Construction and Development of Sinter Line

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Abstract - Sintering is a heat treatment applied to a powder compact in order to impart strength and integrity. In today's era to manufacture sintering furnace involves high end manufacturing technology which is very costlier The prominence of the paper is to reduce the overall cost of construction of Sintering Furnace and Rolling Mill of the Sinter Line using the Some Unused Material or zones by maintaining the required amount of Heating Temperature for proper bonding and to achieve required rolling thickness in rolling mill. The design considerations for this study are to observe heating area and heating temperature for Sintering process and to get proper bond of lining on bi-metal Strip. The paper emphasis on cost optimization of overall process of sintering by changing or developing new parameters in available furnace and rolling mill.

Keywords – Construction, Sinter Line, Heat treatment, manufacturing.

I. INTRODUCTION

Almost all ceramic materials have been made through the powder route, and also a variety of components used in modern technology has undergone sintering as one of the production steps. Sintering is one of the most important processes for the fabrication of ceramic materials [1]. The properties of ceramic materials can be modified through sintering process. The complexity of the sintering process makes this field a fascinating area for research. The process by which small powder particles of a material are bonded together by solid-state diffusion is called sintering. In ceramic manufacturing, this thermal treatment results in the transformation of a porous compact into a dense, coherent product. In sintering process, particles are coalesced by solid-state diffusion at very high temperatures but below the melting point of the compound being sintered [2, 3]. During the sintering of a powder compact, both densification and grain growth occur simultaneously [4]. In order to understand and control the sintering process, the relationship between densification and grain growth must be assessed. It concerns the materials constitutive laws governing the sintering process which is related to the micro structural evolution of the sintering component [5]. Usually, the preparation of ceramic body involves only single sintering process. The sintering process for ceramic preparation involves powder compaction method will be done after the Pressing and drying process. However, in the present work, alumina ceramics which is prepared by powder route has gone through sintering process twice in order to produce porous alumina ceramic body.

II. LITERATURE REVIEW

According to literature it is important to minimize the difference in temperature profile aim to control it to a suitable heat pattern to improve the microstructure of the sinter. Because of the different temperature profiles in the different layers the discharged sinter has different physical properties.[6] Sinter in the top layer is generally weak and able giving a poor yield of sinter with an acceptable size grading and has therefore poor physical properties. The sinter in the middle layer is formed under optimum conditions for fusion and annealing and gives the maximum yield of sinter with acceptable size grading and has therefore optimum physical properties. If constant cooling applies, the sinter in the bottom layer will have almost the same properties as the sinter in the middle layer.[7]The manner and mechanisms involved on the sintering process are essential investigation to achieve the required microstructure and final properties in solids. During the conventional sintering of a compacted powder, densification and grain growth occur simultaneously through atomic diffusion mechanisms. Many researchers have been working on reducing the grain size below 1m aiming to improve some properties, such as strength, toughness and wear resistance in ceramics.[8] In order to obtain ultra-fine ceramic microstructures, nano crystalline powders can be used. Although the sinter ability of nano particles is superior to that of fine particles due to the higher sintering stress, densification of these powders is often accompanied by grain growth. Hot pressing sinter, spark plasma sintering or pulse electric current sintering are typical techniques employed to produce nano

 DOI : 10.18231/2454-9150.2019.0546

structured ceramics. However, many of these techniques are not economically viable depending on the use of the final product. Thus, conventional pressure less sintering is still a more attractive sintering method to produce ceramic products, mainly due to its simplicity and cost compared to other methods.[9] In the conventional pressure less sintering, a controlled grain size with high densification could be achieved by adequate control procedures of the heating curve — herein defined as the maximization of the final density with minimum grain growth.[10]

III. SINTERING PROCESS FOR COPPER BASED BI-METAL STRIPS

The powder for sintering copper alloy is prepared by atomization of a melt of the alloy. The sintering process includes the following stages:

