Innovative Design on Metal Melting Equipment In View of Energy Conservation in Metal Casting

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Abstract
Foundry industry has a dominant influence on the economy of any country because metal-casting is the primary step for a large number of sub-sequential metal shaping operations. It is the basic manufacturing industry whose products are used in almost all aspects of modern industrial economy. The growth of engineering industries generally depends on the casting industry. For this purpose maximum temperature of the furnace may be 1050°C. This is quite suitable for Aluminum, Copper, Tin and their alloys. While performing experiment taking aluminum as raw material and green sand mould for casting than fire the furnace and temperature readings are taken from various points of the furnace with the help of thermocouples, where it is required to know the proper working of furnace. There are very convening results are found during firing of furnace. In developed oil fired tilting furnace, it is provided with a special designed device called recuperator to make use of this waste heat exposed to atmosphere which eventually increased efficiency of furnace. It is observed that efficiency of oil fired tilting furnace without recuperator is 11.35 % and with recuperator it is 20.55 %.This is 44.79 % more than furnace when using without recuperator.

Keywords
Oil Fired Tilting Furnace, Recuperator, Efficiency, Aluminum.

I. Introduction

Metal casting is a very important process in manufacturing and production works; almost more than 80% of automobile parts are made out of the different metal casting process. Millions of people in different status are getting their livelihood through this important branch of engineering works.

In India small and medium class entrepreneurs are involved directly or indirectly with their old tools, and are not at all bothers to point out the unnecessary wastages of fuel, time and the working conditions, which are harmful to their health. It is a surprising fact that we people are wasting a good amount of fuel on old furnaces due to ignorance or are rather innocent to point out the leakage of energy in case of oil fired and furnaces.

These losses in energy area great loss to the nation and hence it is a national interest to find out the losses of energy to through unknown holes. We have to locate these holes and to provide them suitable patch to save the energy

A. Oil Fired Furnaces

There are few common types of furnaces which are in use in small scale industries and wildly in use for making small weight casting, generally involved in automobile industries and general machine manufacturing units. Of all pit furnace is a very common name in use for light and medium weight parts required for plants and machineries. So we will take up a working example of pit furnace and try to observe the leakages of heat energy and their effects.

II. Necessity of Modernization in Foundries

The demands arising from technical and environmental considerations are such that the foundry industries have no other option except to modernize itself. With the introduction of the advanced and latest technologies in automotive, machine building and general engineering industries, the demands on the quality of castings have considerably increased. In order to have a breakthrough in the world market, the products of foundry industry should be cost-effective. The use of expensive machinery to attain the desired consistency in quality demands high investment, making the industry economy only at high volumes of production.

Modernization of the foundry industry to achieve high volumes of quality castings incorporating the latest technology is essential to capture a considerable share of the world market for castings and it is wide open to any nation in the world. Working conditions in foundries need improvement in order to attract good quality human resources to this industry. Poor working conditions command high wage premiums and growing difficulties in obtaining right people for the industry. With the growing awareness of environmental conditions and more stringent pollution control, the foundry industry has no other choice except to meet these demands. The results of modernization include better quality castings, closer dimensional tolerances, fall in rejection rates, improvement in shop-floor working conditions, improvement in environmental conditions and energy conservation

A. Objectives of Foundry Modernization

The objectives of foundry modernization are listed below.

1. Improvement in casting manufacturing processes.
2. Development in product technology and casting design.
3. Quality control of castings.
4. Proper selection of foundry plant and machinery.
5. Materials selection.
6. Application of appropriate management techniques.
7. Cost reduction.
8. Increase in productivity.

B. Technology Upgradation

Technology is one of the terms that have exceeded the etymological dimension with which it was originally accepted. From the simple definition of technique of performance, it has grown with time to develop into a dynamic concept. The impact of technology has been specifically more significant on the metal-casting industry, which within a short span of the last three decades has transformed from a simple to high technology industry. Technology suitable for one country need not be the same and appropriate for a different set of conditions prevailing in another country. The economic, industrial and sociological aspirations of the country should be considered in selecting the appropriate and suitable technology.

