

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 9, September 2018

Blast Furnace Tap Hole Closing By Using Emergency Mudgun System

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ABSTRACT: Blast furnace is a counter current reactor vessel which produces hot metal by tapping operation. Larger blast furnace will be having higher productivity rate at a defined raw material burden ratio with respect to coke rate. Only such kind of furnace is capable enough to extract better productivity rate. Equipment's has to work accordingly to the furnace burden ratio. Abnormal behaviour of the equipment leads to decrease in availability over service period. One of such kind of equipment is Mudgun machine. Mudgun machine is mainly used to close the tap hole after tapping operation is completed. Any abnormality in the Mudgun machine with respect to the mechanical or electrical point of view their will be tap hole closing failure. Due to number assembly components the Mudgun MTTR is too high. Hence their forth the alternate system has to be developed for tap hole closing during emergency situations. By enlightening such situation the Emergency Mudgun system is being developed to close the tap hole by using the alternate source from the drilling machine drifter component to close the tap hole. By enacting such situation we can avoid the furnace shutdown and meanwhile the Mudgun can be repaired without affecting the productivity of the furnace.

KEYWORDS: Mudgun, Drilling machine, Tap hole, Emergency mudgun system, Furnace, Drifter

I. INTRODUCTION

Blast furnace is a system of several auxiliary units which are interlinked to each other for continuous operation to produce hot metal. Several auxiliary units consists of individual equipment's which are categorized into critical and non-critical equipment's. Individual contribution of auxiliary units has made a system to contribute with a highly efficient in equipment's maintenance procedure to give better efficiency in operation. Some of the critical units like cast house, Heating system (Stoves), Water treatment plant, and stock house which plays a major role in handling critical equipment's which run throughout the life cycle without having any stand-by equipment's. Hence the maintenance strategy adopted for these type units is to have Preventive maintenance type to have a good working cycle with improved MTBF. Handling of such type of critical equipment's is cost effective during breakdowns. But the impact on furnace productivity will give an immense major loss in production of hot metal. Hence one of the units which play a major role in handling of tapping practices is Cast house [1].

1.1 Detailed study of Cast-house operations based on the literature survey

During hot metal production at normal levels (close to design), the alternating casting practice is adopted whereby tapping is alternated between the two tap-holes of the furnace to ensure uniform draining of the hearth. During low production levels, single-side casting practice is adopted whereby tapping takes place at only one tap-hole for a period of a week before reverting to the alternating practice. Single-side casting has benefits with regard to optimal usage of the trough refractories and temperature retention [2].

Several factors can influence the smooth operation of the cast-house, some of which are:

- Torpedos not being placed on time for tapping
- Not tapping the furnace dry during the previous tap
- Delays due to cleaning work, preventing the start of tap-hole drilling

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- Cast-house equipment (drill, clay gun, tilter, troughs etc.) failures.

Any of these factors can cause a delay in tapping the furnace and necessitate the reduction of the production rate to Control the liquid level in the furnace.

1.2 Cast house: Cast house consists of two major equipment's which are mainly used for tapping applications [3].

1.2.1 Drilling machine overview:

It is used to open the tap hole by drilling of tap hole using the drill rod which is fixed to drifter component as shown in fig-1.1. Drill rod is fixed to the chuck of drifter and then the drifter operations carried out to drill the tap hole as per the requirement. By considering the various failures in the drilling machine will not give a major impact in shutdown of the furnace. Hence an in depth analysis is not carried further due to its non-impact factor on productivity. But the drilling machine can be used as an auxiliary source of energy input for this project.