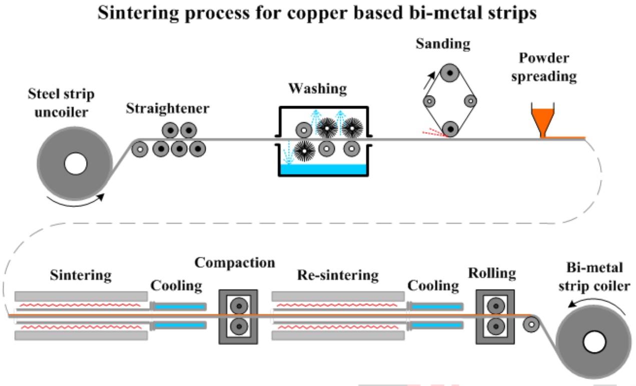

Fig.1.1 sintering process for Bi-metal Strips

- ✓ **De-coiler:-Uncoiling steel strip.**
- ✓ **Straightener:-Straightening the steel strip.**
- ✓ **Washing the strip** by a hot alkaline solution and mechanical cleaning by rotating steel wire cylindrical brushes.
- ✓ **Sanding the strip surface** by an abrasive rotating endless belt.
- ✓ **Powder Spreader: - Spreading the powder** of the copper alloy over the steel surface. The necessary powder alloy thickness is pre-calculated. The calculation takes into account two factors: the ratio between the densities of the powder and the sintered alloy and elongation of the strip as a result of Rolling.
- ✓ **Sintering Furnace:-**The process is performed in a long (about 33ft/10m) sleeve-type continuous sintering furnace. The sintering temperature is within the range 1515-1615°F(824-880°C) depending on the alloy composition. The atmosphere in the furnace is reducing: it consists of a mixture of Hydrogen (H_2) and Nitrogen (N_2), which may be prepared in Ammonia cracker by the process of dissociation of gaseous anhydrous Ammonia (NH_3) according to the reaction: $\mathbf{2NH_3 = N_2 + 3H_2}$. During the sintering process atmospheric hydrogen converts the oxides of copper (and other metals) on the surface of each powder particle into the metallic state ($CuO + H_2 = Cu + H_2O$). The particles then physically join (weld) to each other and to the steel strip due to the mutual diffusion of their atoms.
- ✓ **Rolling Mill:-** After sintering stage density of the alloy is higher than in the powder state but it is still 20-30% lower than in fully compact state. The pores between the joined particles are closed in the compaction stage when the strip passes a Rolling mill.
- ✓ **Re-sintering:-** This stage is performed in order to set physical joining (welding) between the surfaces of the pores mechanically closed in the compaction stage. Re-sintering is conducted in a sintering furnace similar to that of the sintering stage. Parameters of the process are also similar to those of the sintering. As a result of re-sintering sounds (no porosity) sinter structure of the copper alloy forms. The second phase (lead, bismuth) is homogeneously distributed throughout the copper based matrix in form of small particles (0.001-0.002"/25-50 µm) located between the copper grains.
- ✓ **Rolling: -** This stage is performed in order to strengthen (strain hardening) both the steel back and the sintered cooper alloy.
- ✓ **Recoiler: -** Recoiling the bi-metal strip**.**

IV. EXPERIMENTAL PROJECT

Problem Definition:

While inspection we found weak bond between steel strip and lining material so Extra time required for re-processing it which was affecting indirectly on production So to take action on it, re-sintering process need to be introduced, and re-sintering line need to be developed.

Objectives of the project:

The aim to make the strong bond between steel strip and lining by second sintering process by developing the sintering furnace in house by converting unused parts of caster line into Sintering and to indirectly Increase the production with minimum cost of investment.

V.EXPERIMENTAL DESIGN

Assumption:

i) Some Consideration need to be noted for Design Furnace:

High-temperature sintering furnaces are utilized in powder metallurgy for sintering stainless steel and, in some cases, iron-based materials. They are exclusively used in refractory-metal fabrication of molybdenum, tungsten and rhenium. High-temperature sintering furnaces are also utilized in the nuclear-fuel industry for sintering uranium oxide. The ceramic industry has always used

 DOI : 10.18231/2454-9150.2019.0546

high-temperature processes for sintering, co-firing and metalizing. To properly select and size a continuous high-temperature furnace, a number of qualifying questions must be answered.

- What is the operating temperature?
- Is there an existing profile?
- What is the process atmosphere?
- What size furnace opening is required?
- What is the boat/carrier size?
- What is the mass of the component?
- What is the required output?

