Enhancing dip tube performance at high AF rates

The rise in alternative fuel (AF) utilisation in cement manufacturing challenges the lifetime of dip tubes in the lowest cyclone stages of the preheater. A new generation of the HASLE Ceramic Vortex Finder, made from precast and pre-fired ceramic elements, has been installed in a German cement plant. The solution has tripled the lifespan in the lowest-stage cyclone, achieving a full campaign, and has surpassed 3.5 years in the second-lowest stage.

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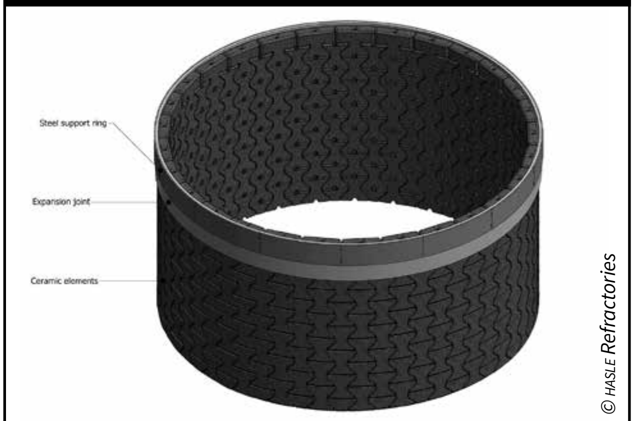
In the global drive towards decarbonisation, many cement plants are adopting sustainable fuel conversion practices to reduce their carbon footprint. This green transition often involves shifting from traditional fossil fuels to alternative fuels (AFs) such as waste materials, biomass and other low-carbon options. While this transition is crucial for achieving environmental sustainability, it also brings about significant operational challenges, including temperature and pressure fluctuations due to unsteady combustion of the AFs as well as increased potential for chemical attacks on cyclone components and refractory linings.

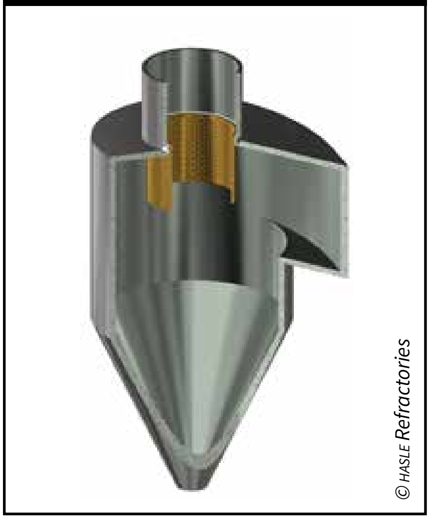
In the cyclone, one of the components significantly affected by the intensified usage of AFs is the vortex finder, also known as the thimble or dip tube. This applies in particular to the cyclones of the lowest stage of the preheater tower, where temperatures can reach 800-1000˚C. At these elevated temperatures, the traditional steel dip tubes, typically made of heat-resistant Cr-Ni-alloyed cast steel, are prone to deformation and corrosion. Burning AFs further increases the concentration of corrosive species in the gas phase. To mitigate the corrosion damage, higher-alloyed steels have to be used, leading to significantly higher investment costs and increased emissions of carcinogenic chromate (Cr(VI)), which are hazardous gases posing health risks to maintenance personnel.

The dip tube plays a significant role in defining cyclone separation efficiency and the pressure drop by shaping the flow field within the cyclone. Proper cyclone and dip tube dimensions ensure that the raw meal is efficiently separated, preventing it from shortcutting to the upper stage. When the dip tube is damaged or missing, the separation efficiency drops significantly, which in turn reduces the heat recovery efficiency of the entire preheater tower. As a result, the temperature at the exit of the preheater increases as well as the pressure-drop across the preheater tower due to increased volume flows. This leads to higher fuel and electricity consumption.

The HASLE Ceramic Vortex Finder provides an alternative to steel dip tubes. It is assembled on-site by individual ceramic elements, which interlock to form a stable tube suspended from a steel support ring welded to the roof casing of the cyclone



Vortex finders are installed in preheater cyclones to improve the separation between the raw meal and the hot gas, thereby increasing the efficiency and process stability of the preheater process. But some plants choose to run without a dip tube in the lowest stage dip tube due to issues with short lifetimes



Challenges of high AF use – a German case study

A 5000tpd cement plant in Germany is running on up to 95 per cent refuse-derived fuels (RDFs) and other AFs. Operating a dual-string design preheater tower with one kiln, the plant has parallel cyclones in the lowest and second-lowest stages. Due to high RDF and AF utilisation, the plant experienced severe corrosion on the steel dip tubes in these stages. Operating at around 850˚C in the second-lowest stage, the steel dip tube lasted three years but was heavily corroded by the end of this period. In the lowest stage cyclone, operating at approximately 950˚C, the steel dip tube only had a few months'

The third-generation Ceramic Vortex Finder fully assembled in one of the lowest stage cyclones at the German cement plant

lifespan before needing replacement, adding cost and working hours to the maintenance plan.

Therefore, the German plant was looking for a longer-lasting alternative to safeguard its operations, uphold operational efficiency and maintain process stability, aiming for the dip tube in the lowest stage to last for a full campaign.

