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Mathematical Analysis and Mechanical Modeling of an Inoculation System on Feeder Control for Pouring Unit in a Foundry Station

P. Gomathi, S. Gowri, A. Viswanathan, T. A. Selvan, S. Madhankumar

***Abstract:** This paper presents on feeder control; the inoculation device has been designed to automatically add inoculating powder to metal stream working with an automatic pouring unit. This system applies a constant dosage of inoculant easily modified by the control unit, with precise repeatability of the process. It incorporates a system of the instant direction of faults at all times, to ensure proper operation. In this project, the human effort is reduced by automating the inoculant feeding mechanism performed in a foundry. By doing pouring in manual manner, it ends up in reducing the rejection of production 2% owing to poor inoculation which disturbs the company's production. This system is used to feed the inoculant to the molten metal in a highly precise amount as per the requirements. After researching various feeding mechanisms, concluded with feeding machine with the help of screw which is more adoptable for desirable number of inoculants to be transferred. The mathematical analysis has been done and it is proven that satisfies the design criterions for modeling of the proposed system. The mechanical modeling is designed in such a way that inoculant occupies in two class of separate hoppers.*

***Index Terms:** Inoculation, mathematical analysis, pouring unit, foundry and screw feeding.*

I. INTRODUCTION

To fulfill the requirements of quality section in casting production unit, which is need and advisable for the adding of an inoculant to molten cast iron material. The machinability and properties on mechanical structure of cast iron with nodular graphite, condense and lamellar significantly depend on the formation of the primary structure and secondary structure. The formation of structure from the cast iron molten metal inoculation is processed by solidification technique. During solidification, the formation of nuclei on the inoculate structure with the fine particle size of less than or equal to 4 micro meters [1]. It serves the precipitation of graphite at the centers of crystallization structure [2].

This inoculation process is carried out by various stages. Initially it has more impact while pouring which is occurs in short span of time. The formation of nuclei on inoculant structure is depends on the cooling states and effectiveness of the materials. The pouring metals are conveyed to the furnace or vessel intermediate occasionally by inoculation system. After pouring into the furnace the mold is prepared for needed components in a foundry unit. Then cooling is required for mass production for reaching the eutectic state 4.3 percentage of carbon should be attained to reach the equilibrium state with atmosphere. In practical the equilibrium conditions are not achieved because the carbon content is majorly present as graphite. The main reasons for this are namely composition of chemical variations, thickness of the wall or cooling rate and temperature for pouring. From this study concluded that to get the good mechanical properties of structures high Sulphur content is recommended [3].

Till today, there is only one idea generated and implemented successfully by “OTTO JUNKER” for Automatic inoculation machine. In the present-day scenario, there are lots of ideas that aid us in Automation, which are similar to the one proposed by Biba Nebbad-Lechani, et al. An assumption was made that extensive holding time of an inoculated g r ay iron melt would result in a loss of physical properties of castings poured from this melt. This theory was examined in both a literature search and by testing and conclusions drawn from these findings are presented and discussed. Although there is a great deal of data available which discusses inoculants and their effects, very little mention is made of the effect of holding time in any of this material. The results indicate that holding time is of considerable importance when dealing with Zirconium based inoculation and inoculated iron are very effective inoculant. To obtain good results from iron casting the inoculation grain size should be taking care [4].

This project objective is to Mathematical calculations of design aspects and three-dimensional modeling an Inoculation Machine on feeder control for pouring unit in a foundry station for removing the errors caused by manual processing and increasing hardness. This implementation is done to avoid dirty, dangerous and difficult jobs and this will service without any disturbances to humans during its usage.

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*Correspondence Author(s)
P. Gomathi, Assistant Professor, Department of Mathematics, SNS College of Technology, Coimbatore, India – 641035.
S. Gowri, Assistant Professor, Department of Mathematics, SNS College of Technology, Coimbatore, India – 641035.
Dr. A. Viswanathan, Professor and Dean, Department of Mathematics, SNS College of Technology, Coimbatore, India – 641035.
Dr. T. A. Selvan, Professor and Head, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India – 641008.
S. Madhankumar, Assistant Professor, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India – 641008.

II. PROPOSED METHODOLOGY

This project is categorized into the following steps as a guide to attain the objective,

1. Focus on the mechanism of feeding the desired amount of inoculant.
2. Study on the mechanism of working components.
3. Perform design calculations for efficient working of the machine.

