefits. Some of the benefits are the increased service life and, therefore, maintenance of the furnace with the crucible inductor. It is important to acknowledge that there are two different types of induction furnaces; one is for holding and casting metals, while the other is used for smelting iron and steel (metals). These are coreless-type induction furnaces and channel-type induction surfaces. The focus of the paper notes the significance of the induction furnace in the steel-making industry, especially for small-scale production units (Fong, 2016, n.p). When it comes to installation, maintenance and operation, they are the easiest and, therefore, a preference for many. In coreless furnaces, the smelting of the steel is facilitated through a charged material that produces heat from the electromagnetic field.

Maintenance Strategy For An Induction Furnace

The paper will also discuss the coreless induction furnace parts, which include a crucible, cooling system, shell, coil inductor, and tilting machinery. The cylindrical crucible is made from the resulting material of the refractory, through which the lining of the coil is performed. The charged material is held by the cylindrical crucible in the subsequent melting processes (Rudnev, Loveless, and Cook, 2017, n.p). When choosing a refractory material determinant of the charge is based on the composition, i.e., acidic, alkaline or neutral. Ultimately, the furnace was constructed and the final aim, which is melting the metal, was achieved.

Keywords: Induction heating, coreless furnace, Equivalent circuit method.

Operation Of Coreless Induction Furnace

The coreless induction furnace is the most popular kind due to its suitability in all the metal industries, and, more so, its easy handling as a major advantage. It is for that reason that the paper has picked a coreless induction furnace. In the description, a coreless induction furnace has been constructed as the simplest unit, which is made up of a helically wound coil that surrounds the refractory crucible that holds the molten charge. It follows a connection to the alternating excitation system. Excitation occurs in the coil through alternating current, which prompts the production of an axial magnetic field. The produced magnetic field experiences a variation, resulting in a field of electric and eddy currents in the concentric paths on the axis. A rapid attenuation of the electromagnetic field is charged. In computation, the determination of the depth of the induced decline of the density (/e) attests to its surface value (Tan and Bayindir, 2014, 241).

Eddy currents are concentrated at the outer surface of the charge due to the skin effect, and heat is developed by the conventional ohmic losses.

Some of the heat produced in the furnace is lost to the surrounding medium, while the remnant is evenly distributed across the mass of charge in the effect of the thermal conduction. Additionally, there is a skin effect as a product that is distributed throughout the coil conductor.

A proximity effect is developed as a phenomenal occurrence due to the un-uniformity of the coil as the greatest current density is prompted in the sectional unit that lies so close to the charge. Following the above discussion, it is evident that an induction furnace is developed on the basis of four principles, i.e., electromagnetic induction, skin effect, heat transfer and proximity effect (Rudnev, Loveless, and Cook, 2017 n.p).

Coreless induction furnaces are developed through a conceptual design of a cylindrical crucible encircled by a charge coil where the energy supply emanates directly or through the frequency converter. The surrounding coils generate the magnetic field, which transfers the energy to the charge.
At the epicenter of the coreless induction furnace is the coil; it is composed of a depressed section of heavy-duty facilitating high conductivity of the copper tubing that makes up the helical coil. The coil takes the shape that fits within the steel shell. In order to protect the coil from overheating cooling using the water is effected through recirculation from a cyclic cooling tower.

The crucible formation is done through ramming of a granular refractory that is found in between the coil and the internal void. All grades of steel and iron are the raw materials used in the coreless induction furnace and undergo melting. In addition, non-ferrous alloys can be melted in the coreless induction furnace. It has proven to be an ideal furnace to facilitate remelting and alloying as it has a high capability to control exceeding temperatures and balance the chemical composition. At the same time, the furnace inducts current, providing a good circulation of the melt substance.
Radiofrequency (RF) energy prompts a unique feature in part of the electromagnetic spectrum under infrared and microwave energy (Rudnev, Loveless, and Cook, 2017, n.p). This is because of the transferring of the produced heat via the electromagnetic waves since it never comes into contact with flame.

Usually, to enable the functionality of the induction furnace, there occurs a rapid but non-polluting heat. However, the recirculation of the cooling water ensures that the induction coil remains cool throughout to avoid building up heat.

Features Of Induction Furnace

A coreless induction furnace is electric and requires an electric enable coil to help in the production of a charge. Coils have the potential to fail and, therefore, are replaced. The failure of a coil can render a coreless induction furnace useless since no charge can be produced and, therefore, unable to operate.

A crucible with a cylindrical structure that holds the melted steel is made of heavy-duty material to resist high heating temperatures. The use of a poor metal in the crucible lacks the ability to resist the immense heat. To ensure optimal resistance of the crucible, the coil is usually cooled to prevent overheating (Ambade, 2015, 157).