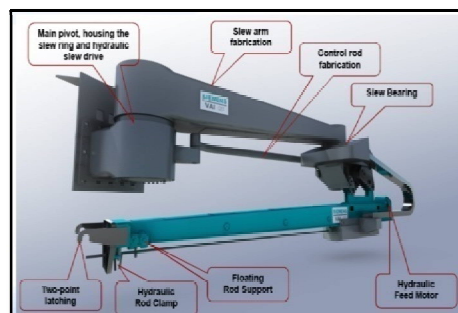


Fig-1.1: Tap hole Drilling Machine

1.2.2 Mudgun machine overview:

It is used to close tap hole by using the Mudgun clay as shown in fig-1.2. The machine consists of barrel which is filled of clay and is pushed by using the piston head into the tap hole. All the operations of Drilling machine and Mudgun machine which work under the hydraulic energy. Mudgun consists of several components which are interconnected to each other in which is mounted on the base frame. By considering the various failures in the Mudgun machine will give a major impact on the productivity of the furnace. Several problems which takes high MTTR in such a way that furnace has to be taken shutdown due to of its non-availability of stand-by equipment to make a change over during failure of the Mudgun machine.



Fig-1.2: Tap hole Mudgun Machine

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II. PROBLEM DEFINITION

Mudgun machine failure rate is less when compared to the other equipments in the blast furnace. But the impact factor on the production of hot metal is very high. Main machine problems that can be defined and solved, but main cause is related to its MTTR which is practically high. Clearance from the repair time will be more due to which furnace stabilization cannot be assured during repair time. Hence furnace had to be taken shutdown until the system gets repaired. This causes huge loss of production and increases down time of the furnace hence their by decreases the reliability of the productivity of the furnace.

Data collected from the TCG team of blast furnace#3 from Vijayanagar steels of mudgun failures which are categorized into different sections [4]. Some of the related issues with respect to the failures of Mudgun are as listed below:

2.1 Types of Failures in Mudgun Machine for FY 2016-2018

Mudgun failures are classified into different sections based on the types of failures. Mudgun is operated by the hydraulic system based on the mechanical linkages with electrical power source. The mudgun machine operations are done by using the wireless remote device. Mudgun machine is fixed at one particular place near to the tap hole. Hence the mudgun machine maintenance leads to a high time consuming work. The total number failures which are caused by different reasons which results to the tap close failure are listed in the below table-2.1.

Problems solving technique are identified by different phenomenon of preventive maintenance practice. Adopting different maintenance practice by change in practise and modification of different segments based on the different sections.

Table-2.1: Failure Frequency of Mudgun Machine Equipment

Section	Problem Description	Frequency
MECHANICAL	Connecting rod got cut	2
	Piston head bolts got sheared off	4
	Split coupling stud bolt got cut	2
	Sleeve in center pin got dislodged	1
	Intermediate cone got burnt	6
	Base frame bolts got cut	2
	Piston rings got damaged	6
HYDRAULICS	Sleeve in cylinder pressure line got punctured.	3
	Ram cylinder O-ring got cut	2
	Proportional valve got stuck	1
	2 way rotary joint seal damaged	2
	High oil temperature reached >70c pump tripped	3
	Hydraulic Pump failure of Mudgun machine	3
ELECTRICAL	Mudgun machine operating remote failure	5
	DCV command interlock failure	3
	Tank oil level feedback sensor malfunctioned	2
	Pressure transmitter malfunctioned	4

Table 2.1 describes about several problems can be solved as per section wise within mean time. But some of the critical problems which require high time in solving the above issues are predictable but cannot be taken any

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different measures to reduce repair time of the machine. During the running period of machine the regular maintenance activity is carried as per the schedule. But any abnormality in the equipment is due to not following maintenance schedule, and irregular operating of the equipment leads to decrease in the reliability of the equipment. The problem solving procedures are well defined and even the safe operating procedure are standardised during each failure event of the Mudgun machine. Hence an alternate system is required to develop a safe working practice in cast house and to close the tap hole without affecting the productivity of the furnace[5].

III.IMPACT OF THE PROBLEM

The problems that are faced by the Mudgun are very frequent in nature because of its low reliability in nature which is working since long time. Even poor maintenance leads to failure of the equipment in many ways. When Mudgun fails to close the tap hole the impact is mainly with the production loss with respect to the annual production rate. Blast furnace#3 of 4019 m³ volume with an average production rate of hot metal is equal to 8600 Tons/day. If Mudgun fails to close the tap hole with any one of the reasons which are listed, then the minimum time taken to repair any of such problems of Mudgun is about 2hrs. Then the average loss of hot metal is 716 tons. The average cost per Ton of hot metal is Rs 20000 and total loss is equal to **Rs1, 43, 33,333**.

