Kawasaki Spouted Bed and Vortex Chamber (DeNOx pre-calciner) − Addressing the global trend of strict environmental regulations

In recent years, industrial plants around the world are increasingly adopting more stringent NOx emissions regulations, and cement kiln systems are no exception. Japanese regulations have set the NOx emissions limit to 250 ppm (at 10% O_2), and an effective countermeasure is to reduce NOx contained in the rotary kiln exhaust gas. Kawasaki has developed a DeNOx precalciner called KSV, which promotes denitration by optimizing the state of combustion and fuel mixture. With outstanding efficiency, KSV has reduced NOx concentration by approximately 70%.

Preface

During its period of rapid economic growth, Japan was faced with serious environmental pollution, and in 1975, the government introduced a new regulation limiting NOx emissions from cement kiln systems to 250 ppm (at 10% O_2) or lower. Industry players responded by implementing measures to reduce NOx emissions from cement kilns.

1 Background

In 1976, Kawasaki developed a DeNOx precalciner called the Kawasaki Spouted Bed and Vortex Chamber (KSV) to reduce NOx emissions from the rotary kiln. It has been demonstrated to effectively remove NOx.

The KSV precalciner has subsequently been upgraded with various improvements designed to further enhance its denitration performance. Since 2000, Kawasaki has delivered 52 suspension preheaters equipped with the KSV precalciner mainly to customers in China, contributing to the global effort to reduce NOx emissions.

2 Mechanism of denitration

NOx is reduced and detoxified with the aid of a highly active hydrocarbon gas that is generated during the combustion process, in a temperature range of 800-1,000°C. NOx is also decomposed through the reaction of gaseous reductants such as CO and H contained in unburned fuel, with cement raw material acting as a catalyst.

Therefore, in order to effectively reduce the NOx concentration in the rotary kiln exhaust gas, the first essential point to observe is to ensure that the raw meal exists and is burned with an excessive amount of fuel injected into the KSV precalciner, and the fuel is adequately mixed with the rotary kiln exhaust gas.

At this time, it is important to ensure that the air-fuel ratio is optimal because while the presence of more reducing gases such as HC (i.e., smaller air ratio in the combustion field) increases the denitration efficiency, NOx is regenerated when unburned fuel is burned. It is also important to ensure that the mixture of unburned fuel remaining after the denitration process and excess air is at an optimal ratio, so that the unburned fuel is completely burned inside the KSV precalciner using a minimal amount of air. These are the second essential points.

3 Structure, features, and advantages

(1) Structure and features

The structure of the KSV precalciner is shown in Figs. 1 and 2.

Each component of the KSV precalciner has the following features.

① Throat

Rectifies the flow of the rotary kiln exhaust gas and leads it directly into the conical portion, which is the main combustion chamber of the KSV precalciner.

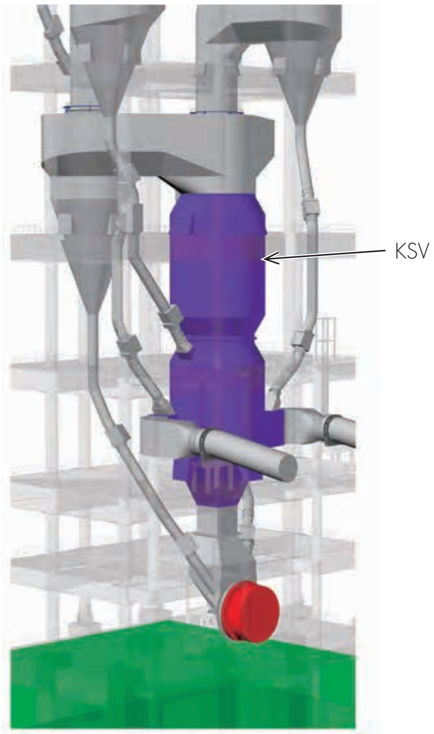

Fig. 1 Overview of KSV (CG)

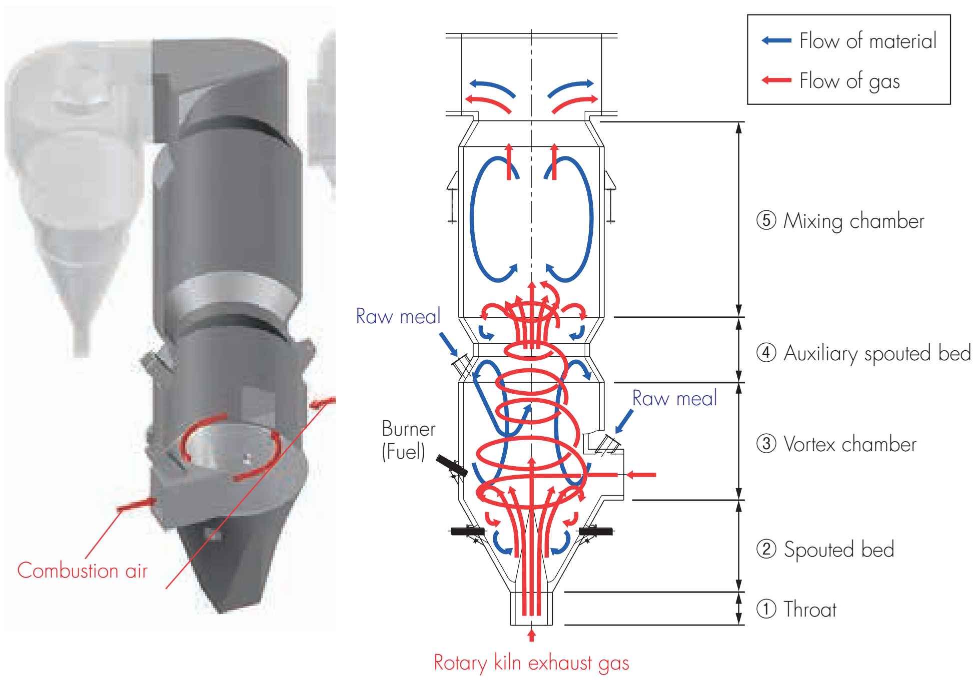

Fig. 2 Structure of KSV

② Spouted bed

Once introduced inside the conical portion, the rotary kiln exhaust gas turns into a jet stream, forming a spouted bed with the raw meal that has been fed.

