Improvement in productivity by application of a slat conveyor design in a steel rolling mill

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ABSTRACT

This work introduces a novel approach to handle heated ingots without lowering down their temperature and productivity of the finished billets. The design and development of slat conveyor for angular trajectory improved the handling of heated ingots in a lot and subsequently improved mechanical properties of finished billet. Hereafter; a detailed cost and replacement analysis was performed to replace the idle or non-functioning assets by working or new resources. The critical analysis of cost includes various items such as plant running cost, replacement cost, increased output cost and total cost. A significant improvement was noticed in the plant efficiency and balance sheet after implementing the proposed slat conveyor model. Design software Pro-E was used to design the slat conveyor before implementation and subsequent cost analysis.

Keywords: Steel rolling; Billet; Slat conveyor; Cost analysis, Replacement analysis

1. INTRODUCTION

This project aim was to study the existing production model of Kashmir Steel Rolling Mill. The idea behind the study was to identify the yardsticks associated with processes. After, careful analysis of existing set-up, a model was proposed to improve the production efficiency and consequently the profit share of the company. However, few minor glitches were identified in numerous processes of the mill but major improvement was required in the travel path of billet from furnace to roller. Based on the study of working parameters and visual inspection performed inside the mill, a model was developed to correct the travel path of billet from furnace to the roller. Operations research critical path analysis was used to estimate the cost of payback period, replacement of items to achieve cost effective solutions of the problem [1-5]. The design of the conveyor was a major aspect before finalizing the model. Steel as a material was selected in the proposed model for the slat conveyor design and development. Steel has good mechanical properties due to its alloying elements in the base material composition [6-9]. According to the carbon percentage in the base material steel can be classified into various categories. Different alloying elements such as manganese, sulphur, vanadium, titanium, silicon, chromium provide good resistance against high temperature deformation, good wear and tear properties, toughness and strength to resist mechanical deformations [10-13]. Billets developments inside the mill are a complex process due to involvement of heating and loading - unloading of billets after processing. In the present work proposed model efficiently supervise the billets developments from furnace to finished TMT bars. Aslat conveyor model was developed to efficiently deduce the size of billets out of rolling mills. Cost analysis was done to cut the unproductive costs associated with the process.

2. METHODOLOGY

2.1 Identification of problem in existing layout

In the present work the problem was to take billets from furnace to the rolling mills. The trajectory of the path was inclined so that correct entrance of the billets was restricted. The description of the problem is available in the Figure 1. Following steps were required to take out heated ingots to the rolling mills.

- ➢ Taking out the ingot from the furnace.
- ➢ Mounting the ingot on a hanger which takes it to a lower platform from where it is taken to roller.
- ➢ Manual handling of the ingot before it is practically put in the roller mill.
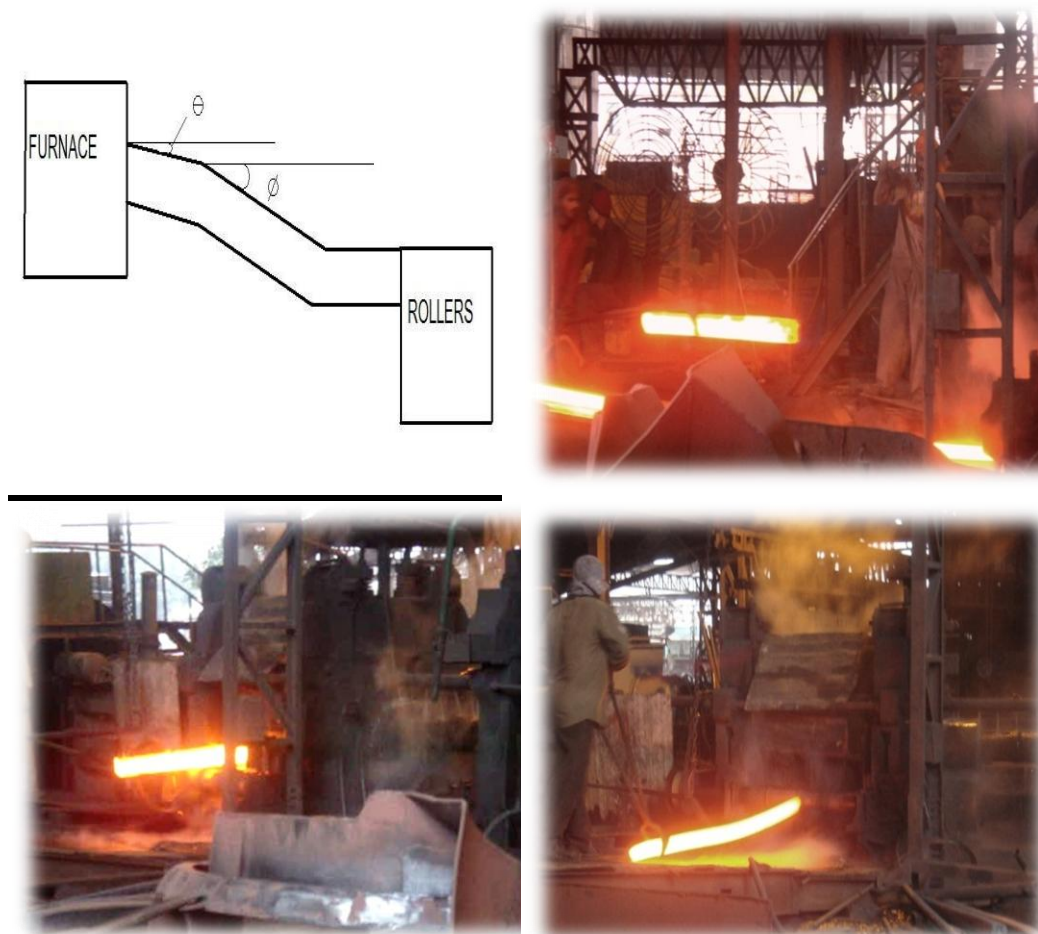

