ISSN: 1793-8236

Design of Pig Casting Machine

S.N. Waghmare, C.N. Sakhale, M.S.Giripunje and V.M. Sonde

***Abstract*—Paper reports the design and development of Pig casting machine. A machine is utilized for conveying pig mould from one station to another with the help of conveyor; the paper describes design calculations, modeling and calculation of load torque, its economical viability. The machine is presently commissioned in one of the renowned steel plant. Paper also describes working and construction of machine in detailed.**

***Index Terms*—Chain Conveyor, PIG casting, Mould, Chain pull, Metal transfer Launder**

I. USE OF CHAIN CONVEYOR AS PIG CASTING MACHINE

A. What Is Pig Casting Machine:

In Steel Industries iron is produced in Blast Furnace by reducing iron ore (iron oxide) with carbon (coke) at temperature of 12000C to 13000C. The iron metal collects at the bottom of blast furnace and is tapped out from time to time. About 50 to 300 ton of molten metal can be tapped at a time in hot metal ladle. The iron in the molten form is transferred to steel melting shop for conversion to steel. Parts of the iron metal are converted to small pieces called as PIGS in continuous casting machine called as Pig Casting Machine (Pcm).

These pieces of iron produced in PCM are marketed in sizes of 10 to 45 kg/pc. Such small sizes of pieces are produced in PCM by pouring the hot molten metal into the mould having small pockets. The metal is there after solidifies by cooling with air followed by water cooling. This solidifies pieces called as Pigs if they are big in size & piglets if they are small in size. The Pig Iron is used as raw material for production of big size iron casting and other application such as conversion to steel of different grade.

Manuscript received September 23, 2010. (Write the date on which you submitted your paper for review.)

Subhash N. Waghmare, Author is working with the Priyadarshini College of Engineering ,Nagpur-Maharashtra State, India-440019 as Lecture in Mechanical Engineering Department. (corresponding author to provide phone: 9423423905; fax: +91 7104 237681; e-mail: subhaswaghmare1981@rediffmail.com).

Chandrashekhar N Sakhale, Co- Author, is working with the Priyadarshini College of Engineering ,Nagpur-Maharashtra State, India-440019 as Lecture in Mechanical Engineering Department. (e-mail: chsakhale@gmail.com).

M.S.Giripunje, Co- Author is working with the Priyadarshini College of Engineering ,Nagpur-Maharashtra State, India-440019 as Lecture in Mechanical Engineering Department. (e-mail: mngiripunje@yahoo.co.in).

V.M.Sonde, Co-Author is working with the Priyadarshini College of Engineering ,Nagpur-Maharashtra State, India-440019 as Lecture in Mechanical Engineering Department.

II. DESCRIPTION OF PIG CASTING MACHINE

A. Metal transfer Launder:

The hot metal drawn in ladle from blast furnace is poured into a metal transfer launder of PCM for casting the pigs. The metal transfer launder has a fabricated casing, which is lined with refractory. A continuous slope is maintained in the refractory for smooth flow of molten metal from receiving point to the discharge point. The launder casing is anchored to the pouring end platform.

B. PCM Strand

The PCM strand is an endless chain carrying the pig moulds. The strands are placed at an inclination. The level of the inclination is decided on the height required for receiving the molten metal and for discharging the cast pigs into the transport wagons. The molten metal tapped from the blast furnace and collected in the ladle and then poured in the metal transfer launder of PCM, through which molten metal is discharged into the traveling moulds for casting. The rate of pouring of metal and the take up rate of metal by the PCM are equalized by adjusting the rate of tilting of the ladle and the speed of the conveyor chain of the PCM strand.

The PCM has LH and RH set of chain links. The chain links are fully machined. These chain links are steel casting joined to each other through a hollow shaft and bushing on which the link can run. Replicable bushes are forced fit to the link and then grubbed for preventing rotating motion between the bush and the link. The LH and RH chain links are assembled on a hollow shaft. At the borehole of the chain, a hardened bush is provided through which the hollow shaft passes through. A rectangular flange is provided to the hardened bush, which engages, the machined housing provided in the chain link. This arrangement maintains the correct relative motion between the sprocket teeth and the chain links and minimizes the wear of the sprocket teeth.

