2013

Development and Application of an Innovative Dry Bed Ash Extraction System for Fluidized Bed Combustion Boilers

Lorenzo Lepore
Magaldi Power Spa, Italy

Alberto Carrea
Magaldi Power Spa, Italy

DEVELOPMENT AND APPLICATION OF AN INNOVATIVE DRY BED ASH EXTRACTION SYSTEM FOR FLUIDIZED BED COMBUSTION BOILERS

Lorenzo Lepore, Alberto Carrea
Magaldi Power Spa
Via Irno, 219 - 84135 Salerno (Italy)
T: +39 089 688223; F: +39 089 274431;
E: lorenzo.lepore@magaldi.com , alberto.carrea@gmail.com

ABSTRACT

The innovative Fluimac® system for Fluidized Bed Combustion Boilers allows the extraction and cooling of the Bed Ash; overcoming the main drawbacks of conventional system such as mechanical wear, maintenance cost and loss of ash heat content. The Ash is extracted and conveyed by the Superbelt® steel belt conveyor and cooled by the counter-flow air. A Fluimac® installation on the 340 MW_e Yeosu#2 Power Plant (South Korea) started its operation on July 2011 and confirmed expected targets.

INTRODUCTION

CFB (Circulating Fluidized Bed) Boilers utilize the fluidized bed principle in which crushed fuel and limestone are injected into the furnace or combustor. The particles are suspended in a stream of upwardly flowing air which enters the bottom of the furnace through air distribution nozzles. While combustion takes place at 840-900 °C, the fine particles are elutriated out of the furnace with flue gas velocity. The particles are then collected by the solids separators and circulated back into the furnace. The particles' circulation provides efficient heat transfer to the furnace walls and longer residence time for carbon and limestone utilization. This technology can handle a wide range of fuels. Thanks to combustion temperature lower than Pulverized Coal (PC) boilers, the oxidation of fuel nitrogen is reduced resulting in very low NOx emissions (1)

The ash resulting from fuel combustion needs to be removed in order to keep a proper height of ash bed on the bottom of the boiler. The ash from the bottom of the boiler takes the name of Bed Ash and is extracted through vertical pipes that start from the boiler bottom floor. The conventional methods to remove and cool the hot Bed Ash from Fluidized Bed Combustion (FBC) boilers undergo mechanical wear, leading to high maintenance costs, and loss of ash latent heat.

Magaldi's Fluimac® system for dry bed ash extraction from FBC boilers overcomes the drawbacks of conventional bed ash handling systems. The Fluimac® system's basic concept is to extract the hot ash continuously from the FBC boiler with the Superbelt® steel belt conveyor. The ash is cooled with ambient air that flows through the belt openings and through the ash bed laying on it, obtaining a regime of fixed bed heat exchange. The main characteristics of the Fluimac® system are the absence of wear, because there is no relative

motion between the Superbelt® and the ash transported on it and the recovery to the boiler of the latent heat contained in the ash bed, increasing boiler efficiency.

Emission reduction, energy saving, as well as water demand reduction, drove the upgrade of the Bed Ash System for the new FBC boiler at Yeosu Power Plant by applying the Magaldi Fluimac® system. On June 2011 the first application of the Fluimac® system for the Yeosu 340 MWe FBC boiler successfully started its operations. After 1 year of trouble-free continuous operation, the Fluimac® system has shown that the expected targets of high reliability, low O&M costs and heat recovery have been realized. This new Fluimac® technology is now available for large capacity CFB boilers.

CONVENTIONAL BED ASH EXTRACTION SYSTEM FOR CFB BOILER

Conventional Bed Ash extraction systems for CFB Boilers are screw coolers and stripper coolers.