The answers to these questions will determine the size of the furnace and determine which style of furnace best suits your production needs. Many furnace manufacturers have standard-size furnaces that they have built in the past. Most, however, customize the furnace to the clients needs. Because the units are produced one at a time, it is not difficult to have the furnace built to the customers exact specifications.

iii) Some Manual Calculation for Designing Sintering Furnace: For a long time engineers have used manual calculations to design and analyze furnaces. The trend today is to use spreadsheet computer software. Time is saved but the underlying calculations are the same. Both manual and spreadsheet calculations start with certain assumptions or inputs. In this sintering furnace example, the manual calculation is based on the specification that the part loading capacity is 700kg. and that Strip will be sintered continuously 3min/meter at temperature. The balance of the calculations involves determining the power requirements in each of the furnace zones by analyzing the heat input to the parts, heat input to the conveyor belt, heat losses through the refractory, and heat input to the process gas.

1) The calculations follow: First, determine the production speed empirically: Production speed (in./min) = Sintering zone length (in.) ×Heating zone efficiency/Time at temperature (min) = 157.48 ×0.65/3 = 35 in./min. Next, calculate the production rate using this equation: Production rate (Mtr/day) = Working hour (hr) ×Production speed (meter/min) = 8x (3 Shift) × (3mtr/min) = 480 Mtr/day. From the available data, the calculated production speed and production rate are 35 in. /min (3mtr/min) and 480mtr/day, respectively. Now a Day, to help illustrate the benefits of design software, an analysis of a furnace was performed first using manual calculations and then using FurnXpert software. The results were then compared. Although FurnXpert software can be used to analyze any type of batch or continuous furnace, the subject of this study was a continuous furnace for sintering powder metallurgy. For Construction of Sintering Furnace we don't need detail design of furnace since we working for the development project we have scope to use the unnecessary or which were not in use from many days we have copper caster line furnace which were not in use for long time, this furnace is as same sintering furnace and match requirement for sintering i.e. Length of zones and Capacity etc. Only we need to build up the inside of furnace for refractory and heating purpose. We studied the required material for Sintering furnace. Some Material required for refractory purpose hot phase bricks, Soft phase bricks, glass wool, thermostat, heater holding bricks etc. This material must necessary for building furnace.

Rolling mill: In metalworking, rolling is a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform. The concept is similar to the rolling of dough. Rolling is classified according to the temperature of the metal rolled. If the temperature of the metal is above its recrystallization temperature, then the process is known as hot rolling. If the temperature of the metal is below its recrystallization temperature, the process is known as cold rolling. In terms of usage, hot rolling processes more tonnage than any other manufacturing process, and cold rolling processes the most tonnage out of all cold working processes. Roll stands holding pairs of rolls are grouped together into rolling mills that can quickly process metal, typically steel, into products such as structural steel (I-beams, angle stock, channel stock, and so on), bar stock, and rails. Most steel mills have rolling mill divisions that convert the semi-finished casting products into finished products. There are many types of rolling processes, including ring rolling, roll bending, roll forming, profile rolling, and controlled rolling. Here we are using cold rolling process as the sheet is coming from cooling zone as per atmospheric temperature. Since we are working under development process rolling mill structure is also ready of caster copper just need to give drive by selecting proper gearbox and motor & also compare the specification required with existing gearbox so that it will be helpful for cost reduction.

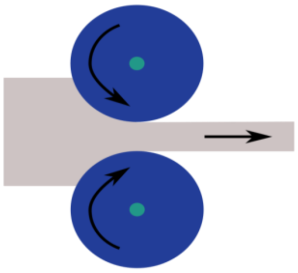

Figure.1. 2. Concept Diagram for Rolling

2) Calculation For Selection of Gear box and Motor for Rolling:-

- Strip Speed - 35 inch/min = 890mm/min
- Roller diameter = 160mm
- Development length = π x 160 =502.4 mm

 DOI : 10.18231/2454-9150.2019.0546

- So if, roller covered 502.4 mm /min per revolution ,
- X be the revolution required to covered 890mm/min
- 502.4 = 890
  1 rev /min X rev /min
- X= 1.77 rev/ min

So we need 1.77 rev/min at G.B Output.

We have Existing Gear box removed from skin-pass for development Previous gear Box Used: Gear box: - SNU6

Gear Ratio: - 30:1

G.B Input speed must be = 53.1 rev/ min,

Pulley Reduction ratio = 1.79

Required Motor output speed = 95.049 rev/min

Existing Motor :- 10 H.P.,R.P.M – 1450 which speed is high as compared to required so we need to reduce the speed it can be controlled by providing drive. Thus we save the costing for gearbox and motor by using existing instead of new.