Split pins are provided on the hollow shaft for preventing fall out of the chain links. The chain links travels on the rollers fixed to the technological structure of the PCM. The rollers are spaced such that the chain links remain always supported on the rollers. On the ascending track the rollers carry the load of the chain and the moulds filled with metal whereas on the descending track, the moulds become upside down and the chain gets supported on the bottom rollers on its other side. The rollers are provided with a collar for preventing derailment of the chain. The rollers are mounted on the brackets. Holes are provided at the base plate of the brackets for anchoring the roller assembly to the ascending and descending tracks of PCM. Bearing caps of the rollers are provided with seals for preventing ingress of moisture and atmospheric dust. Protection guards are also provided beyond the bearing caps, which act as a secondary protecting to the system. Moulds are anchored to the chain at LH and RH links. The chain duly fitted with moulds forms the train. The chain links pass through the sprocket assembly at the discharge end and at pouring end. Motor gear unit drives the sprocket assembly at discharge end whereas the sprocket assembly at pouring end is free to rotate on its bearings. The PCM drive is coupled to the drive sprocket assembly by a geared coupling. The sprocket assembly at the pouring end is made to float to render compensation for expansion of chain links and for overcoming jams due to external reasons. A self-regulating tensioning device is provided at the individual sprocket assembly at the pouring end. The tensioning device consists of the following:

- A fabricated base frame fitted with slide rail.
- Bearing housing with guide seat matching with the slide rail for the base frame and clevis for connecting the tension rod through pins.
- Tension rod having one end to connect to the bearing housing through pin and the other end threaded for adjusting the spring tension.
- Compression springs.
- Nut to suit the tension rod threading.

The drive consists of the following:

- AC sq. cage induction motor
- A pin and bush coupling between motor and gear box
- A helical gear box for speed reduction.
- A geared coupling between the gear box out put shaft and the shaft of the drive sprocket assembly.

A spillage chute is provided below the ascending track of the strand at the location where metal is discharged from the metal transfer launder to the pig mould. The metal spilled at this location due to mismatch of rate of flow of metal and take up rate of metal by PCM, falls on the spillage chute.

A pig-knocking device is provided at the discharge end sprocket assembly for quick discharge of the pigs from the mould. The pig-knocking device has a cam & follower mechanism for free fall of the knocker on the cast pig. The pig-knocking device mainly consists of the following:

A cam disc fitted to the drive shaft of discharge end sprocket assembly. The cam profile is matched to the sprocket teeth for accurate positioning of the knocker and for cent percent repeatability of the striking points.

The cam actuates a lever mechanism.

A roller moving on the shaft is provided at the end of the lever coming in contact with the cam. The other end of the cam is connected to the shaft of the knocking device.

A Knocker arm with one end fitted to the shaft of pig knocking device and the other end having a knocker disc. Springs are provided on the knocker arm for absorbing the shock of the impact of the knocker above the tolerance limit.

A Pig impact device consisting of a chain suspended to the technological structure is placed in front of the discharge end sprocket assembly. The purpose of the impact device is to absorb the impact of the pigs falling from the moulds at the discharge end. The pigs ejected/dislodged at discharge end loose the kinetic energy to the impact chain and fall on to the discharge chute.

A discharge chute is placed below the discharge end sprocket for transferring the pigs to the product collection wagons. A sand bag is provided at the pig-receiving end of the discharge chute for absorbing the impact of the falling pigs. The angle of the discharge chute is selected to around 450 to the vertical to enable easy transportation/sliding of the pigs. The bed of discharge chute is made of rail section, which gives long life and offers minimum frictional force to the sliding pigs. The discharge chute is anchored to the technological structure of the PCM strand.

A grizzly is placed below the return track of PCM strand for preventing fall of stickers on to the ground. The first termination point is before the lime splashing unit and the second at 1 meter above the ground level near the tail end. A chute is provided at the first termination point for collection of stickers at the ground level. The grizzly is anchored to the technological structure of PCM and an adequate clearance is provided between grizzly and traveling moulds such that stickers cannot get entrenched between them.