Figure 1 Travel path of billets from furnace

During the manufacturing it was observed that heated ingots piles up on the bench during their movement from furnace to the rolling mill resulting in loss of heat and material.

2.2 Mathematical relationships for cost and replacement analysis

2.2 Equations for cost analysis

For performing cost analysis after designing the slat conveyor and to find the effective implementation of proposed model, following two approaches were used.

2.2.1 Method of pay-back period

This method determines the payback period during which time the net accumulated cash flow is equal to the total investment on the equipment assuming that the net annual cash flows are equal every year payback to be determined from the following formula [14].

$$P = \frac{C}{(L+V-R)} \ldots\ldots\ldots\ldots\ldots(1)$$

where,

P = Payback period in years
C = Total capital (investment) cost, Rs
L = Cost of annual labour saved
R = Annual running costs of equipment, Rs
The term of capital recovery is calculated and decided by the length of return period.

2.2.2 Return on investment method

The equipment is depreciated over its useful span of life. The approximate life span of a equipment is between 5 and 8 years. Assuming straight line depreciation method, the total equipment investment (capital) is depreciated evenly over the life of the equipment. If 'c' is the investment cost and 'n' is the life of the equipment, yearly depreciation is (c/n). If salvage value of equipment is 'f', depreciation per year can be obtained from (c-f/n).

2.3 Equations for replacement analysis

The study under replacement analysis is concerned with the replacement of man and machines due to lack of output and breakdown of the system. The deteriorating efficiency or complete breakdown may be either gradual or all of a sudden. For example a machine becomes more and more expensive to maintain after a number of years, an electric light bulb fails all of a sudden. In all such situations there is a need to formulate a most economic replacement policy for replacing faulty units or take some remedial special action to restore the efficiency of deteriorating units. Replacement problems can be broadly classified into:

(a) When the equipment deteriorates with time and the value of money:

> ➢ does not change with time
> ➢ changes with time

(b) When the item fails completely all of a sudden

> ➢ Replacement of the equipment that deteriorates gradually with time when value of money doesn't change.

Let, C: Capital cost of equipment
S: Scrap value of equipment
N: No. of years the equipment will be in use.
f(t): Maintenance cost functions
A(n):Average total annual cost
If the equipment is used for 'n' years, then the total cost incurred during this period is given by:
Total cost (TC) = Capital cost – Scrap Value + Maintenance Cost

$$= C – S + \int(0,n) \, [f(t)dt]……..……….(2)$$

Average annual total cost, therefore is:

$$A(n)=1/n \; TC=[(C-S)/n]+[1/n\int(0,n)\{f(t)dt\}]$$

For minimum cost, we must have:

$$d/dn \, [A(n)] = 0$$

or $[-(C-S)/n^2]-[1/n^2\int(0,n)f(t)dt]+[1/nf(n)] = 0$

or $f(n) = [(C-S)/n]+[1/n\int(0,n)\{f(t)dt\}] = A(n)$

A brief analysis of total costs involved in the whole proposed model and their proposed outcomes provides appreciable difference in the real and proposed costs which in result improved the efficiency of the production output and cost effectiveness of the process. To summarize the effectiveness a total cost and benefit analysis was done.