By injecting some fuel into the spouted bed which has a low oxygen concentration, and burning it in an excess fuel condition, the reducing gas that is generated is efficiently agitated and mixed.

③ Vortex chamber

The combustion air that is introduced in a horizontal direction creates a swirling flow, which promotes the agitation and mixture of the reducing gas in the spouted bed. It also helps the reducing gas to mix efficiently with the rotary kiln exhaust gas and promotes the combustion of unburned fuel.

The remaining fuel is injected into the chamber, where the aforementioned mixing effect helps achieve uniform combustion and efficient heat exchange with the raw meal.

④ Auxiliary spouted bed

The middle portion of the KSV precalciner is narrowed to improve the combustion and mixing performance in the vortex chamber, and also to reduce the amount of gas blowing through, thereby keeping the raw meal inside the chamber for a longer time.

The remaining raw meal is fed directly below the auxiliary spouted bed to prevent the gas from blowing through, and also to form an auxiliary spouted bed above the narrowed portion, further increasing the retention time of the raw meal inside the chamber.

⑤ Mixing chamber

The flow of gas from the narrowed middle portion mixes completely with the swirling flow in the mixing chamber. It provides sufficient internal volume to achieve complete combustion of the unburned gas remaining after denitration at a low air ratio.

(2) Advantages

(i) Energy saving

Fuel consumption is reduced through the synergistic effect of the spouted bed and swirling flow, which combine to achieve excellent efficiency in fuel combustion and heat exchange between the raw meal and hot gas.

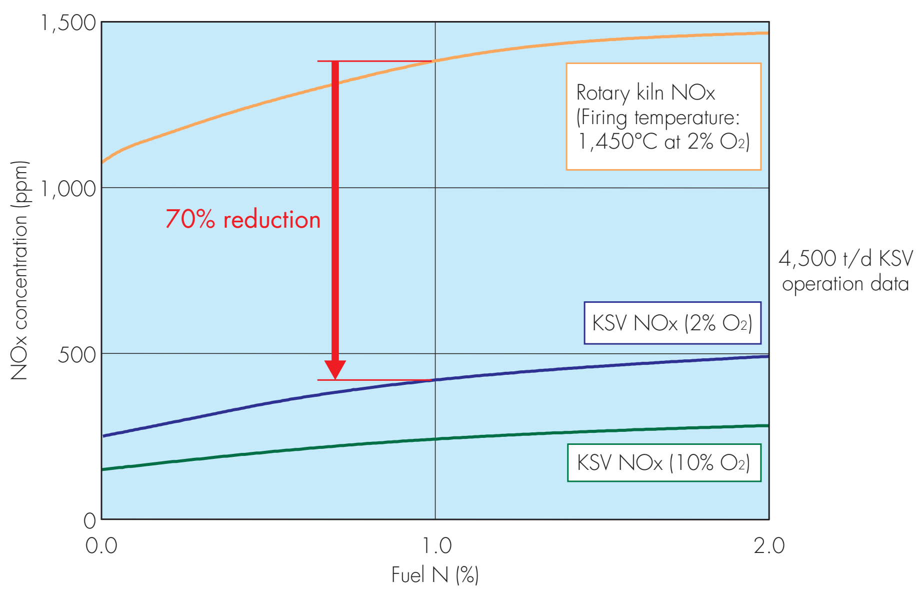

Fig. 3 Denitration effect of KSV

(ii) Stable operation

The temperature distribution inside the KSV precalciner is kept uniform through the distributed combustion of fuel. The wall inside the KSV precalciner is covered with the raw meal due to the swirling flow, which ensures stable operation by preventing the occurrence of hot spots and minimizing coating.

(iii) Low NOx emissions

The generation of HC and other reducing gases is promoted by burning the material in an excess fuel condition within a reduction atmosphere, and these gases reduce the NOx concentration in the rotary kiln exhaust gas by being agitated and mixed together.

4 Dramatic denitration effect of KSV

The NOx generated inside the rotary kiln impacts the ratio of fuel N (proportion of N contained in the fuel), most of which is thermal NOx produced through the reaction of nitrogen and oxygen at a high temperature. Since rotary kilns normally maintain the firing temperature at around 1,450°C, the NOx concentration in a rotary kiln exhaust gas reaches as high as 1,000-1,500 ppm, as shown in Fig. 3.

The precalciner of a suspension preheater, on the other hand, maintains a low combustion gas temperature at around 900°C, which minimizes the generation of thermal NOx and reduces the NOx concentration in the rotary kiln exhaust gas to 40-50% even without the denitration effect. In addition, the KSV precalciner mixes and burns a portion of the fuel with the low-oxygen rotary kiln exhaust gas to generate reducing gas, which removes 40-45% of the NOx contained in the exhaust gas in the process.

Overall, the KSV precalciner reduces the NOx concentration in the rotary kiln exhaust gas by about 70% (at 2% O_2), and has achieved the regulatory limit of 250 ppm (at 10% O_2) as shown by the green line in the figure.

Postscript

As governments around the world are expected to continue to introduce and tighten NOx emissions regulations, we will leverage the KSV precalciner's superior denitration performance to further expand overseas sales.

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