A water trough is provided below the pig moulds at the ascending track for collection of surplus pig cooling water. The trough is connected to the return water pipeline which discharges the water to the return water trench running underground and on to the circulating water tank.

C. Mould

Metallic moulds are provided in PCM for casting pig iron. The mould has cavities for dividing the castings into 4 parts called piglets. The mould is designed with varying section thickness to maintain optimum heat transfer during the casting campaign. 2no. Support brackets are provided in a mould at opposite ends for anchoring the mould to the LH and RH chain of PCM. The support brackets are kept tilted to match the inclination of PCM strand so that the mould surface remains horizontal.

The moulds anchored to the PCM chain forms the Train. For preventing spillage of metal during pouring of metal in moulds, the moulds are required to be interlocked with each other. The moulds are thus designed with twin interlocks as described below. When the metal is poured in the moulds, it can get spilled out between the front and rear matching surfaces of the pair of moulds. For preventing such spillage, the rear side of the mould is made in the form of a prism with a reverse tapered bottom surface. The front side of the mould is made with a rising nose. The front side of the hide mould engages the reverse tapered bottom surface with the leading mould making a perfect interlock. When the moulds are being filled up, the molten metal can leak from either side of moulds, where the anchor brackets are provided. For preventing this leakage ribs, are provided in the moulds and curvatures on either side. The ribs of the preceding and succeeding moulds thus interlock with each other. Overflow notches are provided at the rear side of the mould. These notches limit the filling level of the mould the excess metal cascades to the downstream mould.

The moulds are consumable spares of PCM. The life of the mould depends upon the consistency and uniform filling of mould during casting campaign. In a casting campaign if all the hollow/pockets/cavities of the mould are not filled with the molten metal and the moulds with hallow pockets/cavities travel upwards, water gets filled up in the empty hollow/pockets/cavities at the water-cooling stage of the stand, which causes thermal shocks and might result in the cracking of the moulds.

D. Lime Milk Preparation and Splashing System:

For preventing sticking of metal to the moulds, the moulds are coated with lime powder. Lime coating is done by spraying lime milk on the interior of the mould during their return passage. Lime powder is slaked before it is discharged into the lime milk preparation tank. The slaking of lime is done in a classifier. The purpose of providing a classifier is to remove the grit continuously from the lime powder and to prepare the slaked lime for its transfer to the lime milk preparation unit. The lime milk preparation unit is a steel tank fitted with an impeller, driven by a motor gearbox unit. Continuous mechanical agitation makes a uniform lime milk suspension, which is pumped to the lime milk splasher unit. A port is also provided in this tank for receiving the return lime milk from the splasher unit.

Slurry pumps are provided for transferring the lime milk from the lime milk preparation tank to the splashing tank. The capacity of the slurry pump is selected such that about 3 times the volume of slurry required for coating the mould can be circulated. The excess quantity is returned to the lime milk preparation unit. Continuous circulation of lime milk between the lime milk preparation unit and the splashing unit, helps in getting a uniform lime milk suspension at the lime milk preparation unit as well as at the lime splashing unit and also avoids sedimentation at any location.

The lime milk-splashing unit works on the principle of scooping of lime milk, by continuous rotation of a paddle impeller partially submerged in the lime milk. For this purpose, two discs fitted on a shaft are housed in the fabricated body of the lime-splashing unit. At the periphery of the disc, are provided the scoops. The speed of the disc is adjusted such that adequate splashing velocities are achieved for coating of time on the cavities of the moulds. The location of the splashing unit is selected such that the return mould remains at adequate Temp. for immediate sticking of the lime to it and that the coated mould does not hold any water by the time the mould reaches the pouring end. Gland seals are provided at the exit points of the splasher body to prevent leakage of lime milk at these locations. The paddle shaft is supported on antifriction bearings and is coupled to a motor gearbox unit through a bush and pin type coupling. For the purpose of cleaning and maintenance a manhole is provided at the lower end of the splasher tank. Ports are provided in the splasher body for entry of lime milk and for outflow of the lime milk into the return line of the lime milk preparation unit. Interconnecting pipes and pipe fittings are provided in the lime milk preparation unit and splasher unit for making ring mains. Grating is provided at the topside of the splasher unit to prevent falling of sticker in the tank.