3. RESULTS AND DISCUSSIONS

3.1 Slat conveyor design

Due to insufficient space available at the entrance of rolling mill heated ingots piles up on the bench during their movement from furnace to the rolling mill resulting in loss of heat and material. A large wastage of heat and fuel occur due to ill handling of ingots before rolling. The resulting wastage cost a huge amount of money and efficiency loss to the company. In the preliminary analysis of the problem it was found out that passage of travel of heated ingots to the rolling mill is not straight and narrow to handle large numbers of ingots. Insufficient reduction in the size of ingots after rolling mill produce lower quality billets in result company share in market goes down. In this case it was required to replace the existing manual handling of ingots by an efficient slat conveyor system. Heavy duty slat conveyors generally provide a straight passage and efficient handling of hot, oily parts or items through heat drying processes and can be used for assembly line and production operations. A slat conveyor proposed for mill rolling operations is shown in Figure 2 (a). Slat conveyor model was designed to cover all the angular movement of the ingots as illustrated in Figure 2(c). This inclined trajectory efficiently conveys the lot of incoming ingots [15-16]. The designed slat conveyor for the Kashmir rolling mill is given in Figure 2 (b).

Few distinguished features and specifications of the proposed slat conveyor are listed below.

- ➢ 4 bed widths
- ➢ Rugged- all steel construction
- ➢ Modular construction
- ➢ Roller chain reduces friction
- ➢ It can be used:
  - on-floor
  - operate horizontal and inclined
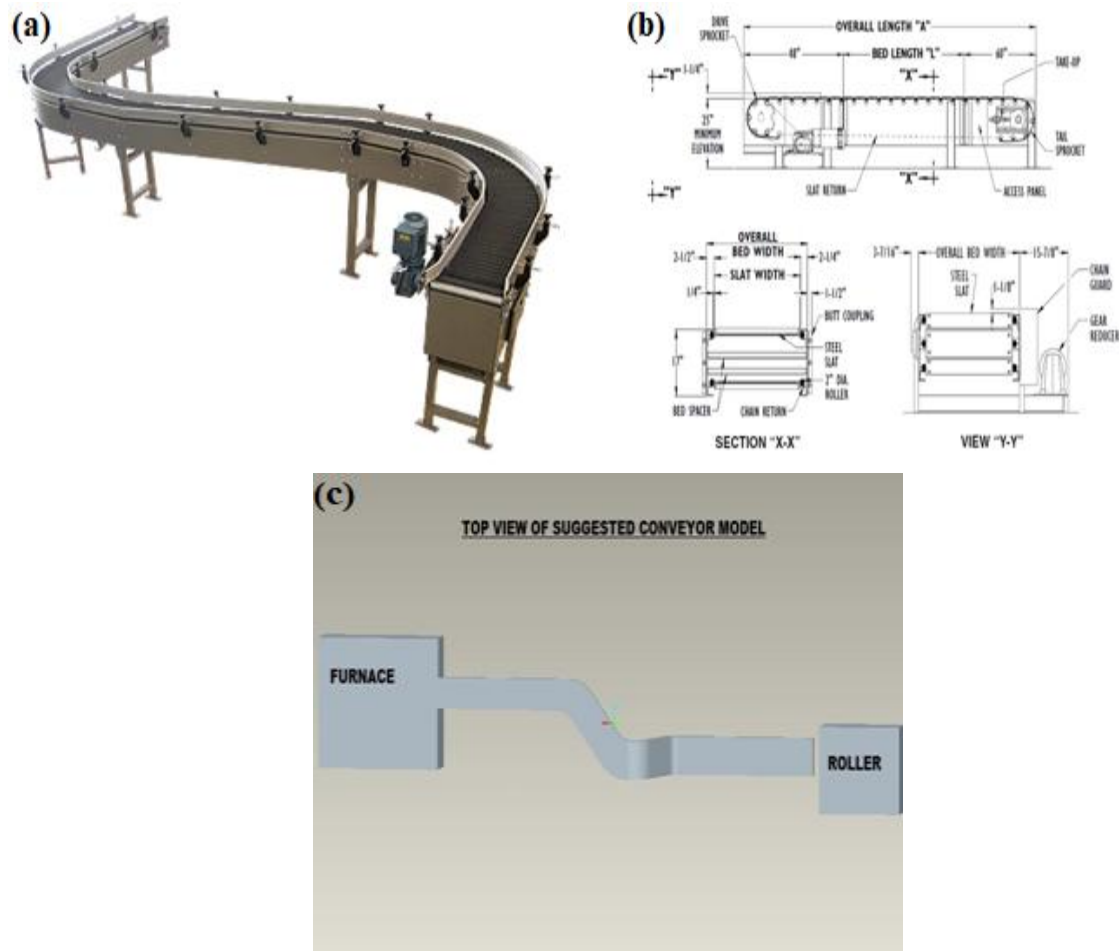 - used for heavy loads or loads that might damage a belt