VI. SELECTION OF MATERIAL

Refractory Material for Sintering Furnace:

A refractory material or refractory is a heat-resistant material, i.e. a mineral that is resistant to decomposition by heat, pressure, or chemical attack. It most commonly refers to a mineral that retains strength and form at high temperatures. Refractory materials are used in furnaces, kilns, incinerators, and reactors. Refractory materials must be chemically and physically stable at high temperatures. Depending on the operating environment, they must be resistant to thermal shock, be chemically inert, and/or have specific ranges of thermal conductivity and of the coefficient of thermal expansion. The oxides of aluminum (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories. Another oxide usually found in refractories is the oxide of calcium (lime).

Fire clays are also widely used in the manufacture of refractories. Refractories must be chosen according to the conditions they face. Some applications require special refractory materials. Zirconia is used when the material must withstand extremely high temperatures. Silicon carbide and carbon (graphite) are two other refractory materials used in some very severe temperature conditions, but they cannot be used in contact with oxygen, as they would oxidize and burn.

Material Used In Furnace While Construction:

1. Glass wool:

Glass wool is an insulating material made from fibers of glass arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties. Glass wool is produced in rolls or in slabs, with different thermal and mechanical properties. It may also be produced as a material that can be sprayed or applied in place, on the surface to be insulated.

Gases possess poor thermal conduction properties compared to liquids and solids, and thus makes a good insulation material if they can be trapped in materials so that much of the heat that flows through the material is forced to flow through the gas. In order to further augment the effectiveness of a gas (such as air) it may be disrupted into small cells which cannot effectively transfer heat by natural convection

2. Silicon Carbide Heater:

The Silicon Carbide Heating Elements is a kind of non-metal high temperature electric heating element. This Silicon Carbide Heating Elements is made of selected super quality green silicon carbide as main material, which is made into blank, solicited under high temperature and recrystallized. Compared with metal electric heating element, this kind of element is characterized by high-applied temperature, anti- oxidization, anti-corrosion long service life, little deformation, easy installation and maintenance. Therefore it is widely used in various high temperature electric furnaces and other electric heating devices, such as in the industries of magnet, ceramics, metallurgy, glass metallurgy and machinery etc. Some other details for heater. Spiral Type made out of thin walled beta silicon carbide heating elements useful for intermittently operating laboratory, Furnaces Rod Heating Elements for use in continuous Industrial Production Furnace, Dumbbell Shaped Elements-Shaped Elements, Very large sizes up to 44 mm dia and lengths up to 3 Mtrs.Custom built

Figure1.3. Heating Elements

The resistance of these elements varies with both temperature and time. The nature of these variations depends on the particular grade of material and manufacturer. For most types, the resistance is high when the material is cold, decreasing as temperature rises, reaching a minimum at typically between 1000°F and 2000°F, then increasing again as its temperature rises further. When kept at a high temperature, the resistance of the material increases with age. The change in resistance can be of the order of 3 or 4 to 1 for both time related and temperature-related phenomena, giving an over-all ratio of

 DOI : 10.18231/2454-9150.2019.0546

the order of 10:1.The rate of ageing is affected by the surrounding atmosphere, and also depends to a large extent on the operating temperature (and hence on the power being dissipated). Most will quote life related to maximum power in various temperatures and atmospheres

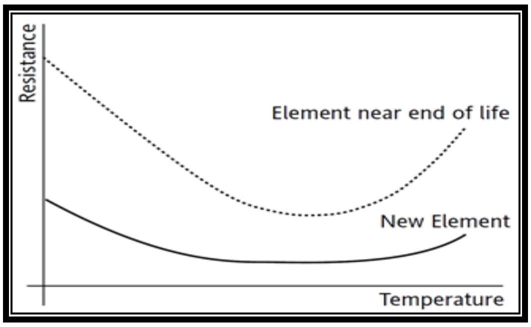

Figure 1.4. Graph for heating Element life

4. **Insulation Bricks:**

Purpose of Insulation

A thermal insulator is a poor conductor of heat and has a low thermal conductivity. Insulation is used in buildings and in manufacturing processes to prevent heat loss or heat gain. Although its primary purpose is an economic one, it also provides more accurate control of process temperatures and protection of personnel. It prevents condensation on cold surfaces and the resulting corrosion. Such materials are porous, containing large number of dormant air cells.