C. Technology Upgradation Strategy

The strategy for technology upgaradation in the metal-casting industry can be divided into three parts namely, short-term strategy, medium-term strategy, and long- term strategy. The short-term strategy includes the utilization of existing resources as efficiently as possible. The medium-term strategy includes investing in more

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productive capital equipment. The long-term strategy includes the development of new products and processes and opening new markets for cast products. Before attempting to implement strategies for technology upgradation, it is essential to agree upon a yardstick to assess the status of the foundry industry in measurable terms and monitor periodically the effects of steps taken to improve the growth and prosperity of this industry. The status of the foundry industry could be measured on the basis of the tonnage of castings produced in any country and the value of its products. The level of technology could be assessed based on a suitable index determined using the percentage of total tonnage of castings produced with the latest and advanced technologies and techniques. The various strategies for technology upgradation are discussed in the following sections.

D. Efficient and Proper Utilisation of Resources

Adequate awareness has to be created to improve the utilisation of resources in the foundry industry. There is a considerable scope for the reduction in the consumption of materials, energy and possibilities of reusing the materials instead of discarding them. It is essential to identify all these areas and improve the utilisation of materials, machines, men and finances [1].

E. Mode of Heat Recovery

Most heat recovery efforts are aimed at utilizing the "waste heat" exiting through the flues. Some forms of heat recovery are air preheating, fuel preheating, load preheating, recuperative, regenerative, and waste heat boilers.

1. Recuperators

Recuperators are steady-state heat exchangers that transmit heat from hot flue gases to cold combustion air. A recuperator is a special purpose counter-flow energy recovery heat exchanger positioned within the supply and exhaust air streams of an air handling system, or in the exhaust gases of an industrial process, in order to recover the waste heat. In many types of processes, combustion is used to generate heat, and the recuperator serves to recuperate, or reclaim this heat, in order to reuse or recycle it. Recuperators have also been used to recover heat from waste gasses to preheat combustion air and fuel for many years by metallic recuperators to reduce energy costs and carbon footprint of operation. Compared to alternatives such as regenerative furnaces, initial costs are lesser, there are no valves to be switching back and forth, there are no induced-draft fans and it does not require a web of gas ducts spread up all over the furnace.

Historically the recovery ratios of recuperators compared to regenerative burners were low. However, recent improvements to technology have allowed recuperators to recover 70-80% of the waste heat and pre-heated air up to 850-900 deg C is now possible.

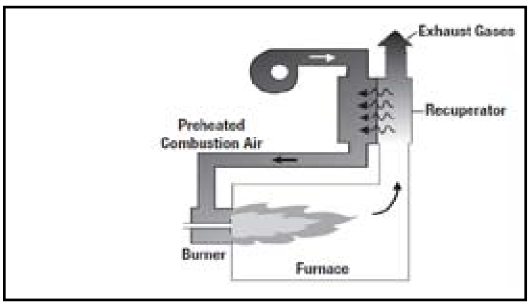

Fig. 1 Recuperator Systems (W. Trinks "Industrial Furnaces" John Wiley)

2. Regenerators

Regenerators are non-steady state devices that temporarily store heat from the flue gas in many small masses of refractory or metal, each having considerable heat-absorbing surface. Then, the heat absorbing masses are moved into an incoming cold combustion air stream to give it their stored heat. Regenerative furnaces in the past have been very large, integrated refractory structures incorporating both a furnace and a checker work refractory regenerator, the latter often much larger than the furnace portion. Except for large glass melter "tanks," most regeneration is now accomplished with integral regenerator/burner packages that are used in pairs. Boilers and low temperature applications sometimes use a "heat wheel" regenerator—a massive cylindrical metal latticework that slowly rotates through a side-by side hot flue gas duct and a cold combustion air duct. Both preheating the load and preheating combustion air are used together in steam generators, rotary drum calciners, metal heating furnaces, and tunnel kilns for firing ceramics [6].

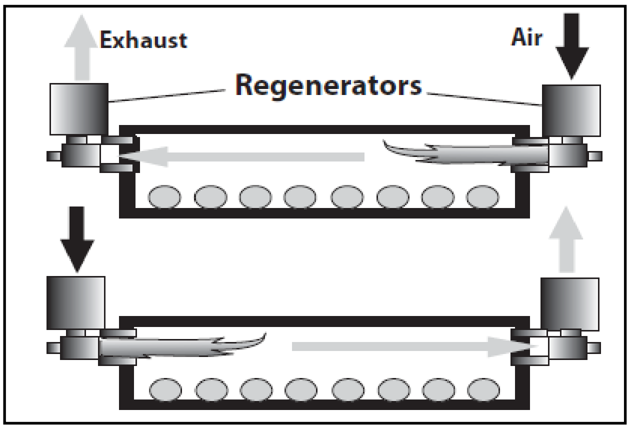

Fig. 2: Regenerator Systems (W. Trinks "Industrial Furnaces" John Wiley)

