GASIFICATION TECHNOLOGY FOR SUBSTITUTION OF FURNACE OIL IN REHEATING FURNACES OF ROLLING MILLS

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1. ABSTRACT

Gasification involves conversion of solid fuels like coal or biomass into gaseous fuel. Once the solid fuel is converted into gas, it becomes compatible for substitution of liquid fuels in furnaces. Reheating furnaces of rolling mills, which consume furnace oil, can utilize gasification technology with great economic and environmental benefits. In most parts of India, the gas produced from coal or biomass is expected to be considerably cheaper than petroleum based furnace oil. Increasing price gap between petroleum and other solid fuels would make the utilisation of gasification technology more favorable.

Gasification is more than two centuries old technology. Age-old moving bed atmospheric air blown gasifiers are still relevant and functional in many installations around the world, including India. In the pre-petroleum era, these gasifiers were used for production of town gas (for domestic heating & lighting), industrial heating and manufacturing of chemicals. Recent interest in coal based Integrated Gasification Combined Cycle (IGCC) power plants has fuelled development of large gasifiers of various types. Most of these new gasifier designs are of oxygen blown type. Some of the notable technologies are Destec (entrained flow), Winkler (fluidized bed), MBEL (fluidized bed), Shell (entrained flow) and Cheveron Texaco (entrained flow).

Present experience of utilizing gasifiers in rolling mills is limited to a few installations of air blown moving bed gasifiers in Central India. The gasifiers installed so far are small, suitable for individual rolling mills of 5-15 tons/hour steel production. The capacities of the gasifiers operating in rolling mills vary in the range of 125 to 500 litres/hour oil equivalent. Both partial as well as complete substitution of furnace oil has been attempted. As the coal and biomass prices in Central India are much lower than that of oil in equivalent energy terms, the gasifier projects are economically attractive.

Installation of large gasifiers to cater to the requirements of cluster of rolling mills needs serious consideration. Such an approach would free the individual units from the financial as well as operational implications of installing gasifiers at their own premises.

2. INTRODUCTION

Reheating furnaces of rolling mills consume petroleum derived furnace oil (or coal in some areas) in their reheating furnaces for heating steel billets / ingots. The coal-fired furnaces are limited to smaller mills in Central and Eastern India. Most of the rolling mills are, therefore, dependent on furnace oil for their reheating needs.

Expenditure incurred on furnace oil is one of the major energy cost inputs of the rolling mill sector. The price of furnace oil, which has increased by almost 50% over the past 3 years, is poised for further increase with the rising international petroleum prices. Thus, any measures towards saving or substitution of furnace oil would certainly improve the financial health of the rolling mill sector.

Gasification technology offers an opportunity for substitution of furnace oil by coal or biomass. Gasification is the conversion of solid fuels (e.g. coal or biomass) into clean fuel gas. Since gaseous fuels are compatible to liquid fuels, gasification would enable the substitution of furnace oil by coal or biomass without any major affect on the process of reheating.

3. GASIFICATION TECHNOLOGY

Gasification involves partial oxidation of carbon containing fuels into a gaseous fuel. The combustible constituents of the gas produced by gasification are mostly H_2, CO and some hydrocarbons. The non-combustible constituents are CO_2 and N_2 (if air is used as the gasifying medium). The proportion of these constituents depends upon the type of gasifier design, conditions of gasification and the gasifying medium.

The gasifying medium is usually air or oxygen along with steam. When air is used, only oxygen in the air participates in the gasification reactions and nitrogen passes through the gasification reactor unreacted and appears as inert in product gas. Steam acts as a temperature moderator.

The gas produced needs to be conditioned, which may involve clean up, cooling and desulphurisation. The extent of conditioning depends upon the envisaged utilisation of gas. Most of the direct heating applications (such as heating steel in reheating furnace) do not require extensive conditioning.