Tap hole closing failure leads to disaster in cast house working environment. Furnace inner pressure will give a jet hot metal spillage around the work place which may damage the nearby equipments[7]. Fumes and dust which cover entire cast house area which creates unsafe working environment as shown in fig-3.1.



Fig-3.1: Tap closing failure caused disaster in cast house

This high impact in terms of cost leads to high maintenance accuracy strategies which are developed in a regular basis to avoid the failure of the Mudgun machine. Since the repetitive problems are very less in records which are unpredictable failure of the equipment leads to catastrophic failure of the Mudgun machine which leads to unplanned shutdown of the blast furnace. This gives an immense opportunity to develop an alternate Mudgun machine which can close the tap hole that can avoid shutdown of the furnace.

IV.DEVELOPMENT OF SOLUTION

A system is being developed to take an action against closing of tap hole during blowing condition of the tap hole. During blowing condition of the tap hole there will be a highly unclear working environment. Hence immediate action plan to be developed before an unsafe with highly unstable condition of the tap hole is created in cast house. The inside pressure of the furnace will be 4 bar, which creates a spillage of hot metal jet throughout the cast house [6].

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4.1 Emergency Mudgun system

It is defined as the system which is used in emergency situations during abnormality of mudgun machine due to tap hole closing failure. The emergency mudgun system is designed systematically by considering constraints. Anyhow this Mudgun system will never replace the Main mudgun machine. This is just a temporary solution which can be used just to avoid shutdown of the furnace during tap hole closing failure.

4.2 Constraints to design Emergency mudgun system

- 1.) Measurements of Drilling machine Guide frame have to be accounted to design of Main Base Frame.
- 2.) Measurements of Drill rod have to be accounted with respect to design of length of the barrel.
- 3.) Measurements of drill depth available have to be accounted to design the length of the barrel.
- 4.) The emergency mud gun is designed to close the tap hole while the regular operating mud gun fails to operate. During this emergency condition the furnace hot metal level should be reduced by opening all other tap holes and the furnace bottom pressure to be reduced from 4bar to (1.5 - 2) bar.

4.3 Considering all the constraints the emergency mudgun is designed. Below are the components of the emergency mudgun system.

- 1) Main Base Frame
- 2) Barrel holder
- 3) Cover Plate
- 4) Push Rod
- 5) Cylindrical Barrel
- 6) Guide Rollers
- 7) Support plate & Stiffeners

4.3.1 Design of Emergency Mudgun Barrel Component

Considering the inner diameter of the cylinder as 200 mm and overall volume required is 80 liters i.e. 0.08 m³. The tap hole clay will be in solid form. Hence the rate of insertion inside the tap hole will be equal to the length of the cylinder would be calculated as

The volume 'V' of the cylinder is given as

$$V = \frac{\pi D^2}{4} \times h$$

Substituting in the above equation we get as

$$0.08 = \frac{\pi \times (200 \times 10^3)^2}{4} \times h$$

Calculating 'h' from the above expression we get

$$h = 2.45 \text{ meters}$$

h ~ 2.5 meters

The length of the cylinder is calculated mainly because of the mass that has to be filled inside the barrel, which is the top requirement that has to be inserted inside the tap hole. By keeping this as constraint and rest of the components of the Emergency Mudgun is designed.

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4.3.2 Selection of the material for the barrel- NICKEL-CROMINUM FERROUS ALLOYS

HT (35 Ni-17 Cr)

About one-seventh of the total production of heat resistant castings is HT alloy because of its value resisting thermal shock, its resistance to oxidation and carburizing at high temperatures, and its good strength at heat treating furnace temperatures. Except in high-sulphur gases, it performs satisfactorily up to 2100 °F in oxidizing atmospheres and up to 2000°F in reducing atmospheres. It is used for load bearing members in many furnace applications, retorts, radiant tubes, cyanide and salt pots, hearth plated and trays quenched with the work. HT grade (35 Ni-17 Cr) following properties can be obtained[8].