E. Water Cooling System

In the PCM, solidification of molten metal is achieved in two stages, first stage being natural air-cooling and the second stage being direct water quenching. The duration of air-cooling is selected such that the top surface of the cast metal reaches a plastic state so that the water spray for quenching can commence without any explosion. The efficiency of the water-cooling system is a vital factor, which governs the temperature of the pigs discharged from PCM. The conventional types of nozzles used in spraying of water on the pigs, has demerit of choking of nozzles because of unavoidable dust/carbon/lime particles getting mixed with the cooling water. The unique water spraying system designed & supplied by us for the various PCM overcomes the problems faced in conventional spraying systems. In our system water spraying is done through the flute holes provided on the top side of the water runner. A specially designed rotor is provided for adjusting the water flow which has self cleaning feature in built in it. Two/three circuits of water spray are provided for avoiding pressure drop in cooling water pipelines. Water pipelines are suspended from the technological structure of PCM. Large sized nozzles for flooding of spillage chute are provided. Large size spray nozzles are also provided at the discharge end for cooling of the discharged pigs (at the wagons). Regular pipeline connections are provided at the lime milk preparation unit for preparing lime milk. Water distributor is provided near the pouring end platform. The inlet of the distributor receives water from the circulating pump of PCM installed at the pump house located near/above the underground return water tank. The water distributor has two main outlets, first for water-cooling of mould/pigs and second for wagon spraying. A direct water connection from BF central water supply is recommended for the lime milk preparation unit and for the maintenance water taps points.

F. Technological Structure of the PCM

The PCM is supported on a technological structure. For convenience of operation and maintenance, following technological platforms, walkways, ladders/staircases and material handling facilities are provided.

Pouring end platform with railing. It is recommended to have refractory flooring at the platform as the hot metal may spill over the place.

Discharge end platform with railing. The discharge end sprocket assembly, strand drive, pig impactor, wagon-spraying unit and discharge chute are mounted on the platform.

Walkways with railings along the sides of PCM strands (with common middle walkway for twin strand).

Staircases/ladders with railing for reaching the walkways at lower lever and discharge end platform.

Covered shed above the discharge end platform.

III. Analatical Calculation for Maximum Chain Pull

To enable the most suitable chain to be selected for a particular application it is necessary to know full application details such as the following:

- Type of conveyor.
- Conveyor centre distance and inclination from the horizontal.
- Type of chain attachment, spacing and method of fixing to the chain.
- Number of chains and chain speed.

- Details of conveying attachments, e.g. weight of slats, buckets, etc.
- Description of material carried, i.e. weight, size and quantity.
- Method of feed and rate of delivery.

The preferred method of calculating the tension in a conveyor chain is to consider each section of the conveyor that has a different operating condition. This is particularly necessary where changes in direction occur or where the load is not constant over the whole of the conveyor. For uniformly loaded conveyors there is a progressive increase in chain tension from theoretically zero at A to a maximum at D. This is illustrated graphically in Fig. 14 where the vertical distances represent the chain tension occurring at particular points in the circuit, the summation of which gives the total tension in the chain. Thus, in Fig. 4.1 the maximum pull at D comprises the sum of:

Fig 3.1: Maximum Chain Pull Diagram

(a) Pull due to chain and moving parts on the unloaded side.

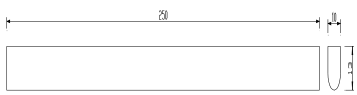
(b) Extra pull required to turn the idler wheels and shaft.

(c) Pull due to chain and moving parts on the loaded side.

(d) Pull due to the load being moved.

If it is imagined that the chains are ‘cut' at position X then there will be a lower load pull or tension at this position than at Y. This fact is significant in the placing of caterpillar drives in complex circuits and also in assessing tension loadings for automatic take-up units. This principle has been used to arrive at the easy reference layouts and formulae to which most conveyor and elevator applications should conform.