Thermal insulation delivers the following benefits:

- Reduces over-all energy consumption
- Offers better process control by maintaining process temperature.
- Prevents corrosion by keeping the exposed surface of a refrigerated system above dew point
- Provides fire protection to equipment
- Absorbs vibration

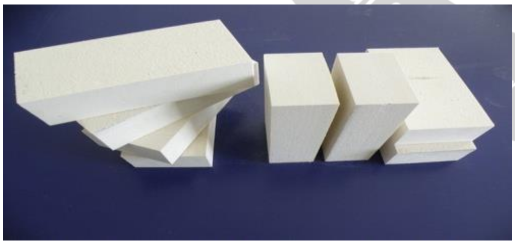

Figure 1.5. Cold Face bricks

Hot Bricks: - IS 80

Figure 1.6. Hot face bricks IS 80

High Alumina Bricks are produced with select bauxite chamotte as main raw material, fired at 1450-1470 °C by advanced process with strict quality control. High Alumina bricks have great features like high temperature performance, great corrosion and wear resistance, high bulk density, low iron content, etc. High Alumina bricks are extensively used in mining, metallurgy, cement, and chemical, refinery and refractory industries. These bricks are used in all kinds of industrial furnaces and high temperature areas to prolong the lives of furnaces. These bricks are used near to the heating chamber i.e. outside of heating element bricks.

Muffle: A Muffle Furnace's primary attribute is that it has separate combustion and heating chambers. The "Retort" is a gas sealed chamber that the material to be heated is placed in. This was really important in the "old days" because the by-products of combustion would otherwise have contaminated the heating process. With the invention of high temperature electric heating elements in the early 50's however, most furnace manufacturers quickly converted their muffle furnaces to electric where the byproducts of heating are negligible for most processes. Electrical furnaces heat by conduction, convection, or blackbody radiation processes, none of which create combustion byproducts and these designs now allow much greater control of temperature uniformity and assure isolation of the heated material from combustion contaminants.

VII. SELECTION OF HEATER ELEMENT

These figures are from kanthal heating handbook which are the leading manufacturer of heater for all types' furnaces.(Shown Below) We refer this handbook for selecting the required heater. The number of options within a given heating element class is ever increasing, and the overlap in the range of application of the classes is growing as well. The information and guidelines presented here are intended to be sufficient to narrow the range of heating element options for a specific application and/or to enable a general assessment of the validity of a proposed solution. However, the detailed specification and design of electric heating elements is best left to either a highly-qualified electric furnace/kiln builder, an experienced and unbiased electric heating system consultant, or a full-range electric heating element supplier who has no bias toward a particular class of element.

Selecting the right heating element starts with collecting the right information, and that begins with asking the right questions. These questions should concentrate on how to heat up the solid, liquid, or gas in question in your industrial process, and what the specifications of the heating element must be to achieve the best heating performance. These key questions include:

– What alloy should be used?

 DOI : 10.18231/2454-9150.2019.0546

– What temperature does the heating element need to reach?

– What sort of control is required?

– How long will the intervals be during which the heating element needs to be active?

Having precise answers to the questions above is critical to selecting the appropriate heating element. It's helpful to have the answers organized before reaching out to a company to procure a heating element or industrial heater because it expedites the process. Selection of alloy or material for the heater can be done on basis of their thermal resistance and capable for operating temperature. Most commonly used material for heater are Metallic element and silica carbide. We use the silica carbide element (kanthal) for furnace by considering following comparisons

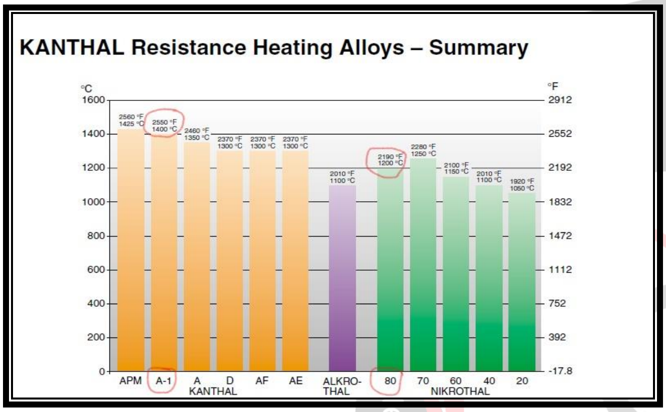

Figure 1.7. Kanthal Heating Alloy Specification Graph

VIII. SPECIFIC DESIGN DATA

Heat losses affecting furnace performance

Ideally, all heat added to the furnaces should be used to heat the load or stock. In practice, however, a lot of heat is lost in several ways as shown in Figure