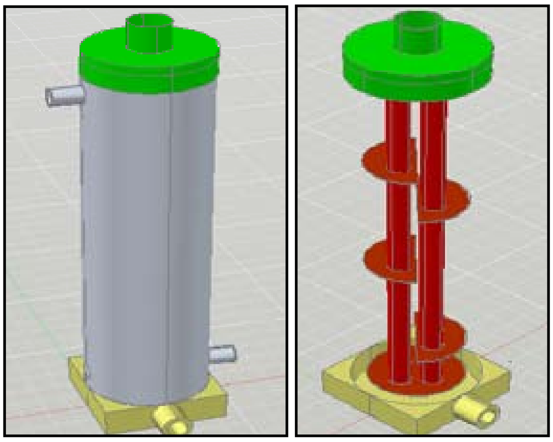

Fig. 3: Designed Recuperator

F. Furnace Efficiency

The words "economy" and "efficiency," when used in their true sense in connection with industrial furnaces refer to the heating cost per unit weight of finished, sellable product. 'Heating cost' includes not only the fuel cost but also the costs of operating and superintending, amortizing, maintaining, and repairing the furnace, plus the cost of generating a protective atmosphere and the costs of rejected pieces. The costs of rejected pieces (poor quality, poor temperature uniformity) include the costs of reworking pieces found defective because of improper heating and the costs of handling the material into and out of the furnace. With so many items entering into the total cost of heating, it is possible that in some cases the highest priced fuel or other heat energy source may be the cheapest.

Some engineering companies use the heat of oxidation of the load itself to reduce their estimate of required furnace fuel rate. Load oxidation heat is a very small fraction of the heat in most furnaces, except incinerators, and it is usually very expensive. For steel loads, heat from oxidizing steel costs more than 20 times that of heat from natural gas. One cannot measure the quantity of load oxidized or where it occurs in the furnace. In many furnaces, fuel cost may be a major item of expense. Therefore, economy is worthy of constant watching for reasons discussed earlier and because of frequent vacillation of fuel prices and availability. In designing or selecting a new furnace, it is necessary to know its probable fuel consumption beforehand.

This information also is necessary to select the correct size and number of burners, to figure sizes of ports, vents, and stack, and to select auxiliary equipment of proper size. When some first observe furnaces, they are astonished by the low thermal efficiency of industrial furnaces. Whereas boiler efficiencies range from 70 to 90%, industrial furnace fuel efficiencies are often half as much. Electrically heated furnaces may appear to have higher efficiencies if one forgets to consider the inefficiency of generation of electric energy, which includes the inefficiencies of converting fuel energy to steam energy, then to mechanical energy, and finally to electric energy. When crossing these many process boundaries, it is often wiser to make comparisons of total heating costs in dollars (or other currencies) per ton of material processed. With good design and operation, fuel-fired furnace efficiencies of 60% or higher can be had, depending much on process temperature. "Efficiency" here is the ratio of heat input into the load/hr to the gross heat released by the fuel used/hr. The Glossary compares efficiency terms. When comparing costs, always ask for clarification as to what is meant by "efficiency."

Furnace efficiency,

$$\eta = \frac{\text{Heat output}}{\text{Heat input}} \text{ X } 100$$

Reading is being taken from thermocouples placed to seven different points in furnace 4 which implies two in furnace and four at recuperator inlet outlet and one thermocouple at oil tank to take reading of oil temperature.

Fig. 4: Actual Picture of Develop Oil Fired Tilting Furnace

A very important observation is found in fig. 4 where temperature variation is shown at inlet temperature of burner. In usual practice air inlet to burner is ambient or atmospheric (32°C) but with the help of recuperator it is achieved near 300°C which is 268°C more than ambient temperature. These raises in temperature make this developed furnace efficient and energy savior

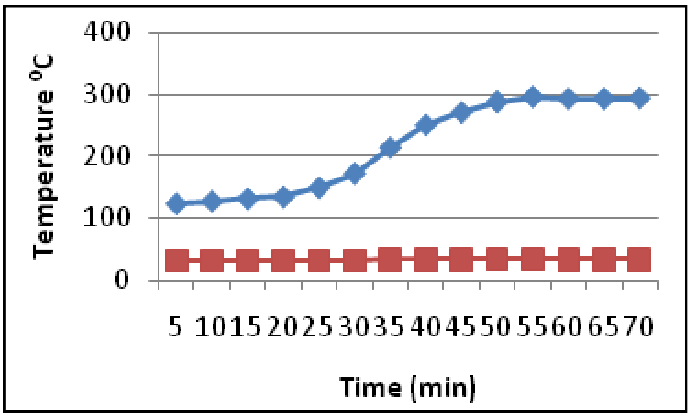

Fig. 5: Variation of Temperature at Inlet of Burner With or Without Recuperator

G. Pin Point Leakages

As we have seen from the demonstration that a jet of fuel and air is formed in the burner is having a good amount of heat energy forced into the furnace. This energy is quite sufficient to make the metal melt which is placed in the crucible within 40 to 30 minutes time.