Screw coolers include a screw extractor installed downstream of the boiler drain pipe: ash from the bed is drained into the screw whose flights, casing and shaft are cooled by softened water. The ash heat is taken by water whose temperature increase is in the range of 5-20°C. The main screw cooler drawbacks are:

- High wear due to relative displacement between the conveyor parts and abrasive material: Bed Ash is composed of sand, ash with high silicon oxide content and limestone;
- Low dependability: due to unplanned maintenance operations on screw coolers due to their unexpected failures or excessive wear, forced boiler shutdowns have been experienced on several boilers
- High water consumption and high cost for the water treatment system
- Heat transfer reduction during operation due to the accumulation of ash layers on the screw surface. The discharge temperature can increase with operation
- Energy losses: The ash sensible heat is transferred to cooling water at relatively low temperatures, therefore the energy cannot profitably be recovered.

Stripper coolers cool by fluidizing the ash which then follows a tortuous course allowing heat exchange with plates (often the plates are water cooled). Stripper cooler heat exchange is very efficient but this equipment is very sensitive to material particle size and in case of material plugging frequent shutdowns are necessary for cleaning. Frequent maintenance and forced boiler shutdown result in an extremely high operating cost.

FLUIMAC® WORKING CONCEPT

The Magaldi Fluimac® is a patented system for the dry handling of bed ash from Fluidized Bed Combustion (FBC) boilers. The Fluimac® extractors take bed ash at high temperature from the drain pipes performing a double function:

• Convey the ash to the downstream equipment.
• Cool the ash by the ambient air flowing in the system.

The heart of the Fluimac® extractor is the Magaldi Superbelt®. Superbelt® is a special belt made of a wire steel mesh above which the steel pans are located. The movement of the belt is obtained by means of the wire mesh which is in direct contact with the driving drum. The absence of any friction between any moving part of the belt or between the belt and ash helps keep the wear to negligible levels, so much that the expected life of the belt is more than 10 years. Its reliability is demonstrated by the evidence that the belt is able to continue to work even in case of breakage of several rings of the underlying wire mesh. Superbelt® technology is field proven in many applications with hot and abrasive material (eg. Bottom Ash of PC boilers, mines and foundries).

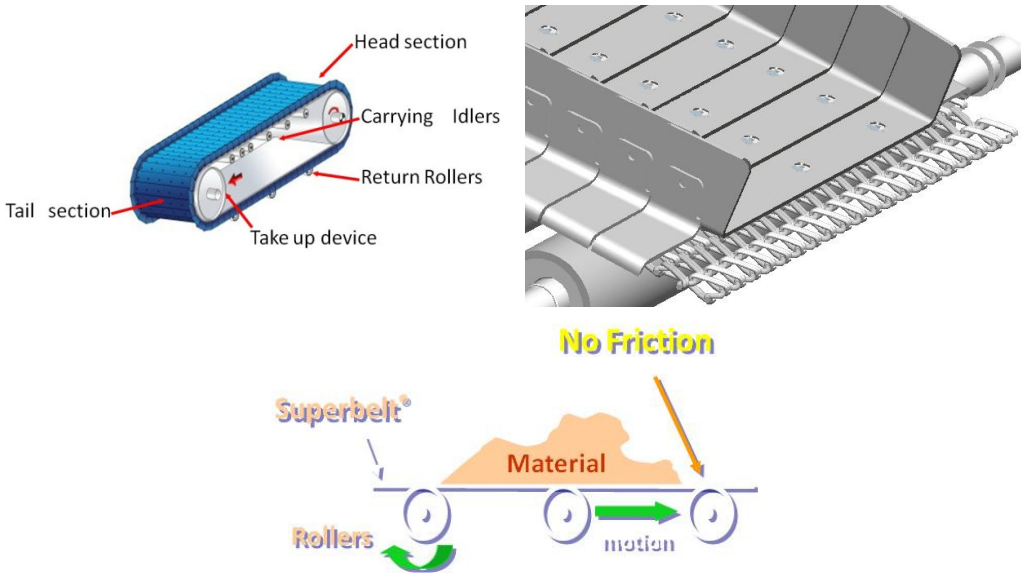

Figure 1: Superbelt® working concept

Magaldi Fluimac® is installed downstream the CFB boiler drain pipes: the ash is extracted smoothly by the Magaldi Superbelt® through a special distributing device located below each CFB boiler drain pipe. The ash rate is regulated by means of belt speed variation (provided by an inverter drive) assuring an accurate control of Boiler Bed material height. The Superbelt® runs inside the casing of the Fluimac® extractor, which is completely sealed. Inside the casing a negative pressure is maintained. The cooling medium is air. No water is required. A controlled amount of cooling air is drawn from the ambient air into the Fluimac® extractor through properly sized inlet valves located on the casing. Cooling air flows in countercurrent to the ash being conveyed and takes heat from the hot ash. Hot air out of the Fluimac® system can be delivered to the secondary air duct by a dedicated fan, allowing for consequent heat recovery to the boiler.