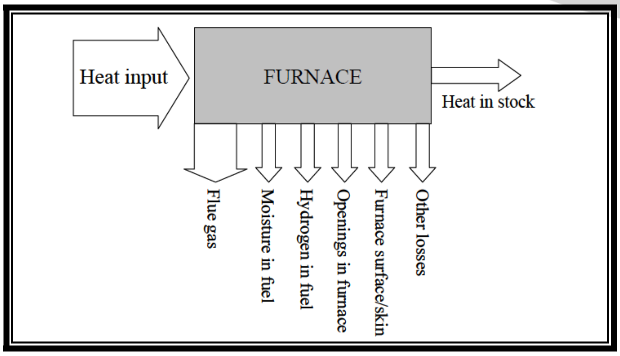

Figure 1.8. Heat Loses from Furnace

Calculating furnace performance

A furnace efficiency increases when the percentage of heat that is transferred to the stock or load inside the furnace increases. The efficiency of the furnace can be calculated in two ways, similar to that of the boiler: direct method and indirect method. Both methods are explained below.

Direct method

The efficiency of a furnace can be determined by measuring the amount heat absorbed by the stock and dividing this by the total amount of fuel consumed.

Thermal efficiency of the furnace = Heat in the stock

Heat in the fuel consumed for heating the stock

The quantity of heat (Q) that will be transferred to stock can be calculated with this equation:

$$Q = m \times C_p (t_1 - t_2)$$

Where, Q = Quantity of heat of stock in kCal

m = Weight of the stock in kg

C_p = Mean specific heat of stock in kCal/kg ^oC

t_1 = Final temperature of stock in ^oC

t_2 = Initial temperature of the stock before it enters the furnace in ^oC

IX. MANUFACTURING & EXPERIMENTAL SET UP

After all selection of furnace refractories materials, heater elements etc. We ordered quotation for same from different suppliers and final it at our requirement and after coming all the materials the assembly of furnace is done which was of copper caster was converted into sinter line and use of existing gear box and motor for rolling mill was cost saving development.

Figure1.9. Assemble Sintering Furnace

X. RESULT AND DISCUSSION

After all the assembly of sintering furnace, assembly of all sintering line is done i.e. Assembly of de-coiler, Straightener, Furnace, Cooler, Rolling mill and Re-coiler in Straight order for trailer. As the trail of Second Sintering is done for proper bond between lining and steel is achieve because after the first sintering and rolling of steel strip lining above the steel is elongated and micro is formed and after the second sintering required bonding is formed between them.

DOI : 10.18231/2454-9150.2019.0546

1) Result of Proper bonding after second Sintering

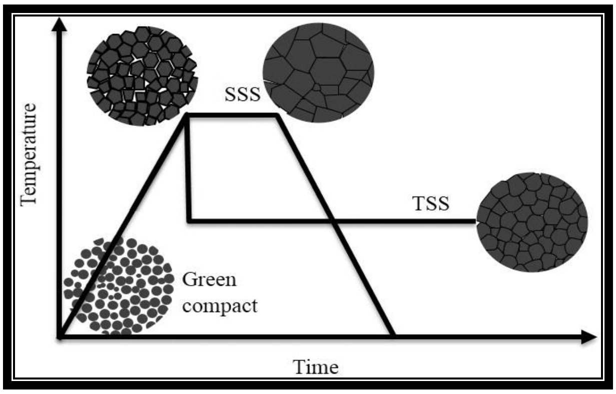

Figure 1.10. Micro-structure

It can be seen in figure that density variation results in increased grain size of the sample, showing that this condition is not yet the ideal to control the grain size in two-step sintering.