A. Data Collected

S.N.	Title	Calculation
1	Hot metal ladle carrying capacity	40 Ton
2	Rate of pouring	01 ton /min
3	Weight of one Piglet for easy charging in foundries	11.5 kg
4	Total kg of piglet in one mould	04
5	Total weight in one mould	11.5 x 4= 45 kg
6	Size of pocket in mould	
7	Density of molten metal (at liquid state)	6.8 ton /cum
8	Keeping the length of one pocket	250mm
9	Total volume required for 11.5 kg of pig let	11.5/6.8=1.691 lit.
10	Since we have considered length of pocket 250mm So cross sectional area will be 	1691/25=65 sqcm Cross sectional area will be of triangular shape of 10 x 13cm
11	Considering the heat transfer rate for cooling of molten metal in pig mould, after pouring the temperature of pig mould should come down below 6000C Size of pig mould was decided as	1050 x 310 x 250
12	Width of mould kept as 310 (305 pitch & 5mm for over lapping)	
13	Molten metal pouring per mould	45 kg at 13000C
14	To carry 1Ton of molten metal in one min total no of pig mould required	1000/45=22. 22 No of pig mould
15	Since pitch of pig mould	305 mm
17	The speed of the pig casting machine comes out to be	22.22 x 305 = 6777.1 mm i.e. = 7 m/min
18	U = Coefficient of friction for bearing,	0.0064
19	f = Coeff. of friction for the track Resistance,	0.1
20	T = Torque, Nm	
21	Pitch Diameter of sprocket	1000 mm
22	Length of Machine c/c	42 mtr

B. Chain Pull Calculation

The system to be chain sliding & Material Carried

- From Renold Designer Guide book we consider BS series Index 400.
- Total Load on Chain Conveyor from take up point = 45 x 37 mtr = 1665 kg
- Estimated mass of chain & mould = 30 kg +128 kg = 158 kg
- Load in one mtr distance =1000/305 = 3.2786
- Weight per mtr = 3.2786 x 158 = 518 kg
- Weight of APRON in empty condition(Wa) (weight of chain link & pig mould) = 518 x 42 = 21756 kg
- 21756 x 9.81 = 213426.36 N (213.42 KN)
- Weight of APRON In Carrying condition (W)= 213426.36 N + (1665 x 37 x 9.81) = 817771.41 N = 817.77 KN

Tension Calculation

Tension T3

T3-T2 = Wa x f, T3 = T2 + (213426.36 x 0.1) , T3 = 21342.63 N

Tension T4

T4 (SR) = Sprocket Resistance Tension

T4 (SR) = T3 (1+U) = 21342.63 (1+0.0064) = 21479.22 N

T4 (CB) = Chain Binding Tension

T4 (CB) = 0.07 x T4 (SR) =0.07 x 21479.22=1503.54 N

T4 = T4 (SR) + T4 (CB) , T4 =22982.76 N

Tension T1

T 1(TR) = Track Resistance Tension

T 1(TR) = T4 + W x f = 22982.76 + 817771.41 x 0.1= 104759.9 N

T1 (SR) = Sprocket Resistance Tension

T1 (SR) = T1 (TR) (1+U) = 104759.9 (1+0.0064)= 105430.36 N

T1 (CB) = Chain Binding Tension

T1 (CB) = 0.07 x T1 (TR) = 0.07 x 104759.9= 7333.193 N

T1 = T1 (SR) + T1 (CB) + T1 (TR)

T1 = 112763.554 N = 112.763 KN

As per Renold Designer Guide Book Design is Safe Since it is below 400 KN

C. Calculation Of Bearing Pressure

Weight of PIG mould & piglet = 45 + 128 = 173 kg x 9.81= 1697.13 N

Load of Chain Over pitch of 305 mm = 30 kg x 9.81 = 294.3 N

Total Load on Roller = 1697.13 + 294.3 = 1991.43 N

Bearing Pr of Roller = 1991.43/1403 = 1.41 N/mm2
Roller material Cast steel 1030, Bearing Pr 3.2 N/mm2
Bearing Pr is Below permissible range so design is safe.