One of the advantages of CFB technology is that these boilers can burn a wide range of fuels. Fuel variation implies Bed Ash particle size variation (2) (e.g. petcoke causes ash plugging). Traditional B.A. handling system operation can be seriously affected by B.A. size variation: this can limits CFB boilers fuel flexibility. Thanks to its operating concept, Magaldi Fluimac® can handle B.A. of various size without problems.

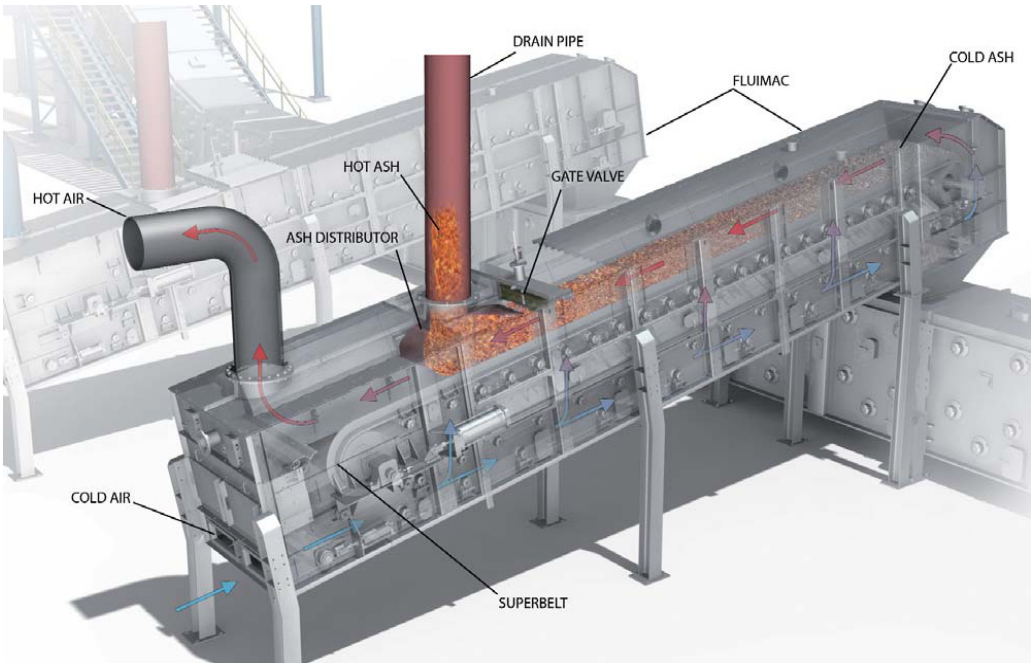

Figure 2: Fluimac® ash extraction and cooling

ASH COOLING

The following characteristics are required for the Bed Ash handling system:

1) capacity to extract and continuously convey the ash with maximum dependability level: each boiler forced shut down is extremely costly.
2) capacity to perform ash cooling to protect the downstream conveying system (e.g. pneumatic system) from high temperature.

Point 1 is assured by the Superbelt® working concept.
For point 2 an accurate evaluation of air/ash heat exchange is necessary for system design.
The main factors for heat exchange of the Bed Ash layer on the belt include:
- Forced convection with the air flow countercurrent on the Bed Layer
- Conduction between the layer of the ash and steel belt which in turn heats the cooling air operating like a regenerative heat exchanger
- Radiation of Bed Ash layer toward the conveyor casing.
- Belt radiation toward the conveyor casing
- Conveyor casing heat exchange with inner cooling air and with ambient

For the cooling simulation the conveyor is divided into wedges perpendicular to the conveying direction. For each wedge the heat exchange factors are considered. Due to the low ash heat exchange coefficient, for each wedge, the Bed Ash on conveyor casing is considered divided in different layers and heat exchange from layers of ash is considered. No temperature variation along the width of the belt is considered (two dimensional model).