Various types of gasifiers in operation or under development are:

- Moving bed gasifiers
- Entrained flow gasifiers
- Fluidized bed gasifiers

Moving Bed Gasifiers

In moving bed gasifiers, the gasifying medium (air or oxygen with steam) enters the bottom of the fuel bed and moves upwards while the fuel bed gradually moves downwards as the fuel at the bottom gets consumed. Because of the counter-current nature of the flow of gases and fuel, the sensible heat of the gases is effectively utilized by the incoming fuel. The temperatures at the bottom are about 1000 ^{0}C or higher and that at the top are in the range of 200-500 ^{0}C. These gasifiers require the fuel to be in lumps, while the fines are generally not acceptable. The ash disposal could be either dry or in slag form.

Moving bed gasifiers are the oldest and have been in existence for over two centuries. They have been used for conversion of coal into town gas (producer gas) for domestic lighting and heating before the natural gas replaced it. These gasifiers have also been used for industrial heating, production of chemicals and even synthetic motor fuels (SASOL project, South Africa).

'Lurgi' dry ash gasifiers and 'British Gas – Lurgi (BGL)' slagging type gasifiers are among the prominent moving bed gasifiers.

Entrained Flow Gasifiers

In entrained flow gasifier, pulverized fuel flows co-currently with the gasifying medium (usually oxygen). In such gasifiers, uniform temperatures of 1000 ^{0}C or more are maintained. The residence time of fuel in the gasifier is very short and therefore the fuel needs to be pulverized to a very small particle size. Since it is difficult to pulverize biomass fuels, entrained flow gasifiers are not suitable for them. The high temperatures maintained in the entrained flow gasifiers ensure that the ash is removed in slag form.

Most of the coal gasification based power projects in the world are utilizing entrained flow gasifiers. Shell, Destec and Cheveron – Texaco are among the prominent entrained flow gasifiers.

Fluidized Bed Gasifiers

In fluidized bed gasifiers, solid fuel is suspended in the gasifying medium (usually air) with air and solid particles together behaving like a fluid. In such gasifiers, the temperatures are generally maintained less than 1000 ^{0}C so that the ash remains in solid form. These gasifiers are suitable for both coal and biomass.

High Temperature Winkler (HTW), developed by British Coal Corporation and now marketed by Mitsui Babcock Energy Limited (MBEL) is one of the examples of fluidized bed gasifiers.

4. "COSMO" MULTI-FUEL UPDRAFT GASIFIERS

"Cosmo" Multi-fuel Updraft Gasifiers are air-blown, atmospheric pressure moving bed gasifiers. The main features of these gasifiers are as flowing:

- These gasifiers are suitable for both coal (of any grade up to 35% ash content) and biomass. Fuel flexibility has been one of the major considerations while developing these gasifiers. Switching of fuel between coal and biomass is possible while in operation.

- The gasifiers are suitable for lumpy fuels and are not suitable for fines. The fuel size range could be 20-200 mm for biomass and 25-75 mm for coal.

- Cosmo gasifiers have been developed for individual, small & medium industrial users. These have been built in the capacity range of 0.5 to 5.0 million kcal/hour output (equivalent to 50 to 500 litres/hour oil substitution).

- Cosmo gasifiers operate with air as the gasifying medium. However, enriched air or oxygen can also be used if the application so demands. The steam required for gasification is produced from the water jacket of the gasifier.

- With air as the gasifying medium, the gas produced has a calorific value of 1100-1300 kcal/Nm^3. The cold gas would have 15-20% CO, 10-20% H_2, 6-10% CO_2, 3-6% CH_4 & C_2H_6 and 40-50% N_2. In hot condition, as it comes out of the gasifier, the gas also contains heavy hydrocarbons (in the form of tars) in vapor form. The efficiency of gasification is 75-85%.

- The gas can be used either in hot condition or after cooling & scrubbing. When it is used in hot raw condition, the gas is conveyed through insulated pipelines so that tars remain in vapor form and contribute to energy at the burner.