The heating curve control, combined with the presence of nanoparticles inclusions can further optimize the microstructure control. Table 4 shows the sintering procedure and results of relative density (%TD) and mean grain size for alumina-Zirconia samples. Results for TSS13 and TSS14 conditions show that the two-step sintering promoted reduction of the mean grain size compared to the conventional sintering (CS1) (Manosso et al., 2010)

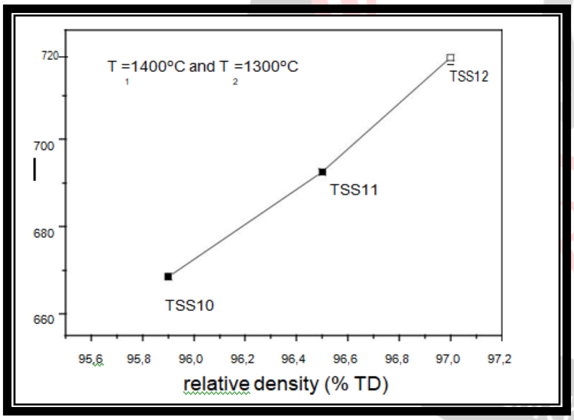

Figure 1.11. Relative/ Temperature Result

As the grain size increase the bond between the lining and steel is proper and thus it will be directly reduction of customer complaints.

2) Cost reduction and increase in daily target:

As we uses the maximum parts required for sinter line from existing caster line which is not in use. Since it is development we reduces the cost for purchase all the parts from outside for sinter line it can be so costly and developed furnace in-house is very cheap only costing for construction, material & labor etc.

On y axis = cost in lack. And x axis = Objectives

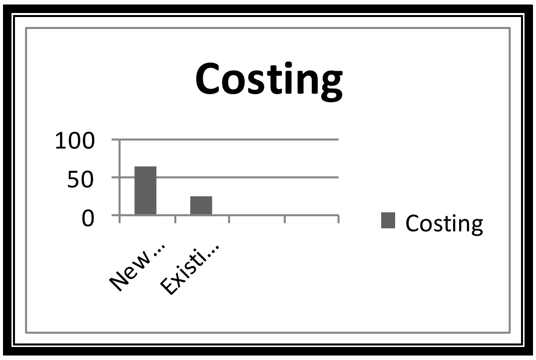

Figure 1.12.Effect on cost

Before this sinter line, there is indirectly effect on the production because after the first sintering, Second sintering also should be done on same and that's why new strip production is not possible. We were sintering two times on same sinter line so time for production of new strip is consumed.

After this sinter line, we can able to sinter the new strip after one sintering process thus we can achieve our daily target of strip production i.e.500 meter/day.

On y axis = % Percentage. And x axis = Objectives

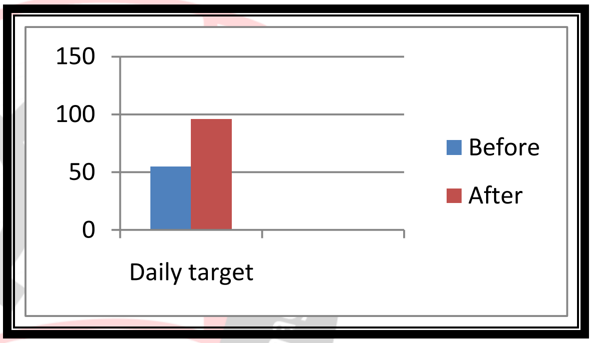

Figure 1.13. Effects on Production

XI. Conclusions and Future Scope

In this project, As we introduced the new sinter line for second Sintering process after the second sintering we achieve the required thickness and bond between lining and strip thus there is reduction of customer complaints regarding bond issue and As this also impact on the production rate because if same strip will be again sinter at same sinter line then there will required more time to produced one complete strip, as new sinter line is introduction in this strip only came for second sintering process so that new strip is produced on first sintering process,i.e time required for one complete strip is less than previous one and as we developed this line on unused caster line so cost required for building is very less as compared to purchase it from outside.

Future Scope is that as we all get the knowledge and experience about building the sintering Furnace, if production of bearing , bush increases we can build new sintering furnace in house because if we purchase it from outside as we calculate sintering furnace cost is too high as

 DOI : 10.18231/2454-9150.2019.0546

compared to build it in house as labor charge and some intense cost and also we can achieve required specification at cheap rate and also it has benefits to maintenance department as they know the infrastructure of furnace they can do the maintenance of furnace easily as possible and also we can make Development.

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 DOI : 10.18231/2454-9150.2019.0546