Overhauling the HASLE Ceramic Vortex Finder

To overcome the drawbacks of traditional steel dip tubes at elevated temperatures, the HASLE Ceramic Vortex Finder (CVF) was developed in the 1980s. The CVF consists of pre-cast and pre-fired refractory elements that interlock to form a stable tube hanging from a steel ring welded to the roof casing of the cyclone.

As the German cement plant was already in discussions with HASLE Refractories regarding other precast solutions in its clinker cooler area, it also considered trialling the HASLE CVF in the lowest-stage cyclone. A development programme was already under way to give the CVF product line a general overhaul to cope with the harsh operating conditions in cement plants using AFs. This programme featured a new X-shaped element design with advanced tongue-and-groove joints as well as developing a new refractory material.

The plant agreed to trial the CVF in the lowest-stage cyclones using the new element design while different castables were explored in an initial field-test phase. At first, the lifespan of the CVF did not reach satisfactory levels.

This led the plant to temporarily operate without a dip tube in the lowest-stage cyclones. However, running without a dip tube here proved to not be viable in the long run due to the very aggressive environment inside the cyclones, in combination with the specific cyclone design. Build-up and coating quickly formed inside the cyclones and feed pipes, making them highly prone to blockage and at high risk of stoppages for cleaning out the build-up. The plant experienced numerous stops during the campaign with no dip tube in the lowest-stage cyclone.

CVF Generation 3 with new high-performance castable

In the meantime, HASLE Refractories worked intensively on developing a new high-grade, non-cement castable specifically to be used in the ceramic elements of the CVF, containing pure synthetic and high-performance raw materials. Nanoparticles are included for high fracture toughness, abrasion resistance and maximum strength. In addition, the materials used are providing high resistance to chemical attacks, making the HASLE CVF suitable for plants burning high levels of AFs.

The HASLE CVF Generation 3 elements are manufactured under strictly controlled conditions at HASLE's factory in Denmark. The shapes are carefully cast and cured in specialised moulds to obtain a smooth surface and sustain their unique profile. Subsequently, they are pre-fired to elevated temperatures to achieve maximum strength.

The result is a dip tube capable of withstanding temperatures up to 1200˚C (2200˚F) without deformation or creep and exhibiting high dimensional stability. This ensures that the CVF maintains a high separation efficiency throughout its service life. Additionally, only the precast, ceramic elements are in contact with the hot gas

The CVF in the lowest-stage cyclone after one year of operation at the German cement plant

The CVF in the second-lowest stage cyclone after one year of operation at the German cement plant

The CVF in the second-lowest stage cyclone after three years of operation at the German cement plant

Following the welding of the steel support ring, Ceramic Fibre Blankets are placed against the steel ring to ensure sufficient space for thermal expansion

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Assembling the HASLE CVF: the top row of ceramic elements is placed on the brackets of the steel support ring; the remaining elements are suspended from the elements in the top row

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The final row of elements is locked in place using a heat-resistant sealant

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phase reducing the chromate emissions significantly.

Furthermore, the small-sized ceramic elements minimise the risk of cyclone blockage in case of falling elements as they can pass through the feed pipe, allowing operations to continue.

Flexible installation

Following the introduction of the new castable, the German cement plant has now installed the CVF-Gen3 in the cyclones in the two lowest stages of the preheater tower – all four with equal-sized dimensions, featuring a diameter of approximately 3.6m and a length of 1.6m.

Starting with the two second-lowest stage cyclones, the HASLE CVFs were successfully installed in 2020 and 2021. Having proved its capabilities in the second-lowest stage cyclones from the spring of 2022 onwards, the lowest-stage cyclones have also been running with the HASLE CVF-Gen3 since then.

The installation sequence of the HASLE CVF begins with welding the steel support ring to the roof casing. Ceramic fibre blankets are then placed against the steel ring to allow adequate space for thermal expansion. Following this, assembly of the ceramic elements itself takes only a few hours. The assembly process is initiated by placing the top row of ceramic elements onto the brackets on the steel support ring. The remaining CVF elements are suspended from the elements in the top row. Thanks to the low weight of each individual element (ranging between 6-19 kg), no heavy lifting equipment is required for handling and it is possible to use the existing manholes for the installation. Lastly, the final row of CVF elements is securely locked in place with a heat-resistant sealant.

Trial turning into permanent solution

In the lowest-stage cyclones, the German plant has now achieved the one-year target lifespan of the HASLE CVF with no dip tube related emergency shutdown or stoppages. Further up, in the second-lowest stage, the CVF installed in the spring of 2021 has now been extended into its fourth operational year.

Following a thorough inspection in the latest shutdown in the spring of 2024, this CVF was found to be in excellent condition with no visible damage, leading to the decision to continue its operation. And after 3.5 years it remains in operation.

Global roll-out

After field tests in Europe, the roll-out of the HASLE CVF-Gen3 is continuing globally. A 4000tpd cement plant in Australia, operating on 40 per cent RDF charged into the calciner, was running without a dip tube in the lowest-stage cyclone, where the operating temperature is maintained at 850-900˚C. A CVF was installed in January 2023 and continues to be in operation after 1.5 years, with an expected lifespan of at least two full campaigns.

More recently, CVF-Gen3 installations have also been completed in two plants in the USA in the spring of 2024. ■