The recent Yeosu#2 installation gives the possibility to test the ash cooling in the real operating condition. Test results allow tuning of the model calculation. Table 1 indicates the operating condition and the measured parameter:

Fluimac® in operation	1
Ash rate	2.4 t/h
Air rate	4.5 t/h
Air/ash ratio	1.85
Fluimac® Ash inlet temperature	750°C
Fluimac® Ash outlet temperature	260°C
Final ash temperature [1]	70°C
Air inlet temperature	4.5 t/h
Air outlet temperature	1.85

Table 1: Cooling Test on Yeosu#2 Fluimac®

Figure 3 shows model results after tuning with experimental results. Fluimac® Ash discharge temperature is still quite high. However the Secondary conveyor follows the same working concept of Fluimac® with it's high temperature and wear resistant Superbelt®. Further cooling is performed by the Secondary conveyor and Contact Cooler giving a discharge temperature that is lower than 70°C suitable for the downstream pneumatic system.

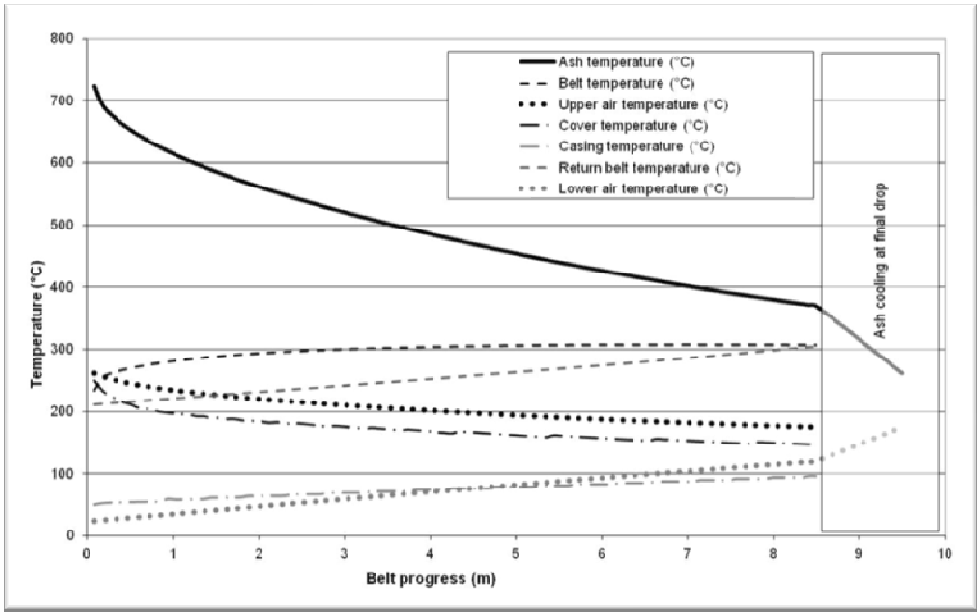

Figure 3: Ash cooling simulation results

HEAT RECOVERY

The Fluimac® system, unlike traditional systems, gives the possibility to recover ash heat: the air heated by the ash is delivered back to the boiler.
The potential heat that it is possible to recover from the ash is very high.
For example considering:
- ash rate =10 t/h
- ash specific heat = 0.8 kJ/kg°C
- Ash initial temperature = 750°C
- Ash final temperature = 100°C

[1] This value refers to the ash temperature at Fluimac system discharge after Secondary conveyor and Contact Cooler further cooling.

The potential heat from ash is approx 1.5 MW_t which, assuming boiler global efficiency of 0.4, equals approx. 600 kW_e.

To concretely perform the heat recovery it is possible to add the hot air from the Fluimac® to the Boiler Secondary air. The scheme indicated in Figure 4 shows a configuration where the hot air is delivered to the secondary air duct downstream the Flue gas heat exchanger.