A. Inoculation

- The molten metals are solidified with the help of inoculations by apprise with nuclei and it initiated crystal formation.
- Inoculants are used for reducing the degree of penetration on the metal (molding) along with sand.
- It is provided sufficient nucleates to precipitate cementite.

Fine inoculant gives the modified structure without changing the chemical composition of the melt of cast iron. This is the key when the iron is to be kept low in carbon and silicon to make heavy-duty better-quality castings of iron [5]. Inoculants employed with barium is used for minimizing the formation of chill and resistant in better fade. The zirconium based also gives fade resistant.

The inoculant essential percentage is about 0.25 percentage or the total weightiness of the liquify to be preserved. At 1450 degree Celsius to 1500 degree Celsius the finest inoculation is ended.

B. Pneumatic Conveyor

The pneumatic conveying systems form the most developed and dissimilar class of control engineering by mechanical [6]. The pneumatic conveying systems with specified parts are shows in figure 1.

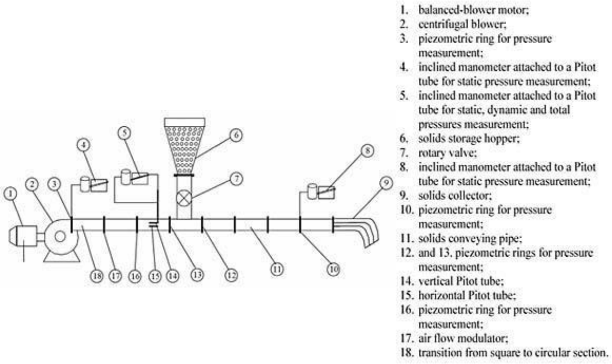

Figure 1. Pneumatic conveying system

C. Screw Lift

Screw lift is used for translating motions are required. Lifting of any weight, pulling or pushing of mechanical apparatus, tense clearances adjustment of mechanical components is done by screw lifts. Mechanical power of screw jacks is ranges from 5 KN and 2000 KN. Jack screws is used as linear actuators and motors, or lifts for mechanical structures depending on nature of movement [7].

The components of screw lifts are; worm screw, gear covering, trapezoidal lifting screw and worm gear. Figure 2 shows the screw lift.

Apart from that components namely compressor, FRL unit, direct control valves, solenoid operated valve, pneumatic conveyor, feeding nozzle, thermometer CT laser, IR sensor and Ball bearing are used for designing this proposed system. Thus, all these equipment's mentioned above are used to their full effectiveness and hence the automation for inoculation machine feeding control is done to reduce or prevent the human interaction with the inoculation process.

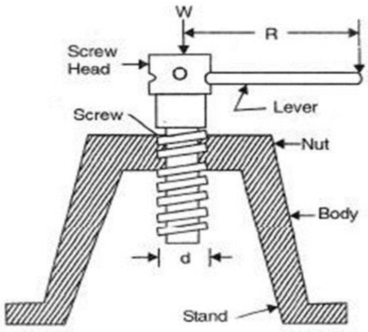

Figure 2. Screw lift

III. RESULTS AND DISCUSSION

A. Mathematical Design Calculations

The designs of every innovative system, products or mechanical structures are initiated with the help of mathematical design calculations to know or prove the systems are in safe mode. The results of system is not achieved, the system mathematical design calculations gets iterated to reach the safe design. This calculation is used for decision making.

Screw Lift:

In screw design, the forces required to lift the load upwards (P_U) and downwards (P_D) are the important values to designing the system. The upward and downward force values are found using equation (1) and equation (2) respectively. To know the aforementioned values, assumed the total system weight (W) is 100 kg, roller diameter for heavy duty (d) is 7 cm, pitch (p) is assumed to be 10 mm, Length (L) is 100 mm and the coefficient of rolling friction (μ) taken from the Databook, it is ranges from 0.001 to 0.002.

$$P_U = \frac{W \times d}{2 \times L} \times \frac{p + (\mu \times \pi \times d)}{(\pi \times d) - (p \times \mu)} \quad (1)$$

$$P_D = \frac{W \times d}{2 \times L} \times \frac{(\mu \times \pi \times d) - p}{(\pi \times d) + (p \times \mu)} \quad (2)$$

From the above equations the calculated forces required to lift the load upwards (P_U) and downwards (P_D) are 12.910 N and 3.521 respectively. For reducing the input load, increase the length to 200mm. Therefore $P_U$is equals to 6.45 N, it reduces compared to the previous one.