Figure 2 Slat conveyor design

3.2 Cost analysis

Calculation of payback period requires:

  ➢ Total investment
  ➢ Cost of annual labour saved
  ➢ Added value of increased output
  ➢ Annual running cost

Total investment cost

  (a) Initial investment in buying equipment, i.e. slat conveyor
  (b) Cost of installing machinery
  (c) Transportation cost

  Therefore estimated total investment cost = Rs 3, 20,000/-

Cost of annual labour saved

Presently there were two workers under the current setup and after installing the slat conveyor, only one worker will be required. Therefore annual labour cost of one worker is saved.

  (a) Monthly wage of one labour   = Rs 3500/-
  (b) Cost of annual labour saved   = Rs 42000/-

Added value of increased output

   (a) Cost of ingot scrapped
   (b) Cost of furnace oil utilised in processing the scrapped ingot
   (c) Cost of coal utilised in processing the scrapped ingot

Number of ingots scrapped daily   = 3 pieces

Unit cost of ingot   = Rs 140/-

Annual cost   = Rs 84000/-

For processing 1000 kg of steel, 5 litres of furnace oil is required.

Cost of 1 litre furnace oil   = Rs 48/-

Annual cost of furnace oil   = Rs 21600/-

Annual cost of coal   = Rs 16200/-

Total added value of increased output   = Rs 121800/-

Annual running cost

   (a) Electricity cost
   (b) Lubrication cost
   (c) Wear and Tear of elements of slat conveyor
   (d) Depreciation of machinery (assuming 12.5%)

Power rating of motor used = 1.5 kW

Annual electricity cost   = Rs 7200/-

Depreciation cost   = Rs 40000/-

Annual running cost   = Rs 47200/-

Payback period   = 2.74 yrs.

3.3 Replacement analysis

In this analysis we have found out in how many years, the equipment that is installed needs to be replaced. For determining this, we require the following three parameters:

   (a) Cost price of slat conveyor   = Rs 320000/-
   (b) Scrap value of slat conveyor = Rs 10000/-
   (c) Yearly breakdown of running cost

Year (No.)	1	2	3	4	5	6	7	8
Cost (Rs)	40,000	46,000	55,000	65000	76500	88000	100000	115000

3.4 Calculation for estimation of replacement period

Year of service	Running cost (in rupees)	Cumulative running cost (in rupees)	Depreciation cost (in rupees)	Total cost (in rupees)	Average cost (in rupees)
1st	40,000	40,000	3,10,000	3,50,000	3,50,000
2nd	46,000	86,000	3,10,000	3,96,000	1,98,000
3rd	55,000	1,41,000	3,10,000	4,51,000	1,50,333
4th	65,000	2,06,000	3,10,000	5,16,000	1,29,000
5th	76,500	2,82,500	3,10,000	5,92,500	1,28,500
6th	88,000	3,70,500	3,10,000	6,80,500	1,13,416
7th	1,00,000	4,70,500	3,10,000	7,80,500	1,11,500
8th	1,15,500	5,86,000	3,10,000	8,96,000	1,12,000

3.5 Return on investment

Annual rate of return = [(Added value of inc. output) + (Cost of Annual labour saved) - (Annual depreciation) - (Annual maintenance cost)] / Total capital cost

Annual rate of return = [(121000+42000-45714-5000)100] / 320000 = 34.32 %

4. CONCLUSIONS

1. A slat conveyor design was proposed instead of manual handling of ingots which improved the efficiency of steel rolling mill in terms of productivity than the existing layout. In the proposed model design and development of angular slat conveyor and cost analysis of processes and resources involved in production efficiently reduced the current running cost of the unit.

2. Critical cost analysis revealed a reduction in total annual running cost the plant. The initial investment of Rs. 10, 00,000 for implementation of a slat conveyor can be recovered in 3.6 years. Also, slat conveyor can be replaced after 10 years of service, but the service life may increase or decrease depending upon the operating conditions. The annual rate of return as calculated will be 34.32% which is quite good.

3. The slat conveyor design orients the path of billets from the furnace directly into the mouth of steel rollers which ensures safety of workers surrounding furnace area in a steel rolling mill.

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