This energy after heating the crucible is allowed to go waste into atmosphere where it is of no use. As a matter of fact, flames after heating the crucible are left with the sufficient amount of energy in it, on physical checking it is felt that the temperature of outgoing flame are even more than the melting temperature of melt. It is approximately in the range of 800°C to 1000°C in case of aluminum casting.

Further, there are two types of losses from outgoing flames.

1. Wastage of energy and
2. Increasing of surrounding temperature

Thus wastage of energy heat which could have been be the utilized for other useful purpose is going waste in the air creating a hazardous unhealthy working conditions for the workers who are deployed on the works. There is a double in the owner, the working capabilities of workers are decreasing and expense of cost of casting has adversely been affected.

H. Losses During Transportation

In this process the crucible is required to lift from the PIT with the help of crucible tong. After lifting the crucible is placed on special made for the purpose. After putting crucible on the same is taken to the moulds and pouring process starts. While pouring three workers are required to perform the operation of pouring. Two men are supposed to handle LADLE and third one is required to guide the proper pouring. After completion of proper unloading process, the crucible is replaced on its original location.

I. Minimizing Casting Defects

Casting defects can be defined as 'departure from conformance to customer requirements,' with respect to (i) geometry: ex. Mismatch and swell, (ii) integrity: ex. porosity and inclusions, and (iii) property: ex. segregation and hard spots. The resulting loss of foundry productivity and customer confidence is a heavy price to pay. Jobbing foundries encounter a higher level of defective castings, averaging 8-15%. Even production foundries have overall 3-6% defective castings.[5]

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III. New Technology is Enabling People, Not Machines to Produce Massively Scalable Work

Brent Frei believes that "the next gusher in productivity and profit will come not from technology replacing humans, but rather technology enabling humans to do work that to date hasn't been economically viable". The shift should give companies a sharp rise in productivity, which arises at the rate of ingenuity. The unitary objective is to cut the production cost per task of desired quality, whether it is consummated by design or technology or simply process approach is of no big cognizance. Arguably, "In the chasm between "computer-capable" and "requires a human", a massive amount of work is waiting for either the computer to get smarter or the human get faster so that the price offered per-task will be profitable." A case in point is the effectiveness of simulation software or technology, which are collectively dependent upon the potency of software, configuration of equipment and the methoding stipulations of the founding engineer [2].

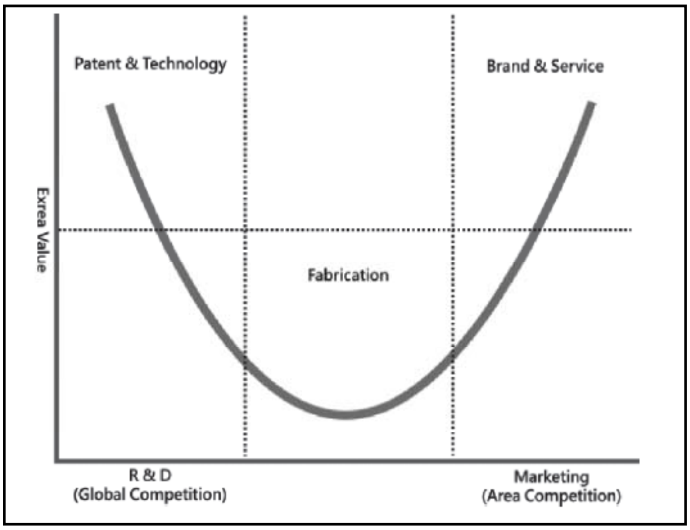

Fig. 8: Smile Curve Plotting Extreme Value Afforded to Customer by Dint of the Innovation in Technology or in Continual Process Management of Equipment Through Servicing. (Courtesy: Stan Shih, the founder of Acer.)