Pneumatic Conveyors:

The equivalent length of the conveyor is 3 m. The velocity of inlet conveying air (V_{air}) is 1.5 times the number given the data book, value is 4.5 m/s.

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The rate of volume flow or discharge (Q) is calculated by the product of conveying air velocity and area of the pipe (A), the value is to be 2.277×10^{6} liters per second. For finding particle velocity (V_p) the 70 percentage of the conveying air velocity is taken for calculation, it gives 3.15 m/s and slip ratio is 0.7.

From mathematical definition, the rate of volume flow or discharge is stated by limits.

$$Q = \dot{V} = \lim_{\Delta t\to\infty} \frac{\Delta V}{\Delta t} = \frac{dV}{dt} \qquad \text{(i)}$$

For curved surfaces, the equation becomes a surface integral,

$$Q = \iint_A^{\hat{n}} v.dA \qquad \text{(ii)}$$

Power is the rate of work is done. This is expressed by the equation (iii) and in terms of limiting value of is expressed in equation (iv). The equations (iii) and (iv) are used for the compressor driving power equations are formulated.

$$P = \frac{dW}{dt} = \frac{d}{dt}(F.x) = F.\frac{dx}{dt} = F.v \qquad \text{(iii)}$$

$$P = \lim_{\Delta t\to 0} P_{avg} = \lim_{\Delta t\to 0} \frac{\Delta W}{\Delta t} = \frac{dW}{dt} \qquad \text{(iv)}$$

By using the above equations (i) and (ii)the estimation of air consumption (Q_{air}) is formulated, weight concentration of mixture (w), pressure calculation on inlet (P_i) and outlet (P_o), and driving power of compressor is calculated by using equations (3), (4), (5), (6) and (7) respectively, this is referred from PSG Design data book [10].

$$Q_{air} = \frac{\pi d^2}{4} \times V_{air} \qquad (3)$$

$$w = \frac{Q}{4.32\times V_{air}} \qquad (4)$$

$$P_i = \sqrt{1 + \frac{\mu\times\beta\times L\times V_{air}{}^2}{d}} - (H \times P_{air} \times \mu) \qquad (5)$$

$$P_o = \sqrt{1 + \frac{\mu\times\beta\times L\times V_{air}{}^2}{d}} + (H \times P_{air} \times \mu) \qquad (6)$$

$$N = \frac{248.4\, V_{air}}{\eta\times\log(1.2\times P_w + P_{loss})} \qquad (7)$$

Where,

Q is the capacity of the conveyor = 0.00279 kg/s.

β is the weight concentration factor = 2.95×10^{-7}

P_{air} value is 1.6 bar.

η is compressor or blower efficiency = 0.55

P_w and P_{loss} is nothing but working pressure and loss in pressure due to leakage, values are 14.7 Psi and 0.3 Psi respectively.

From equation (5) and (6), the pressures are calculated, the values are 1 bar and 1.04 bar. The calculation for driving power of compressor is done by equation (7), the value is 283 kW. This mathematical calculation part was used to design this proposed system and it proved the design is safe.

B. Three-Dimensional Modeling

The three-dimensional modeling is done with the help of Solidworks software which is the solid modeler, and utilizes a parametric based feature approach to generate models and assemblies [8], [9].