5. GASIFIERS FOR INDIVIDUAL REHEATING FURNACES OF ROLLING MILLS

Most of the rolling mills in India are small & medium enterprises (SMEs), with output capacities in the range of 5 to 15 tons/hour. The furnace oil consumption of their reheating furnaces would be in the range of 200 to 750 litres/hour.

If it is proposed to install a gasifier within the premises of a particular rolling mill to substitute furnace oil, then the size / capacity of the gasifier would be such that the air-blown, moving bed gasifier is likely to be the most suitable. Such a gasifier would have the flexibility of fuel (coal or biomass), which is an important consideration in regions away from coal mines. Further, moving bed gasifiers are more flexible towards variations in output, fuel size, etc.

The gas generated from an air-blown gasifier, which has calorific value of about 1100-1300 kcal/Nm^3, along with preheated combustion air (200-300 ^{0}C), can generate the temperatures required in the reheating furnace (1150-1200 ^{0}C). Therefore, in principle, it is possible to completely substitute the furnace oil by producer gas. However, there are many occasions during rolling mill operation when sudden increase in fuel firing to the furnace is desired. Also, there are occasions when the furnace is operated at more than designed production capacities. To take care of such contingencies, it is advisable to retain the oil firing system along with the producer gas firing arrangement.

The quantity of solid fuel required (coal or biomass) to substitute furnace oil will depend upon the calorific value of solid fuel. Table 1 lists the conversion ratios to determine the requirement of solid fuel.

Table 1: Conversion Factors for Solid Fuel to FO

Calorific Value of Solid Fuel (kcal/kg)	Quantity of Solid Fuel Required to Substitute 1 litre of FO (kg)
3000	4.5
3500	3.9
4000	3.4
4500	3.1
5000	2.7
5500	2.5
6000	2.3
6500	2.1

For heating of steel ingots / billets, it is possible to utilize the gas in hot raw condition. The temperature of the gas at the burner inlet is maintained such that most of the tars in gas remain in vapor form and contribute towards energy input to the furnace. In order to achieve such an operation, the gas pipeline from the gasifier up to the burners is insulated and the gasifier is installed as close to the furnace as possible.

The pipeline is laid in such away that it enables easy cleaning whenever required. While the gas burners are installed on the furnace walls, the oil burners are also retained.

6. ECONOMICS OF UTILISING GASIFIERS IN INDIVIDUAL ROLLING MILLS

The investment required for installation of a gasifier will depend upon the size of the plant, type of fuel, location, distance of furnace from the gasifier, complexity of fuel & ash handling facilities, extent of automation, etc. the average cost of gasification facility (excluding fuel & ash handling facilities) could be taken as about Rs. 2.5-3.5 million (Rs.25-30 lacs) for every 100 litres/hour oil substitution equivalent. On the lower end of the capacity, the costs are expected to be higher than the average values, while higher capacity gasifiers would require lower average costs. For example, a 5 million kcal/hour (equivalent to 500 litres/hour oil substitution) is expected to cost Rs. 8.5-9.5 million (Rs. 85-95 lacs), excluding fuel storage and handling facilities.

The operating cost and savings as compared to furnace oil (FO) operation would depend upon a number of factors, such as manpower costs, landed price of furnace oil, landed price of substituting solid fuel, interest costs, local electricity tariffs, operating hours of the furnace, etc. While most of these factors are similar across India, the landed price of substituting solid fuel varies widely from one location to the other. To compare the available solid fuels, they need to be evaluated in terms of price for a given energy content. One of the convenient ways could be to evaluate the landed price in terms of Rs. per 1000 kcal of the fuel. For example, if D-grade coal with a calorific value of 3700 kcal/kg is available at Rs. 1500/ton in Central India, its price can be considered as Rs. 0.405 / 1000 kcal. Similarly, if B-grade coal with a calorific value of 5500 kcal/kg is available at Rs. 3500/ton in Northern India, its price can be taken as Rs. 0.636 / 1000 kcal.