- Tensile strength of the material – 517.106 Mpa
- Yield strength of the material – 310.2 Mpa
- Brinell hardness number – 180
- Modulus of elasticity in tension of the material-186.15 Mpa

4.3.3 To calculate thickness of the barrel

To calculate the thickness of the plate material that should be used for the fabrication of barrel is calculated on the basis of hoop stress or circumferential stress which is acting on the walls of the cylinder due to inside pressure. HOOP STRESS is the amount of stress which is acting on the outer circumference of the cylinder in the radial direction; it is usually tensile in nature[9].

The value of Hoop or Circumferential stress ' σ_{Hoop} ' in N/m² is given as, in terms of

Pressure inside the cylinder – 'P' in N/m²

Diameter of the cylinder – 'D' in Meters

And, Thickness of the cylinder – 't' in Meters as,

$$\sigma_{Hoop} = \frac{P \times D}{2 \times t}$$

Considering the Factor of safety of 1.5

$$FOS = \frac{\text{strength}}{\text{stress}} = \frac{\sigma_{yield}}{\sigma_{Hoop}} = 1.5$$

$$\sigma_{Hoop} = \frac{\sigma_{yield}}{1.5}$$

From **STEP 2** we have selected the material as Nickel-chromium- iron alloy HT grade which has yield strength 186.15 Mpa, So the maximum stress that can be applied on material is as follows

$$\sigma_{Hoop} = \frac{186.15}{1.5} \text{ mpa}$$

The pressure inside the cylinder 'p' would be 100 bar which is 100×10^5 N/m², and the diameter of the cylinder is 200 mm i.e. 200×10^{-3} meters. To calculate the thickness value from the hoop stress equation is,

$$\frac{186.15 \times 10^6}{1.5} = \frac{100 \times 10^5 \times 200 \times 10^{-3}}{2 \times t}$$

The value of thickness from the above equation on calculating is obtained as

$$T = 0.00805 \text{ meters} \sim 8 \text{ mm}$$

The final standard thickness which is available is of 8 mm is considered to be in design aspects for components of the Emergency Mudgun system

4.4 Geometrical drafting and assembling of Emergency Mudgun

Entire Emergency Mudgun components are designed in SOLID EDGE V19 software and respective components are fabricated as per the drawing and assembled by considering the constraints. Below is the figure-4.1 which is described as per the assembled view of emergency mudgun system.

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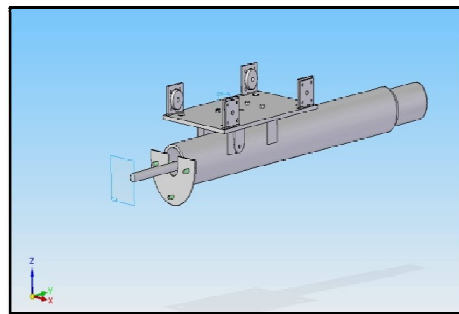


Fig 4.1: Assembled view of Emergency Mudgun

Emergency mudgun system part drawings are designed and assembled as per the dimensions as shown in the fig-4.1. Hence the system gives a scope for fabrication of the parts of emergency mudgun machine. Complete parts of the emergency mudgun are assembled in solid edge software only.

4.5 Assembly procedure of emergency mudgun to drilling machine

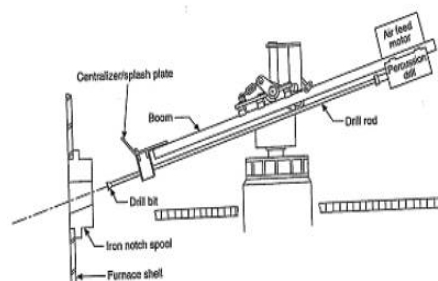


Fig-4.2: Dimensional view of Drifter Position in drilling of tap hole.

