Adaptation aspects of an existing Electrostatic Precipitator for operation in new conditions

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Abstract Electrostatic Precipitators (ESPs) are commonly used for the efficient removal of solid particles from aerosols in different industrial applications and operating conditions. The applied ESP mechanical configuration depends on the aerosol quality and the collected dust characteristic at operating temperatures. The ESP's design restrictions and recommendations for successful operation with required particulate removal efficiency are different for hard coal fired boilers compared to biomass fired boilers or chemical boilers. Nowadays there are a number of existing boiler installations rebuilt for operation in new conditions with mixed fuels, greater variation in gas flows, its chemical composition, differentiation in operating temperatures and dust quality. Observed effects of some chemical reactions in the collected dust layer increase the complexity of the dust removal process in the new conditions. In this paper some ESP configuration and adaptation aspects are discussed for new operating conditions.

Keywords: Electrostatic Precipitation, acid dew point, sticky dust, fly ash structure

1. Introduction

In different industrial processes for the efficient removal of solid particles from aerosols, electrostatic fields created in ESPs are used. Depending on the composition of the gaseous mixture and the collected solid particle layer properties, which are different in each process, the applied ESPs have different mechanical and electrical configurations to meet the required outlet emission.

Some ESP suppliers has developed rules for design, erection and successful operation of the ESP for a given process. There are a number of recommendations with consideration of specific conditions and collected dust properties and operating temperatures: for example, dust size distribution, collected dust density, resistivity, abrasiveness, stickiness, hygroscopic properties.

The dust properties dictate which ESP bottom arrangement should be used: a pyramid bottom hopper with a given valley angle through a bottom hopper with a screw or a chain conveyor or a flat bottom with crapper. Also the collected dust evacuation from the bottom hopper must be adequate.

2. Moisture in combustion gases

Moisture content in flue gases have a strong influence for the quality of separation of dust particles in the electrostatic field. At very low moisture contents in the gas mixture, the collected dust layer shows high resistivity whereas at high moisture contents there is a risk of moisture condensation in high quantities.

Water vapour can very easily penetrate all volumes of the dust collector – also in places with no intensive gas flow. If in gas phase in point A, water concentration is higher than in point B, therefore molecules of water will travel to point B until the difference of its concentration exists – the process is called water mass transfer by diffusion between point A and B.

In the gas mixture water vapour has a partial pressure which can reach saturation point, which depends on the temperature. The saturation state is when water evaporation and condensation in the given temperature are balanced. When water changes phase there is a change in the potential energy of the water particles. The energy absorbed or released during a change of phase from liquid to gas is called specific latent heat of vaporisation.

If in one place there is slightly lower temperature locally, close to the water dew point, then in that place condensation of water vapour might occur. If there are some objects like solid particles or metal elements which can take heat of vaporisation from the condensed water –then the process of condensation will follow faster. After condensation the water concentration in the gas phase locally becomes lower than in the other place and the mass transfer of water vapour from the other place will continue by diffusion until reaching a new thermal balanced condition.

Presence of hygroscopic solid particles, which easily absorb water, will intensify the process of moisture condensation.

Collected solid particles create a dust layer – a structure with pores filed by gas. Pores in the dust layer create small gas channels and related to this effect of capillary hysteresis require a higher temperature for evaporation of the same amount of water that condensed at lower temperature.

In places of an ESP, where there is no intensive flow of hot gases, steel elements might have a lower temperature.

Some elements of the ESP like casing walls, bottom hoppers or roof always lose heat to the ambient air (determined by the heat transfer surface, applied thermal insulation quality, thickness of insulation material and temperature differences). In each case the thermal insulation design is adjusted to the operating conditions and type of process for the application of the ESP.

In the case of an ESP applied for removal of fly ash from combustion gases from hard coal fired boilers, where moisture concentration is in the range 5-10% by volume, temperature of flue gases is relatively higher than acid dew point. The typical thickness of mineral wool for thermal insulation is about 100 mm – then there are no problems with intensive moisture condensation. In some places some small amount of water that is fully absorbed by collected dust and it is not making problems might condense (e.g. dust layer stays as a semi dry loose material and it can be easy dislodged from the ESP).

If in some places condensed water amounts are higher than the dust layer absorbs, become wet and creates structures which are more sticky or creates lumps.

