Efficiency Improvement in Sugar Mills; The Role of High-Pressure Boiler Technology in Cogeneration

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Abstract. Pakistan's electricity shortage has had a significant impact on its economic growth, people's livelihoods, and industrial operations. Currently, thermal methods like oil and gas satisfy around 67% of its electricity needs, with hydropower generating 30% and nuclear means generating only 3%. Bagasse, a solid waste produced during sugar production, accounts for only 0.9% of Pakistan's energy production. However, by implementing cogeneration retrofits, bagasse's capacity can increase up to 3000 MW. Sugarcane is a significant crop in Pakistan, and sugarcane crushing mills have been utilizing boiler technology for many decades as a means of generating steam and producing electricity. The process of cogeneration, which uses bagasse to generate steam and produce electricity, has several advantages, including reducing reliance on fossil fuels, providing a reliable source of electricity, and a source of revenue for sugarcane mills. High-pressure boilers have several advantages, including higher energy efficiency, higher electricity generation, less wear and tear on equipment, lower installation and maintenance costs, and a smaller footprint. As most sugar mills are in rural areas so we can also use this as a benefit and provide electricity to remote areas. A case study related to JDW Sugar mill has been added at the end to compare the results of High- and Low-pressure boilers. From the results, it is clear that if we want to have highly efficient Cogeneration scheme in Sugar mills, we need to shift urgently towards High pressure boilers.

Keywords: Bagasse, Sugar mills, High pressure boiler, Cogeneration

1. Introduction

Pakistan has been grappling with a significant shortage of electricity for many years. During the summer season, this shortage is exacerbated, resulting in severe load shedding. Urban areas currently experience 3-5 hours of load shedding each day, while rural areas experience 8-10 hours. The consequences of this daily power outage have negative effects on the country's economic growth, people's livelihoods, and industrial operations. Pakistan satisfies approximately 66.8% of its electricity requirements through thermal methods, such as oil and gas, while 30% is generated by hydropower and only 3.3% by nuclear means...
According to research, bagasse currently accounts for only 0.9% of energy production in Pakistan, which is equivalent to around 500 MW [2]. However, studies indicate that by implementing co-generation retrofits, this capacity can be increased to 3000 MW [3]. The daily increase in electricity demand in Pakistan, driven by population growth, modernization, and urbanization, is challenging due to limited native resources of oil and gas. The country relies heavily on imported oil for electricity generation, resulting in a significant economic impact, costing billions of dollars. To meet the growing electricity demand and provide access to rural areas, exploring alternative energy resources like biomass is necessary. Sugar mill waste could play a significant role in generating electricity due to its potential, especially given the rural location of many mills.

1.1 Sugarcane Statistics in Pakistan

Sugarcane is a significant crop in the Indo-Pak Subcontinent, serving as a primary source of sugar and also generating a substantial amount of solid waste known as bagasse. This waste is commonly used as a heat energy source for various sugar production processes such as the clarification and crystallization of juice, as well as for generating electricity to partially meet the local demand of sugar mills. Pakistan, being the fifth-largest sugar-producing country in the world, relies heavily on agriculture as its primary resource, given its status as a developing country. The sugar industry's output represents around 3.7% of the value added by the agriculture sector and 0.8% of the Gross Domestic Product (GDP). Here are some Statistical datapoints of sugarcane in Pakistan [4]:

<table>
<thead>
<tr>
<th>Years</th>
<th>No. of Mills</th>
<th>Cane Crushed (Tons)</th>
<th>Sugar Made (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>51</td>
<td>22,603,696</td>
<td>1,908,838</td>
</tr>
<tr>
<td>1995</td>
<td>66</td>
<td>28,151,434</td>
<td>2,449,598</td>
</tr>
<tr>
<td>2000</td>
<td>65</td>
<td>29,408,879</td>
<td>2,466,788</td>
</tr>
<tr>
<td>2005</td>
<td>74</td>
<td>30,090,632</td>
<td>2,588,177</td>
</tr>
<tr>
<td>2010</td>
<td>84</td>
<td>44,511,571</td>
<td>4,119,421</td>
</tr>
<tr>
<td>2015</td>
<td>88</td>
<td>56,460,524</td>
<td>5,587,568</td>
</tr>
<tr>
<td>2021</td>
<td>90</td>
<td>58,603,839</td>
<td>5,631,249</td>
</tr>
</tbody>
</table>

1.2 Cogeneration Through Bagasse

The cogeneration cycle in the sugar industry typically begins with the combustion of bagasse, a waste product of sugarcane processing, in a boiler. The heat generated from this process produces steam, which is then used to generate electricity in a turbine. The electricity produced can either be consumed on-site or sold to the grid. As the steam is used to generate
electricity, it also produces heat, which can be used for various processes in the sugar production plant, such as the heating of the sugarcane juice. The remaining steam can be used for additional power generation or exported for other uses, such as district heating. The processing of bagasse, the fibrous residue remaining after crushing sugarcane to extract juice, relies heavily on boiler technology. Bagasse can be burned to generate steam, which in turn can be used to power turbines and generate electricity. [5]. This process is known as cogeneration and is a sustainable way for sugarcane crushing mills to produce surplus electricity.

The boiler technology used in cogeneration systems is typically high-pressure boilers that generate steam at high temperatures and pressures. The steam is then used to power turbines, which produce electricity. The excess steam can also be used for other purposes, such as distillation or drying.

Sugarcane crushing mills have been producing surplus electricity using bagasse for several decades. In fact, many sugarcane mills are now net exporters of electricity, selling their surplus power to the grid. For example, in India, where sugarcane is a major crop, over 300 sugar mills generate more than 4,000 MW of electricity, of which around 2,500 MW is exported to the grid [6]. The use of bagasse for cogeneration has several advantages. First, it reduces the reliance on fossil fuels for electricity generation. Second, it provides a reliable source of electricity for sugarcane mills, which often operate in remote areas where the grid may not be reliable. Finally, it provides a source of revenue for sugarcane mills, which can sell their surplus electricity to the grid.

![Cogeneration Cycle in Sugar Mills](image)

**Figure 2:** Cogeneration cycle in Sugar Mills

### 1.3 Technologies available for cogeneration

It is crucial to discuss certain technologies that are already in use, such as rolling mills, low-pressure boilers, condensing turbines, and evaporators. The focus of this research paper is to explore the impact of retrofitting one of these technologies on improving the efficiency.
of sugar mills and increasing their co-generation process, resulting in higher electricity generation. To meet their in-house electricity and steam demands, many sugar mills in Pakistan rely on conventional boilers and steam turbines. To improve this, high-pressure boilers (at 65 bar) and condensing extraction steam turbines (CEST) should be developed and installed in sugar mills throughout the region. Using high-pressure boilers can generate more steam per ton of bagasse, increasing electricity generation. Steam production is directly proportional to the boiler pressure, and the higher the pressure, the greater the steam production. Moreover, boosting the steam pressure and temperature of CEST can further increase electricity generation [7].

In contrast, low-pressure boilers have been used in sugarcane mills for many years. These boilers operate at lower pressures and temperatures than high-pressure boilers, which means they are less energy efficient and generate lower amounts of steam. Low-pressure boilers are often linked to back pressure turbines, which are less efficient than the condensed extraction turbines used with high-pressure boilers [8].

The shift towards high-pressure boilers in sugarcane mills has been driven by a number of factors, including the need to reduce greenhouse gas emissions, improve energy efficiency, and reduce operating costs. This trend is likely to continue in the coming years as mills look for ways to improve their production processes and reduce their environmental impact [9].

2. Benefits of using high pressure boiler

- High-pressure boilers operate at higher temperatures and pressures, which allows for greater steam generation and energy production per unit of fuel. This results in higher energy efficiency and lower fuel consumption, which translates into cost savings and reduced greenhouse gas emissions [10].
- High quality steam is produced with the help of HP Boilers, which is free from impurities and has a higher heat content. This allows for more efficient energy transfer and better performance of steam turbines, resulting in higher electricity generation and less wear and tear on equipment [11].
- High-pressure boilers have a smaller footprint than low-pressure boilers, as they require fewer heating surfaces to achieve the same steam output. This results in lower installation and maintenance costs and allows for more flexible plant layout and expansion [12].
- High-pressure boilers are designed to operate at high temperatures and pressures, which allows for better control of combustion and reduced emissions of pollutants such as nitrogen oxides (NOx) and sulfur dioxide (SO2) [13].