IV. Energy Conservation

India's dream on super power in the year 2020 is largely dependent on energy. During the year 2010–11, base load requirement was 861.591 GW against the availability of 788.355 GW, i.e. at 8.5% deficit. During peak loads, the demand was for 122 GW against availability of 110 GW i.e., 9.8% deficit. In a May 2011 report, India's Central Electricity Authority anticipated, for 2011–12 year, a base load energy deficit and peaking shortage to be 10.3% and 12.9% respectively. The peaking shortage would prevail in all regions of the country, varying from 5.9% in the North-Eastern region to 14.5% in the Southern Region. As per the 17th electric power survey of India reports over 2010–11, India's industrial demand accounted for 35% of electrical power requirement, domestic household use accounted for 28%, agriculture 21%, commercial 9%, public lighting and other miscellaneous applications accounted for the rest [3].

V. Continuous Casting Principle

The continuous casting process is used to overcome a number of ingot-related difficulties such as piping, mould spatter, entrapped slag and structure variation along the length of the product. It is used to produce blooms, billets, slabs and tubing directly from the molten metal. In this process, molten metal flows into a refractory-lined intermediate pouring vessel, where impurities are skimmed off. From there, the metal travels through a bottomless water-cooled copper mould in the form of a vertical tube open at both ends and begins to solidify as it travels downward along a path supported by rollers [4].

VI. Leakage Due to Transporting Molten Metal in Crucible

The crucible filled with the molten metal is lifted with the half of lifting tong and placed on the ladle. Proper packing is provided to the crucible while transported towards the state of moulds. This operation is completed under the proper guidance of experts. The process of lifting the crucible from the PIT furnace to fill the moulds takes sufficient handling time which reveals loss of heat. As there are chances of early solidifications and we are bounded to overheat the melt. This is again wastage to heat energy which required. To raises the temperature of melts fears early solidification. The excess energy which was utilized to avoid early solidification could have been saved if the transportation processes have be re designed. This pouring of metal can be improved and the loss of energy during transportation can be saved. The heat loss during transportation is multiply losses.

One due to raising the temperature to avoid early solidification and other is loss of time and labor hours during the process of transportation. Again, there is a loss of heat energy which is required to region the temperature of crucible for second change. As during the crucible will get cooled and takes more energy to regain its lost heat. This could have been saved by on the spot tilting system. Hence, if we sum up the all losses, we will finally observe that the system required big changes in which the present wastage should be totally abolished. Also a new design of furnace is urgently required to patch up all the leakages, at a glance; we have the following leakage hostage of energy in the present system of melting.

1. Input energy is not utilized properly for the purpose it was generated and going waste in the air after heating the crucible. This waste going heat energy should be used for some other useful purpose like heating of incoming blower's air and fuel, before feeding with the burner to increase the overall efficiency of the melt.
2. As there is no control on outgoing energy which is not only going waste in the atmosphere but creating a hazardous situation in the surrounding nears the working zone of the workers. The unfriendly surroundings not only badly effect on the health of the worker but also decrease the working efficiency. So we can design such a furnace in which there should have system to control this waste going air for the useful purposes.
3. Wastage due to transportation can be avoided if the system of tilting is provided. Transportation can be abolished but at the same time, the heating should be done in such a way that heat provided to the furnace should also be well controlled to avoid heat to expose in the atmosphere

VII. Conclusion

At present the furnace like pit furnace, rotary furnace and induction furnaces the input heat after heating the metal is exposed into atmosphere having no use. In our invented furnace, it is provided with a special designed device called recuperator to make use of this waste heat exposed to atmosphere which eventually increased efficiency of furnace. With recuperator it is also easy to achieve desired temperature, where without recuperator maximum temperature achieved is 780°C and with recuperator maximum achieved is 1154°C. Efficiency of furnace is also increased where without recuperator efficiency of furnace is 11.35 % and with recuperator it is 20.55 %, which is highest among all oil fired furnaces. Percentage saved of efficiency is 44.79 %. Specific fuel consumption without recuperator is 0.166 liter/ kg of material, where as with recuperator it is 0.138 liter/ kg of material. This means that for one charge we can save 0.858 liter (approx 1 liter). Internal time between one charge to next change is minimum possible. As the pouring of metal is quick, this revealed further saving of fuel and time similar to continuous casting. This invented furnace has a specialty to be connected with the process of pouring in centrifugal casting as the pouring system can easily be done with the addition of simple attachment. this is also a smart fuel saving process High melt quality due to low burn-off and reduced hydrogen absorption in the melt. Operator exposed to less heat in the area above the crucible. Due to complete burning of fuel make this furnace environment friendly.

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