D. Power Calculation

(112763.554 x chain speed)/ 1000= KW
(112763.554 x 0.1167)/1000 = 13.159 KW
For vertical lift
Work Done = mgh=((158+ 45) x 9.81 x 8)/1000 = 15.93 kw
Total kw Reqd. = 13.159 + 15.93= 29.09 KW.

IV. Future Modification

In this system of PCM overall weight of the system can be reduced by reducing the weight of chain link,

By Selecting high tensile strength alloy and reducing the weight of chain link will not make much difference in the cost of chain link.

But since weight of chain link is reduced which is consisting ¼ of the weight of chain mould & roller assembly will result in selection of lower weight of roller & supporting structure

This will also result in reduction of power requirement for PCM drive system.

Since all the strength of different components are related to the strength & weight of chain link.

Considering the above aspect it is possible to reduce the cost of overall system of pig casting machine.

References

[1] Alexandrov, M. P.,1978, " Material Handling Equipment ", Mir Publications; Moscow , Ussr
[2] Spivakovsky, A. And Dyachkov, V., 1985," Conveying Machine " Vol I, Mir Publications ;Moscow,
[3] Renold Design Data Book
[4] Design of Machine elements by – B.D. Shiwalkar
[5] Design Data for Machine elements – B.D. Shiwalkar

Annexures

List of Figures

Figure 1: Tail End Sprocket View of Pig Casting Machine
Figure 2: Strand View of Pig Casting Machine
Figure 3: Discharge End View of Pig Casting Machine
Figure 4: View of Drive at Driven End
Figure 5: View of Lime Splasher
Figure 6: Discharge End View of Pig Casting Machine with Water Cooling
Figure 7: View of Pig Casting Machine with Air Cooling
Figure 8: View of Drive End Sprocket
Figure 9: View of Launder & Hot Metal Ladle
Figure 10: View of Launder & Filling Of Mould With Hot Metal
Figure 11: View of Pouring Hot Metal In Launder
Figure 12: View of Filling of Molten Metal In Launder
Figure 13: View of Hydraulic Tilting System of Ladle
Figure 14: View of Slag Formation in Hot Metal Ladle
Figure 15: View of Discharge of Piglets at Discharge End Of Pig Casting Machine

Figure 1:

Figure 2:

Figure 3:

Figure 4 :

Figure 5:

Figure 6 :

Figure 7:

Figure 8:

Figure 9:

Figure 10:

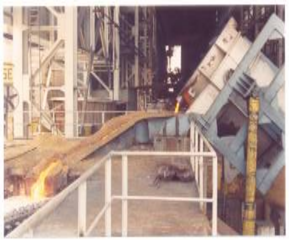


Figure 11:

Figure 12 :

Figure 13:

Figure 14 :

Figure 15:

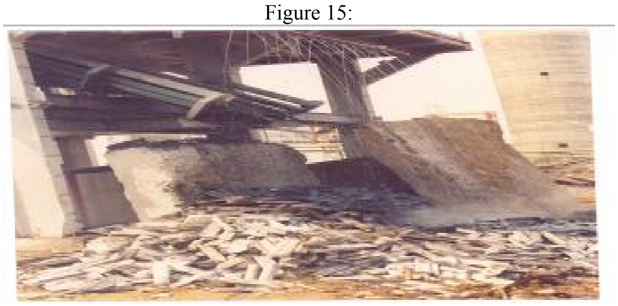


Figure 16 :

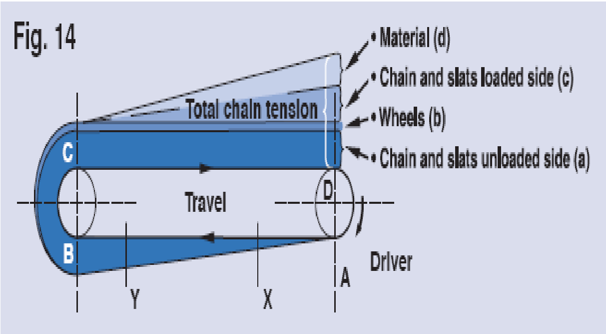


Figure 17: