THERMAL UTILISATION OF VINASSE AS ALTERNATIVE FUEL

By

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Abstract

SAACKE has designed a special burner for utilising biogenic fuels that occur as by-products, for example during the production of bioethanol. When the fermented mash from soy or sugarcane molasses is distilled to separate bioethanol, soy molasses and vinasse are produced. From the point of view of combustion, molasses and vinasse are very similar (40–50% water, 40–50% organics, about 10% ash). These are liquid by-products with an extremely low calorific value that could not be used to generate energy in the past. Today, the SSB-LCL swirl burner makes it possible to use these materials in concentrated form, with around 20 percent support fuel added to them, to generate heat, which is in turn fed back into the production process. As a result, 80 percent of the fuels previously required to produce bioethanol can be saved. When soy molasses and vinasse are burnt, only ash remains as a high-quality, odourless fertiliser that can be returned to the soil. This is an enormous benefit for the environment because nowadays the residue from soy and sugar production in Asia and Latin America is generally dumped on the area under cultivation. The first step in this direction has already been taken in Brazil: in Araucaria, in the State of Paraná, where molasses and vinasse have been burnt using SAACKE burners since 2007.

Introduction

Several academic works deal with efforts to achieve ‘zero effluent’ in alcohol distilleries as well as significant energy savings (Perera, 2008, Avram-Waganoff *et al.*, 2009, Schopf and Erbino, 2006). These papers put forward irrefutable arguments demonstrating the feasibility and desirability of this goal.

One of the requirements for achieving these goals is utilisation of vinasse as a fuel, which will be explained in detail in the following.

Functional principle of the SSB-LCL burner

Low calorific fuels such as soy molasses or vinasse have calorific values that are too low to be burnt with conventional burners. However, it is possible to burn such fuels in a SSB-LCL (SAACKE Swirl Burner for Low Calorific Liquids) firing system and to feed the resulting exhaust gases to a boiler or a combustor. The system consists of a SAACKE swirl burner with a special burner throat.

The SSB is a well-proven gun-type burner for industrial and power station plants. This burner was developed for the combustion of natural gas and fuel oil and operates according to the ‘mixing at the burner mouth’ principle. This burner results in particularly low CO and NOx emissions. It is meanwhile also used in a lot of applications for low calorific gases with even below 3 MJ/m³ LHV.

The swirl-type burner primarily consists of the following structural components (Figure 1):

- Tangential wind box.
- Central fuel gun for vinasse.

- Second fuel gun for support fuel (liquid or gaseous).
- Combustion air control damper with control drive.
- Core air damper with control drive.
- Combustion air monitoring system consisting of a pressure monitor with test valve and pressure gauge with isolating valve.
- Flame scanner and gas-electric igniter.

The firing plant is started up with a high calorific fuel using the swirl burner and heated up to the temperature in the throat required for complete combustion of the gases. The typical temperature is about 650°C which is reached in about 30 minutes.

The low calorific fuel is then supplied to the burner via a dedicated atomising system. The fuel quantity required to start up the combustor is reduced for subsequent low calorific combustion so that a pilot flame is continually maintained assuring safe combustion of the low calorific fuel.

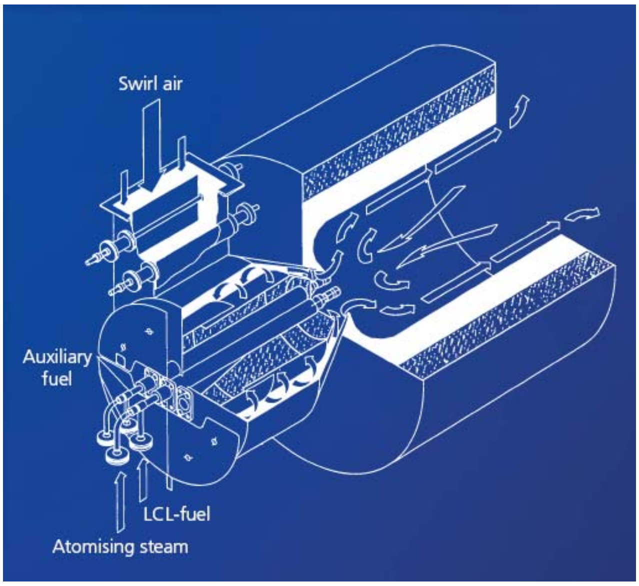

Fig. 1—SSB LCL principle.

The required quantity of support fuel depends on the burning characteristics of the low calorific fuel used.

The required combustion air is tangentially supplied via the burner inlet elbow. In this inlet it is fed into the annulus between inner and outer body and accelerated in the conical part from which the swirled air then enters the furnace. The air annulus is adjusted such that an overcritical swirl is generated in the furnace. The core air is supplied to the burner separately and flows through the annulus between the fuel gun and the concentric core air tube. The combustion air and the core air control damper are adjusted by a control drive depending on the load requirements. The control drives are activated by the compound control system.

By optimum positioning of main and core air a wide control range, optimum combustion and low emission values are safely achieved at all burner loads.

The strong swirling of the combustion air causes a very intense mixing of fuel and air, which together with the hot brickwork lining provides for safe ignition of the mixture and total burn-out with a homogeneous temperature profile. Liquid as well as gaseous fuels can be used as start-up and pilot fuel. Ash fusion is avoided by controlling the flame temperature, either by means of the excess air ratio or percentage of support fuel. Therefore, all ash components are in the flue gas as dry powder.

Table 1—Fuel characteristics.

Fuels		Vinasse	Soy molasses
Organic content	% (by weight)	52.65	51.1
Water content	% (by weight)	35	41.5
Ash	% (by weight)	12.35	7.4
Sulfur	% (by weight)	0.84	0.14
Carbon	% (by weight)	21.87	30.1
Hydrogen	% (by weight)	3.58	4.4
Nitrogen	% (by weight)	0.75	0.06
Oxygen organic	% (by weight)	25.6	16.6
Viscosity	cSt 50/100 C	~ 80/~ 15	289/20
Lower heat value (LHV)	MJ/kg	7.47	10.3/11.2

Vinasse	is a final by-product of fermentation to alcohol. After removal of the alcohol by distillation the remaining material is vinasse. For combustion it should be concentrated up to 40–50% of water.
Soy molasses	is a final by-product of the soy protein industry. For combustion it should be concentrated.

Case study

Two SSB-LCL burners, each rated at 26 MW, were installed on a boiler at Araucaria in Brazil (Schopf, 2009). At about the same time, a 35 MW burner was installed on another boiler. The case study examines the boiler containing the two 26 MW burners (see Tables 2 and 3).

One of the main fuels is vinasse with either natural gas or fuel oil as support fuel. The specification for the boiler design required that maximum percentage of the support fuel must not exceed 20%. It is planned to upgrade the boiler to 42 Bar (g) and 70 t/h in the future. The burners are designed for this purpose.

Table 2—Boiler data.

Location	Araucaria, State of Parana, Brazil
Application	Water tube boiler
Type	Biomass design (see Figure 3)
Capacity	60 t/h (future 70 t/h)
Boiler heat input at MCR	52 000 kW
Steam pressure	13 bar(g) (future 42 bar(g))
Steam temperature	saturated steam (future 400°C)
Furnace size (width x height x length)	5175 x 4945 x 13 200 mm
Furnace projected heating surface	285 m^2
Furnace volume	331 m^3
Combustion air temperature from design	230°C
Burner type	2 x SSBS-LCL 200
Burner input	2 x 26 MW
Burner position	Horizontal, two above each other
Main fuels	Vinasse or soy molasses
Support/secondary fuel	Natural gas, oil from animal fat and soy bean husks
In operation since	July 2007 (Schopf, 2009)

Obstacles surmounted in the projects

High ash content in soy molasses/vinasse fuels

It was mainly a problem of the boiler design. The solution was achieved by means of an optimised flue gas system design, strategic soot blower system equipment installation and the scrubber system. Considering the high amount of ash in the fuels, we can say the results have been satisfactory. The continuous operation time of the boiler is about 3 months without shutdown. Most of the ash is removed behind the boiler by a Venturi scrubber.

High water content in soy molasses/vinasse fuels

It was a major point to be considered from the point of view of the boiler design because the water vapour generated in exhaust gases due to the water content of the fuel is extremely high (up to 40% by volume).

In addition, it is a major obstacle for the combustion system. Flame stability was only possible by using the special SSB-LCL combustion system. The high swirl and special LCL burner throat ensure flame stability.

Very low heat calorific value of soy molasses/vinasse fuels

It was a challenge especially for the combustion system. Flame stability was only possible by using the special SSB-LCL combustion system. The high swirl and the combustion chamber ensure flame stability.

Conditioning system for proper atomisation of soy molasses/vinasse fuels

This point requires special attention due the corrodibility of soy molasses, the crystallisation (sugar caramel) that occurs in contact with heated surfaces and the difficulty in achieving good atomisation. The piping material and pumps used are specially designed. The heating system with a viscosity control loop involves direct steam injection. The optimum atomisation was achieved by testing several nozzle types and testing different viscosity conditions as well several molasses concentrations (see Figure 2).

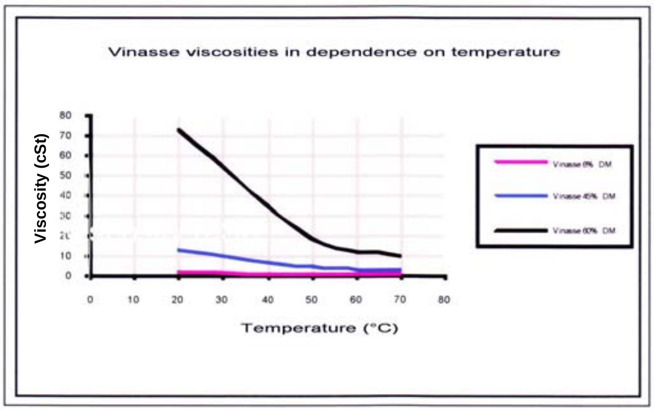

Fig. 2—Influence of dry matter levels and preheating temperature on the viscosity of vinasse.

Results

The experience gained provided good feedback and knowledge for the combustion system manufacturer and the boiler manufacturer. The technology is a proven one.

The main points are that at 5% oxygen in the fuel gas (typical operation point) the CO emissions are significantly below 50 ppm and the NOx value is below 300 ppm (Table 3). Another important point is that no slagging occurs in the burner throat or the boiler, which is achieved by the burner management system (BMS) supplied by SAACKE. This is done by controlling the flame temperature in a small range between 850–950°C with the help of either excess air ratio or percentage of support fuel. By this the continuous operation time of the boiler is more than 3 months.

Last but not least: the plant in Araucaria (Figures 3, 4, 5) will pay for itself within far less than two years because 80% of the natural gas previously used is saved! The results surpassed the initial expectations.

Table 3—Emission values SSB-LCG burner, case study boiler at Araucaria.

Steam flow production	T/h	70
Steam pressure (production)	bar(g)	11.6
Nat gas flow	Nm3/h	550
Soy Molasses flow	t/h	15
Molasses burner inlet pressure	bar(g)	16
Molasses concentration (tank)	brix	75
Viscosity before burner	cSt	54
Molasses temperature	°c	92
Furnace pressure	mmWC	–4
Combustion air temperature	°c	180
Carbon monoxide on flue gases	ppm	30
Nitrogen oxides (NOx)	ppm	280
Carbon dioxide in flue gases	%	8.5
Oxygen in flue gases	%	5

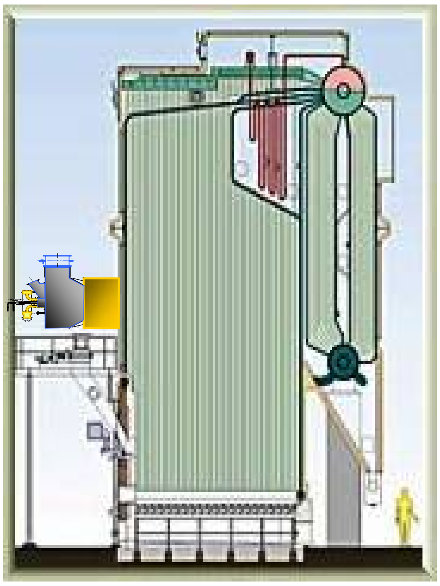

Fig. 3—Sketch of the case study boiler at Araucaria.

Fig. 4—Picture of the case study boiler at Araucaria.

Fig. 5—Picture of burner for case study boiler at Araucaria.

Conclusion

When soy molasses and vinasse are burnt, only ash remains as a high-quality, odourless fertiliser that can be returned to the soil. This is an enormous benefit for the environment because nowadays the residue from soy and sugar production in Asia and Latin America is generally dumped on the area under cultivation.

This paper has shown that firing plants for soy molasses/vinasse offer an economical and ecological answer to the increasing and highly diversified industrial demand for alternative fuels. Various technological innovations and improvements now make it possible to utilise the potential heat energy available in by-products and waste from the sugarcane and bioethanol industries by firing them as alternative fuels instead of merely disposing of them. This means that, depending on the application, they can be used to replace, completely or partially, expensive standard fuels such as natural gas. In addition, CO_2 emissions from non-renewable fuel are considerably reduced as well.

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UTILISATION THERMIQUE DE LA VINASSE COMME CARBURANT DE REMPLACEMENT

Par

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MOTS-CLES: Vinasse, Mélasse, Production De Vapeur, Brûleur à Faible Turbulence.

Résumé

SAACKE a conçu un brûleur spécial pour les carburants biogènes qui sont générés comme des sous-produits, par exemple lors de la production de bioéthanol. Lorsque le soja et la mélasse de canne à sucre sont distillés après fermentation, pour la production de bioéthanol, mélasse et vinasse sont produites. Du point de vue de la combustion, mélasse et vinasse sont très similaires (40–50% d'eau, 40–50% les produits biologiques, environ 10% de cendres). Ce sont des sous-produits liquides avec une valeur calorifique extrêmement faible qui ne pouvaient être utilisés dans le passé pour produire de l'énergie. De nos jours avec le brûleur à faible turbulence, il possible d'utiliser ces matériaux en forme concentrée en mélange avec 20% de carburant pour générer de la chaleur qui est à son tour réinjectée dans le procédé de production. Ainsi, 80 pour cent des carburants précédemment nécessaires à la production de bioéthanol peuvent être économisés. Lorsque la mélasse et la vinasse sont utilisées comme combustible il en résulte seulement des cendres qui constituent un engrais inodore, de haute qualité qui peut être incorporé au sol. Il s'agit d'un avantage énorme pour l'environnement car de nos jours le résidu de la production de soja et de la canne à sucre en Asie et en Amérique latine, est généralement disposé sur les superficies cultivées. Le premier pas dans cette direction a déjà été fait en Araucaria dans l'état du Paraná au Brésil où la mélasse et la vinasse ont été utilisées à l'aide de brûleurs SAACKE depuis 2007.

EMPLEO TÉRMICO DE LAS VINAZAS COMO COMBUSTIBLE ALTERNATIVO

Por

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PALABRAS CLAVE: Vinazas,Melazas,Producción de Vapour, Quemador de Torbellino.

Resumen

SAACKE ha diseñado un quemador especial para el empleo de combustibles biogénicos que constituyen sub-productos, por ejemplo durante la producción de bioetanol. Cuando el mosto fermentado de soya ó de caña de azúcar se destila para separar bioetanol se producen melazas y vinazas. Desde el punto de vista de la combustión las melazas y las vinazas son muy similares (40-50% de agua, 40–50% de orgánicos, cerca de 10% cenizas). Éstos son subproductos líquidos con un extremadamente bajo valor calórico que no podían ser empleados en el pasado para generrar energía. Hoy el quemador de torbellino SSB-LCL hace posible emplear estos materiales concentrados, con adición de alrededor de 20% de combustible soporte, para generar calor, el que es retornado al proceso productivo. Como resultado, el 80% del combustible anteriormente requerido para producir bioetanol puede ahorrarse. Cuando las melazas y las vinazas se queman solo quedan cenizas como un fertilizante de alta calidad e inodoro que puede retornarse al suelo. Este es un enorme beneficio al ambiente, porque actualmente los residuos de la producción de soya y azúcar en Asia y Latinoamérica generalmente se arrojan en las áreas de cultivo. Los primeros pasos en esta dirección se han dado en Brasil, en Araucaria, en el estado de Paraná, donde las melazas y vinazas se queman empleando los quemadores SAACKE desde el 2007.