In consideration of the difference in the level of production, there is a range of induction furnace sizes that can handle low production to mass production of clean metal through smelting. The different sizes of induction furnaces also help I various applications in the in the industry. There is a high advantage of using an induction furnace. One, it helps in the production of clean metal, achieves energy efficiency and has a well-managed melting process that is easily controlled; no complexities involved. It is the best means of metal melting in comparison to other available alternatives.
Due to their easy maintenance, the coreless induction furnaces are now used in the foundries and replacing the cupolas to facilitate the melting of cast iron. This is because the cupolas have been found to produce a lot of dust during the melting process, thus significantly contributing to environmental pollution. On the other hand, the induction furnace is clean, therefore environmental friendly (Dey, 2018).

With all the goodness found in the coreless induction furnaces, there is a major drawback that has been identified in its application in the foundry. The furnace lacks the capacity to refine the final products.

The coreless induction furnace is made of technical and economic features. Each of the features has its functions to perform.

Technical Features

The technical feature assists in the adjustment of temperature and control processes. Another feature helps achieve high analytical accuracy and reproducibility, keeping check of the high melting rates and operational flexibility. The management of the melting point suitability is performed by the technical features and they have the capacity to handle a wide range of diversity of raw material compositions in alternation mode. The technical features allow maximum and effective management of metallurgical selectiveness capacity (Moreira et al., 2014, 415).

Economic Features

The economic features relate to the enhancement of induction furnace efficiency in terms of energy and waste heat reduction. Through the installed features, there is a huge set of low energy consumption, leading to maximum production. Waste heat is no longer a significant concern as the furnace experiences extremely low loss of melting heat. A coreless induction furnace is readily available and comes with a minimal installation cost in comparison to other furnace systems. Additionally, the ease of its maintenance and handling makes it a preference for many smelting companies (Moreira et al., 415-419).

Advantages Of Induction Furnace

Coreless induction furnaces have been found to offer numerous advantages in comparison with other developed furnace systems. Some of the advantages realized by the users include:

- Production of high yields since it drastically reduces oxidation losses, which are significant in the production economics.
- Faster startup procedure upon the availability of a reliable power supply. The instant ability to startup helps in reducing the duration of optimal temperature required in the process.
- The higher level of flexibility as no molten metal is needed to initiate the medium frequency of the coreless induction melting equipment. It helps in facilitating a repetitive cold start and the frequent changes of the alloys.
- The induction furnaces provide a better working environment in that they are quieter than other gas furnaces, cupolas and arc furnaces. The lack of combustion gas helps in minimizing the loss of heat. In regards to energy conservation, coreless induction furnaces are the best due to their efficiency, as the melting rates range from 55-75%.

Disadvantages Of Induction Furnace

- Induction furnaces lack the capacity to facilitate intensive refinement of the metal product as in Electric Arc Furnace (EAF). Secondly, it illustrates a low refractory lining in comparison to the EAF and selection of charges must be administered to produce final products with minimal impurities.
- Frequency Evaluation
- Coreless induction furnace has an advanced high-power medium frequency that is made up of the following features i.e.

Melting Furnace, Comprising

Furnace body, including a coil
Furnace tilting cradle (optional backward tilting)
Hydraulic power pack
Pit guard
Operator control desk
Exhaust hood

Electric Power Supply System Comprising

Rectifier transformer
Frequency converter
Capacitor rack
Power cables

Process Control System, Comprising

Weighing system
Auxiliary and ancillary equipment,
Water recooling system with air cooler/cooling tower
Dust collection system
Charging equipment
Charge make-up system
Crucible ejector system

Evaluation Of Frequency

During the operation of a coreless induction furnace, eddy currents are produced due to the built-up charge, and as a result, it prompts a stirring action. To improve the performance frequency, laminations of iron are provided externally so as to provide a primary wound that helps the creation of a low reluctance platform for flux. It also contains a path to direct, induced heavy currents to the stray field. The size of the furnace is used to determine the level of frequency to be employed (Moreira et al. 415-419).

For furnaces with low capacities, usually, a higher frequency capacity is employed to an order of 3000Hz, while those of higher capacity are brought down to 600Hz. Hollow copper tubes are wound in the water holding compartment to reduce losses of the metal.

In reference to the medium frequencies developed in the induction furnaces, the level of efficiency in production is expressed by taking into account the total heat transfer and the deductible electrical loss achieved in the process. To accord a typical balancing of the equation, the electrical losses of transformers are considered, the condenser, coil, cable unit and frequency converter. The heat loss experienced through the conductivity of the furnace wall and the coil side causes a radiation effect, increasing the loss of heat from the melt surface. In order to reduce the prevalence of heat loss, cooling water is directed to the coil through recirculation. Through the intervention, heat efficiency is achieved since high and medium frequencies are attained in the furnace. Usually, it is around (60%-70%) and for low frequencies furnaces (58%-71%).