3. Case Study of JDW Sugar Mill

A case study of JDW Sugar Mills, located in Southern Punjab, which have been installed by HMC (Heavy Mechanical Complex, Taxila), we will study the details for both the High-pressure and low-pressure boilers. Data has been taken for the installed capacity of 6000 TCD. Conventionally, different Sugar mills were working with the boiler of 20-25 bar and the high-pressure boilers which are being installed these days are working around 60-65 bar. Before this, there was not any Cane crushing boiler having capacity of that much high pressure. In light of the facts mentioned above, we came to know that High Pressure Boilers are way more efficient in terms of cost, energy consumption, efficiency and Bagasse consumption.
The study revealed that low pressure boilers typically generate 120 tons of steam per hour with a pressure capacity of 25 Bar. However, switching to high-pressure boilers can produce the same amount of steam at a pressure of approximately 65 bar and a temperature of 485°C. Following table can explain the stats for the assumed capacities:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>L.P Boilers</th>
<th>H.P Boilers</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average crushing / day</td>
<td>6000</td>
<td>6000</td>
<td>Tons/day</td>
</tr>
<tr>
<td>Average crushing / h</td>
<td>250</td>
<td>250</td>
<td>Tons/hr</td>
</tr>
<tr>
<td>Bagasse / cane ratio</td>
<td>30</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Steam % cane</td>
<td>45-50</td>
<td>39-42</td>
<td>%</td>
</tr>
<tr>
<td>Bagasse Produced</td>
<td>75</td>
<td>75</td>
<td>Tons/hr</td>
</tr>
<tr>
<td>Bagasse Consumed</td>
<td>61.65</td>
<td>55.22</td>
<td>Tons/hr</td>
</tr>
<tr>
<td>Bagasse Saved</td>
<td>13.35</td>
<td>19.78</td>
<td>Tons/hr</td>
</tr>
</tbody>
</table>

Typically, low pressure boilers have an efficiency range of 68% to 72% based on the Net Calorific Value (NCV). However, with modified high-pressure boilers, efficiency can be increased to 84% [14]. And Steam % Cane stands for utilization of 100% cane how much steam will be required, in easy words, for a specific amount of cane, how much percentage of steam is going to be used. Moreover, calculations indicate that high-pressure boilers can reach an efficiency of 86.7% with a moisture content of 48% and a pressure and temperature of 65 bar and 485°C, respectively.

**With LP Boiler bagasse consumption = 13.35 Tons/hr**
**With HP Boiler bagasse consumption = 19.78 Tons/hr**

**Total Savings = 6.43 Tons/hr**

There exists around 120 days in Sugarcane season [15], so:

\[
= 6.43 \times 24 \times 120 = 18,518.4 \text{ Tons saving per Season}
\]

In case of bagasse consumption in two scenarios. Installing high-pressure boilers can lead to a saving of approximately 18,519 tons of bagasse per season. Mostly traditional sugar mills do not have surplus bagasse for cogeneration during the season, so saving bagasse for off-season use can be an effective way to meet the plant's energy needs.

### 4. Conclusion

In conclusion, this study highlights the significance of cogeneration systems, within the utilization of High Pressure Boiler, in Pakistan’s current energy landscape. In a country like Pakistan, where Power plants primarily rely on expensive Gas or Furnace Oil, Co-Generation systems can offer a better alternative. Additionally, cogeneration systems that use bagasse as a fuel source are environment friendly since they produce minimal ash and do not contain Sulphur. Sugar Mills are typically located in rural areas and utilization of power by these can help in electrifying these rural areas and promoting the growth of Agro-based Industries. So, by saving bagasse through HP Boiler and then using it as a fuel source, Pakistan can save foreign Exchange that would otherwise be spend on purchasing oil. Furthermore, during the winter season, when Hydal power production is at its lowest due to reduced river flow, utilising power from sugar mills can alleviate the burden on the National Grid.
References


3. National policy for power co generation by sugar industry and guidelines for investors.