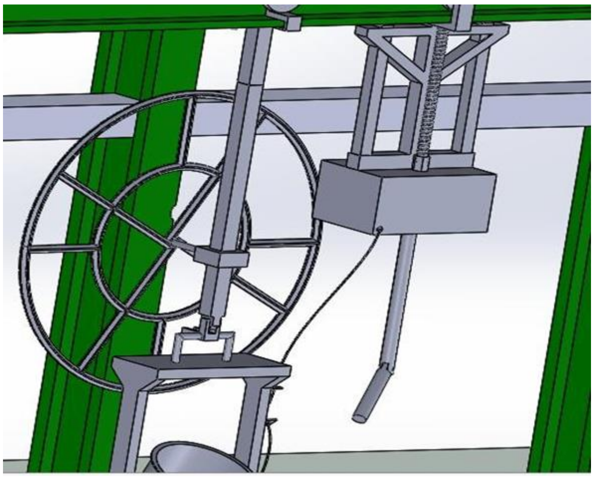

Figure 3. Screw Lift Isometric view

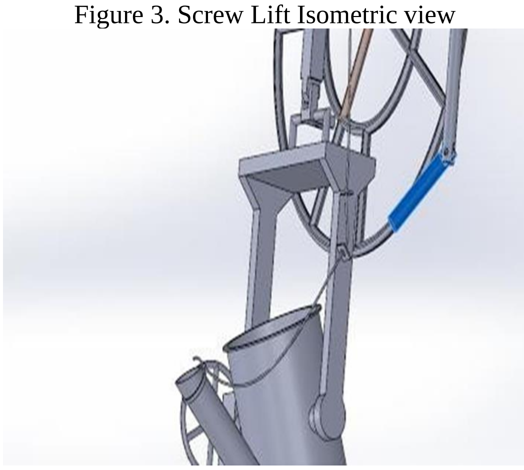

Figure 4. Feeding tube path

The detailed design has been drawn and drafted according to the design calculations made and industries requirement. Screw lift isometric view and feeding tube path designed model shows in the figure 3 and 4 respectively.

IV. CONCLUSION

Designed the Inoculation machine of feeder control for pouring unit in a foundry station from mathematical design calculations. Based on mathematical design calculations the proposed inoculation system is designed for feeding and it gives the design as safe. It consists of a highly precise screw feeder which is rotate in only one direction. After researching various feeding mechanisms, it ended up choosing the screw feeding mechanism which would be appropriate for desired amount of inoculant to be added. The mechanical structure is designed such that it can occupy two class of inoculants in separate hoppers and switching between them is made possible by the control mechanism. This results 2% product rejection due to poor inoculation by manual pouring method which affects company's production is reduced.

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AUTHORS PROFILE

Prof. P. Gomathi is working as an assistant professor in the Department of Mathematics at SNS College of Technology, Coimbatore, Tamilnadu, India – 641035. She has Obtained B.Sc., degree in Mathematics from Nirmala college for Women, Coimbatore, India in 2001, M.Sc., degree in Mathematics from Government Arts College, Coimbatore, India in 2003 and M.Phil., degree in Mathematics from PSG College of Arts & Science, Coimbatore, India in 2005.

Prof. S. Gowri is working as an assistant professor in the Department of Mathematics at SNS College of Technology, Coimbatore, Tamilnadu, India – 641035. She has Obtained B.Sc., degree in Mathematics from Government Arts & Science College, Coimbatore, India in 2006, M.Sc., degree in Mathematics from Kongunadu Arts & Science, Coimbatore, India in 2008 and M.Phil., degree in Mathematics from Kongunadu Arts & Science, Coimbatore, India in 2009.

Dr. A. Viswanathan is working as Professor & Dean in the Department of Mathematics at SNS College of Technology, Tamilnadu, India – 641035. He has Obtained B.Sc., degree in Mathematics from Madras University, India in 1982, M.Sc., degree in Mathematics from Bharathidasan University, India in 1984 and M.Phil., degree in Mathematics from Bharathidasan University, India in 1990. He has completed his Doctor of Philosophy from Bharathidasan University in 2009 and published a number of research papers in international journals.

Dr. T. A. Selvan is a dedicated, resourceful, technically sound professional; had 30 years of service in Technical Education. He has effectively working as Head of the Department and Professor in Mechanical Sciences. He has Obtained B.E, degree in Mechanical Engineering from Government College of technology, Coimbatore, India in 1986, M.E., degree in Engineering Design from Government College of technology, Coimbatore, India in 1991 and completed his Doctor of Philosophy from Paavai Engineering College in 2013. He has published several papers in International and National Level Journals and guided a number UG and PG Scholars.

Prof. S. Madhankumar is working as an assistant professor in the Department of Mechatronics Engineering at Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India – 641008. He has Obtained B.E, degree in Mechanical Engineering from Sona College of technology, Salem, India in 2015 and M.E., degree in Engineering Design from Government College of technology, Coimbatore, India in 2017. His Research interests include Mechanical Design, Optimization Techniques and Material Sciences. He has published a number of research papers in international journals and conferences and guided a number UG Scholars.

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