While exact economics of installing a gasifier would be site specific, representative calculation of pay-back periods are shown in Table 2 for different landed prices of solid fuels. The major assumptions made for calculating the pay-back period are also indicated in the Table.

The figures shown in Table 2 highlight the importance of landed price of solid fuel. It also indicates the significance of choice of fuel in terms of coal vs. biomass. In areas away from coal mines, such as Northern & Southern India, biomass fuels are likely to be much cheaper than coal in Rs./1000 kcal terms. Therefore, the use of coal instead of biomass may be economically more attractive.

Table 2: Economics of Gasifier Installation with respect to Price of Solid Fuels

Assumptions		Solid Fuel Price (Rs./1000 kcal)	Pay-back Period (years)
Capacity of the gasifier	5 million kcal / hour (equivalent to 500 litres/hour oil)	0.25	0.73
		0.30	0.79
		0.35	0.87
Investment (excluding coal handling)	Rs. 9.00 million (Rs. 90 lacs)	0.40	0.96
Furnace oil substituted	400 litres/hour (average)	0.45	1.07
		0.50	1.21
Price of furnace oil	Rs. 13.00/litre	0.55	1.40
Operating hours	12 hours/day (3600 hours/year)	0.60	1.65
Interest	9% flat	0.65	2.00
		0.70	2.56

7. ENVIRONMENTAL CONSIDERATIONS

Detailed studies to evolve the comparative emission data between FO operation and producer gas operation are yet to be conducted. However, the following points indicate that the producer gas operation should be more environment-friendly than FO operation:

- Gas burns with a cleaner flame as compared to FO. This leads to lower dust emissions through stack, which are evident from the invisible emissions at the top of the chimney when the furnace operates on producer gas.

- Biomass fuels have negligible sulphur. Even the sulphur content of Indian coals is much lower than that in FO for a given energy output. Therefore, SO_2 emissions are expected to be much lower than that with FO operation.

- CO is normally a result of incomplete combustion. With better mixing of air & gas in gas burners, the CO is expected to be within acceptable limits. However, if the furnace is operating with insufficient combustion air, the CO emissions may go up.

- When biomass is used for substituting FO, the CO_2 emissions to the atmosphere are reduced as the biomass combustion has net zero CO_2 emissions.

Any observations on Nox emissions may be made only after detailed studies are made in this direction.

8. CENTRALISED GASIFICATION FACILITY FOR A CLUSTER OF ROLIING MILLS

In some parts of India (like Raipur in Chhattisgarh and Mandi Gobindgarh in Punjab), a large number of rolling mills operate in close-by premises in industrial areas. For such clusters, establishment of centralized gasification facility may be considered. Such an approach would require conduction of detailed cluster specific studies to evaluate the following aspects:

- Number of units that could be included in a cluster based on their closeness & scatter in an industrial area
- Cumulative FO consumption profile of the selected cluster with respect to time to determine peak, average and minimum consumption data
- Selection of gasification technology and sizing of the suitable equipment
- Piping layout, gas metering, gas quality monitoring, etc.
- Pricing, management, ownership, logistics, etc.
- Environmental and safety related issues

The cost of FO substitution may be higher in centralized gasification approach due to expected higher investment. But, at the same time, this approach has several advantages. The individual rolling mills (which are generally SMEs with limited financial resources and technical & managerial skills) are spared from additional physical and financial efforts required for owning and operating a gasification plant. The gas generation utilities could come up as co-operative ventures or separate business entities.

9. CONCLUSIONS

Gasification technology offers an opportunity for substitution of furnace oil (FO) in reheating furnaces of rolling mills by producer gas generated from solid fuels, like coal or biomass. This enables the mills to achieve substantial financial savings with associated environmental benefits for the society. The technology is readily available for utilisation at the individual mill level. The pay-back periods are expected to be attractive, mostly less than 2 years. Some experience already exists in India for utilisation of producer gas to substitute furnace oil. The approach of centralized gasification facility to cater to the needs of a cluster of rolling mills seems feasible as well as suitable and needs to be studied further in detail.