In the case that the amount of condensed water is higher than amounts of collected dust able to absorb water, then liquid water on the surface of steel elements can cause corrosion. Presence of SO_3, HF and HCl in combustion gases will intensify the corrosion process.

In the case of an ESP applied for removal of fly ash from combustion gases from biomass fired boilers, where moisture concentration is in the range 12-25% by volume, temperature of flue gases is relatively higher than acid dew point and the typical thickness of mineral wool for thermal insulation should be thicker than in the case of the coal fired boiler.

The fly ash from combustion of a biomass typically contain a few times more hygroscopic alkali compounds than any hard coal ash.

Collected fly ash properties have differences in bulk density, stickiness, angle of natural slip and chemical activity. For successful operation the design of the ESP bottom has to be adjusted to the collected dust properties.

Typical arrangement of pyramidal bottom hopper can have a different height and related angles of wall inclination to avoid problems with discharge of collected ash. The minimum angle for hopper wall inclination is lower in coal ashes than in biomass fly ash.

There are observed number of ESP installations originally designed for removal of fly ash from coal fired boilers which now are used for combustion gases from firing mixed fuels with biomass (without any mechanical changes in ESPs, the same bottom hoppers and without thermal insulation improvements).

In those cases, typical problems which occurred are:

- dust bridges in bottom hoppers are often created,
- a high level of ash in bottom hopper and difficulties with ash dislodging,
- a faster erosion of moving internal parts,
- more intensive corrosion internal elements,
- problems with pneumatic ash handling systems.

Number of ESP's originally designed for hard coal fly ash removal and to keep the outlet emission on a level about 100-200 mg/Nm^3 tolerated some imperfections.

The applied arrangement of baffle plates in the bottom hoppers of the ESP for coal fly ashes allowed for some flows of hot gases under electrostatic fields in bottom hoppers. In that case, the applied bottom hoppers without heating were working correctly for many years. An injection of cold purged air from a pneumatic ash handling system to the ESP inlet or bottom hoppers did not disturb the ESP operation and still kept the emissions in range of 100-200 mg/Nm^3.

Eliminating a gas sneakage in the bottom hopper by additional screen plates allows for improved dust collecting efficiency. However, without heating the bottom hopper for heat loss compensation and when using the same ESP for biomass ash, a number of problems appear.

A higher moisture in combustion gases from biomass and presence of more hygroscopic components in the fly ash make conditions for more intensive moisture condensation.

In some installations pneumatic ash handling systems are used with purged air injected into the ESP. On the path of the cold air mixed with wet combustion gases inside the ESP, the occurred moisture condensation creates the wet dust and corrosion of steel elements.

Figure 1. Corroded collecting plates on the way of colder gas flow in the ESP

On the way of the colder stream of wet gases, rotating rapping shafts with hammers have a much faster wear than similar elements in hot places.

For many years some ESP suppliers used gas distribution elements to get a non-uniform flow of hot gases inside the ESP. Based on numerical modelling, the collecting efficiency improvement was expected [1, 6]. An achieved skewed flow in the ESP many times was good enough when the boiler operated at load 100% of Maximum Continuous Rate (MCR). A number of boilers are rebuilt and modernised so that they are able to operate in greater variations of loads – the minimum load is drastically decreased. A prolonged operation at a load lower than 40% MCR is not unusual. Often at the minimum boiler load there is more than 3 times lower volume flow of combustion gases and usually their operating temperature at the ESP inlet is lower. If for example the ESP was designed for the maximum boiler load with the average gas velocity inside the ESP around 0,80 m/s then at minimum load (40% MCR) in the ESP, gas velocity will be lower than 0,27 m/s in actual conditions. In this situation the gas distribution quality inside the ESP not be as required– with a risk of getting large dead zones (e.g. zones with no flow of hot dusty gases but water vapour flow by diffusion).

Figure 2. Fast wear of rapping shaft and hardened bearing on the way of colder gas flow in the ESP

Often operation for a prolong time at minimum boiler load drastically decreases the ESP lifetime, previously from decades to only a few years.

If in the inlet gas ducts flue gas velocity is 3 times lower than maximum designed, then there is a risk of dust drop in the gas duct. Dust build-ups in gas ducts absorbing moisture become heavy and difficult to blow up later at higher boiler operation. Big dust build-ups in the gas duct cause the maldistribution of the gas at the ESP inlet.