Failures Evaluation

The refractory system succumbs to deterioration that occurs in a rubber tire. The feature is consumable as it gradually wears out. To resolve the problem and therefore requires to repair the lining to their minimum thickness to prevent failure.

The wearing out of the lining is referred to as sidewall wear. This is due to thermal stress and continuous churning (stirring) of liquid metal.
A coreless induction furnace has a bottom that is prone to damage due to severe heat stress. The bottom is usually exposed to consistent chemical attacks and has severe damage to the weight charge (Fong).

When the features of an induction furnace fail they pose a risk to the workforce and also the environment. Many times, the metal works are always risky, and the workers are vulnerable to numerous kinds of accidents. Through improved designs, the furnaces have been constructed in consideration of occupational safety and hazards to provide good working and safe environments. The designers have focused on building energy-efficient furnaces that provide less hostile working environments. With recent increased concern for the natural environment, models and kits to help reduce noise and pollutant emissions have been incorporated to develop a healthy and clean production. However, it should be noted that despite the numerous measures to improve safety and efficiency, dangers have not been inherently eliminated. More especially, workers should avoid being in close proximity to the molten metal.

Recommendations

Following the usual practice, checking the level of temperatures was used through tapping of heat manually using shovels or pressing bundles of low-grade scrap. To ensure the safety of the workers and avoid getting close to the molten metal, there is a need for the use of safety measures such as using the help of crane-filled with low-grade scrap and spreading them over the furnace space. As a result, the charge does not become dense since the furnace does not draw sufficient power.

Control of Furnace Power during De-slagging Operations In reference to the power of the furnace, there needs to be the making of control panels in the moments of de-slagging the molten bath.

Once the solid scrap (raw materials) is still held in the bath, allowing the reduction of power in the potentiometer settings, the incorporation of this will lead to the prevention of overheating of the molten.

Globally, the designing of induction furnaces and rapid development and the immense increase in the last decades. Significant growth in the sector has been noted in the utilization of wind power. A number of factors that have contributed to the increasing drive in the sector that has seen the improvement in wind turbine technology are rising environmental concerns, especially climate change, cost reduction, and interest in decreasing reliance on non-renewable sources of energy (Kipepe, 2015).

By 2009, 86% of the total installed capacity can be accounted for in the three markets. Despite the fact that the cost variation in the installation of the furnaces for steel production is trending globally, thus the use of coreless induction furnaces, in comparison to the channel-type induction surfaces is becoming more economical and competitive. Due to the economic benefits and advantages that come with the use of a coreless induction furnace, it is the best alternative and a preference of the furnace and so far ascertains sustainability with not much complication in their maintenance.

The induction furnace and the industry have recorded much proliferation in advancement and can be considered to be the fastest-growing industry. The amplified permeation of increased research in the improvement of the furnace has prompted efficiency and forges towards sustainability of the steel and iron industry (Tan and Bayindir, 2014). The relevant grid requirements need furnaces to perform correspondingly to improved melt plants. Particularly the necessities for the designing of induction furnaces to stay in connection to help the development of a technical empower to go beyond the prospective challenges in designing induction furnaces. Coupled with challenges in the last decades, researchers have been motivated and prompted studies to be conducted focused on the development of improved induction furnaces and modern designs and control panels for purposes of efficiency and increasing their potential to produce enough energy. It will also ensure all the grid requirements have been met (Fong).

Conclusions

The paper has put a focus on the development of improved efficiency in the steel melting industry. Through the analysis of the coreless induction furnace, it is evident that the major concern is in reference to heat loss and energy efficiency. Considerably, there are milestone achievements to improve the efficiency of the induction surfaces. The paper has made recommendations for molten metal delivery, preheating, and scheduling of operations.

Referring to the case of the coreless furnace induction has had significant fallbacks in the system caused by ignorance of observing the lab safety guidelines to the point of unethical behavior that can lead to misdiagnosis of the subjects under their care. The company has an issue with its culture, as illustrated.

On further assessment, another problem exists. To ensure occupational safety, labeling is critical and of great importance in ensuring the right specimen for a particular subject is easily identifiable to avoid a mix-up that could be detrimental. Instead of acquiring another system, the staff compensates the only effective technique to track the achievements to proof of the unsafe practices in the industry, which goes against the professionalism of working in occupational hazards.

Notably, lab safety, rules and guidelines are being taken for granted by the staff. Rene notices that some of the staff are taking foodstuff in the lab, which is very unhealthy and even unethical as they put a risk to their own life. Again, the protective gear is specifically meant for workforce uses only and should remain within the confines of the slide wall. Wearing protective gear outside the smelting factory goes against the rules and guidelines that ascertain safety. It poses a threat of contamination of the safe environment from the external environment.

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