The Dimensional view of drilling machine is shown in the fig-4.2 that describes the overall length which is available for the drifter travelling is 6176mm. Hence the stroke length is considered to design the required barrel length.

Consider a rectangular plate of thickness of 10mm and cut according to the required dimensions. Now drill a hole of respective bolt diameter of 20mm with four in numbers. Now consider another roller fixing plate of size 150x100 mm with centre cut section circular $\varnothing 100$ mm and drill holes of m16x65mm of four in number in each plate and weld to the plate. Fix another barrel angle adjustment plate below the plate with dimensions 150mmx100mm with a hole of diameter 20mm. This completes the design of main base frame. Consider a rectangular plate with a cross section 600mmx300mm and drill holes as similar to the main base frame to fix with it. Now consider a plate of 150x100mm to design the legs and weld it to the barrel holder at bottom portion. Now assemble this frame to the main base frame by using bolted system. Now consider a pipe of diameter $\varnothing 200$ mm with a length of 2500mm with thickness of 8mm. Take this barrel and fix it to the legs of the barrel holder by welding.

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Fig-4.3: Fabricated Emergency mudgun fixed to drill machine guide frame

The push rod is considered by the OEM designed for drilling of the tap hole. The same rod is considered for drilling operation. At the tip of the rod a circular disc of 6mm thickness and $\varnothing 200\text{mm}$ diameter is welded. Cover plate is designed with semi-circular plate with R220mm and drilled with holes 20mmx65mm of three in numbers. And this cover plate is fitted with bolted system to the brackets that are welded to the barrel assembly. The rollers are fixed to the main base frame which OEM designed. For safe precautions the tip of the barrel is made reducer type and applied a castable material such that it can withstand high temperature during closing of the tap hole. All welding has to be done with welding rod of 4mm 7018 rods.

Finally fabricating all the parts of the emergency mudgun system, they are now assembled individually to make a single component of the system which is shown in the fig-4.3 the assembled emergency mudgun components are taken trail for matching the tolerances to the guide frame of the drilling machine.

4.6 Procedure for EMG Trail Implementation

During Mudgun machine got stopped to close tap hole due to any of the reason mentioned in the table, then the furnace hot blast pressure is being reduced to 1.2-2 bar pressure. This process takes nearly 30 min, meanwhile the Emergency mudgun machine is fixed to the drilling machine and the tap hole is closed.



Fig-4.4: (a) Taphole surface impression marking

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Fig-4.4(b) Tap hole closing using EMG system

Once the entire system is designed as per the dimensions then tap hole centring is checked as shown in the fig-4.4a to ensure the exact fitment of barrel nozzle tip to the tap hole. If found any deviation in the fitment then the angle of barrel is adjusted by using the tie rod. Later on the tap hole is closed by using the emergency mudgun system as shown in the fig-4.4b by reducing the wind volume to 1.2 bar of the blast furnace.

Below are the steps to be followed while in such emergency situations.

- 1) Shift the EMG to the work location.
- 2) Remove of drilling machine heat shield.
- 3) Align EMG to the drilling machine guide frame.
- 4) Fix the guide rollers and tighten it on either side.
- 5) Adjust the angle of the EMG nozzle tip to match the tap hole centre by using tie rod adjustment pin.
- 6) Fill the weighed tap hole clay mass inside the EMG barrel component.
- 7) Insert the push rod inside the drifter chuck assembly and lock it.
- 8) Sleeve in the drilling machine towards the tap hole.
- 9) Latch on the guide frame assembly to match the barrel tip to the tap hole front surface.
- 10) By operating drifter forward and rotation operation push the mass inside the tap hole.

V. CONCLUSION

- Emergency Mudgun System is used to close the tap hole in a successful operation during furnace under running condition by reducing hot blast pressure to 1.2 bar.
- Design and fabrication of the emergency mudgun machine has given a top priority to close the tap hole in emergency situations in different blast furnace.
- This design of emergency mudgun machine provided a best solution for closing of tap hole in emergency situations during failure of mudgun machine.

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ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

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Visit: www.ijirset.com

Vol. 7, Issue 9, September 2018

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