For more and more coal fired boilers there are erected installations of Selective Catalytic Reactors (SCR) for NOx removal. There is ammonia (NH_3) injected into the combustion gases in higher than stoichiometric quantities – it gives ammonia slip. The present SO_2 in combustion gases on the surface of the catalyst is converted into SO_3 – the typical increment of conversion rate is typically by 1%. The higher the concentration of SO_3 in combustion gases, the higher the temperature of the acid dew point.

Operation of the ESP in conditions: low boiler load, low gas temperature at inlet of the ESP, biomass fired with high sulphur coals and SCR installation make fly ash easier for electrostatic precipitation but when the collected dust is getting wet it is more problematic for the typical ESP configuration and its lifetime is shortened. The typical life time of moving elements like bearings and rotating shafts with rapping hammers is shortened from 2-5 years to a few months for operation in conditions with moisture condensation. In some cases, using bearings and shafts made from more wear resistant materials helps slightly but there are still often more maintenances required and replacement of wearing parts. A number of mentioned problems could be avoided when the ESP is correctly designed and rebuilt for new operating conditions, more precisely defined by the customer.

Figure 3. Dust build–ups in oversized gas duct before the ESP

There are special designs for ESPs dedicated for the industrial application with extremely clogging dust collected from flue gases. The collected dust is very reactive and in some conditions components create eutectic mixture which smelts at slightly higher operation temperatures than the acid dew point. In this process, collected dust is loose when fresh and it is possible to remove it by normal rapping, but when it is exposed for too long to reactive process gases it creates hard build-ups which are difficult to remove. So the temperature window for optimal operating of the ESP is relatively narrow.

The mechanical construction developed for this type of ESP has a very advanced system of rapping and inside the ESP any horizontal surfaces without rapping are avoided.

Using mechanical solutions for this type of ESP for power plants could be possible but remarkably increases the dust collector investment costs.

Customers are modernising existing boilers to be able to operate in greater variations of loads but not giving a bigger space for rebuilding existing ESPs. However, there is an opposite tendency to use available free space for SCR installations or other equipment. Practically it is only possible to rebuild the ESP into a taller one to meet required collecting efficiency. The taller ESP will have a bigger cross section area for the same volume flow of combustion gases, therefore the effective average gas velocity will be lower. This will make the system more sensitive to excessive moisture condensation at lower boiler loads.

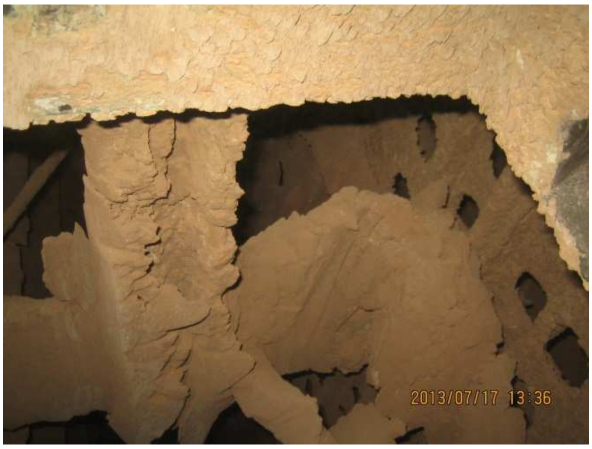

Figure 4. Hard dust build –ups on stiffeners of ESP of the flash copper smelter

3. Conclusions

Scientific and technological progress in different activities has allowed us to apply new solutions for ESPs, however, today there are more complex conditions for the size and configuration for dust collectors:

- higher dynamics of an installation operating conditions – frequent operation on low load when a gas flow is 3 times lower than at max load,
- blended fuels with various types of biomass,
- changes during the operation of ESP – especially during longer periods of low loads getting more sticky and abrasive dust with the process of equipment wear.

Experience from previous ESP installations applied for specific industrial processes helps to improve an ESP in more common applications for upgrading existing installations or building new ones.

The ESP flue gas ducts configuration and collected gas handling system must be taken into consideration for successful operation of modernised ESP with required particulate removal efficiencies. In order to avoid excessive dust fall-out, the gas duct design must consider the characteristics of the gas, the fly ash properties and gas velocity.

For successful operation of the ESP it is extremely important to obtain a full knowledge and understanding of the processes, new operating conditions, plant conditions and emission requirements.

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