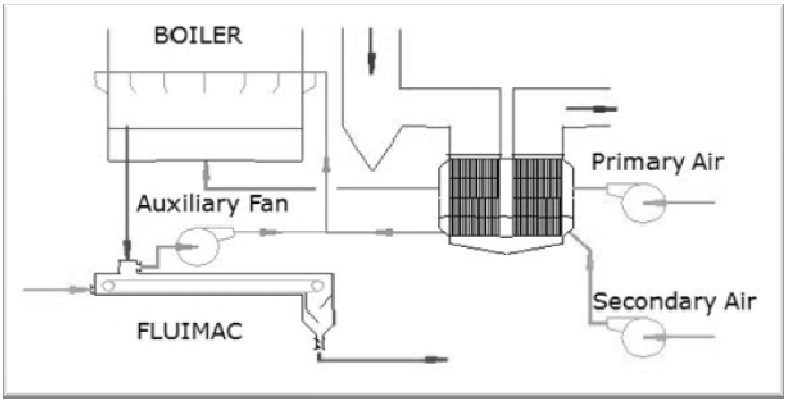

Figure 4: Yeosu#2 heat recovery scheme

CASE STUDY: YEOSU#2 340 MW CFB BOILER FLUIMAC® INSTALLATION

With its 340 MWe power Yeosu#2 is, at the moment, one of the biggest coal firing CFB boiler installations. Yeosu#2 Fluimac® system is designed for 11 t/h of ash during continuous operation and for 22 t/h of ash during emergency condition. The boiler has 4 drain pipes for Bed Ash extraction and for each drain pipe one Fluimac® Conveyor is installed. Fluimac® conveyors discharge the ash into a Secondary conveyor suitable for hot and abrasive material. At the Secondary conveyor discharge the ash is further cooled in a special device (Contact Cooler) The Contact Cooler is an ash/air heat exchanger whose purpose is to further reduce the ash temperature. The ash cooling is totally performed by means of ambient air. Dedicated fans draft the ambient air that flows inside conveyors and Contact Cooler, takes heat from the ash and it is delivered to boiler S.A. duct performing heat recovery.

On June 2011, the new KOSEP 340 MWe Power Plant of Yeosu (South Korea) started its operation. After approx. one and a half years of operation the "Fluimac® choice" is rewarded by:

- Safety and Dependable operations: no boiler stoppage due to Fluimac® System (100% of dependability)
- Minimum wear: all the conveyors were found to be in perfect condition during the inspection of September 2012: Magaldi Superbelt® confirms its special design and unique advantages.
- No water consumption (contrary to conventional solution like water cooled screw).
- Heat recovery of B.A. sensible heat to the boiler.
- Efficient ash cooling

Figure 5: Bed Ash conveyed by Superbelt®

CONCLUSION

CFB Boilers were introduced in 1980 and use of this technology is rapidly growing hanks to the advantages compared to PC boilers. Also capacity of CFB boiler installations is rapidly increasing to over 300 MW_e. This requires not only Boiler technology but also auxiliary system improvements. One of the critical auxiliary systems of a CFB boiler is the Bed Ash handling system suitable for hot and abrasive material. Continuous wear causes frequent maintenance with high cost. Moreover a failure of Bed Ash extraction system can cause a boiler forced shut down. Using the same field-proven technology used for PC boilers Bottom Ash technology, Magaldi developed Fluimac® technology.

The Fluimac® installation on Yeosu#2 (340 MWe) power plant confirms the expectation in terms of dependability, absence of conveyor wear and heat recovery. This technology is now mature and available for future CFB boiler installations.

ACKNOWLEDGMENT

Mario Magaldi, Fulvio Bassetti, Monica di Domenico, - Magaldi Power S.p.A.
Doosan Heavy Industries & Construction Co., Ltd.
KOSEP (Korean South East Power) Co. Ltd.
Paul Dodd (UK representative for Magaldi Power) - Bulk Handling Products

NOTATION

CFB: Circulating Fluidized Bed
FBC: Fluidized Bed Combustion
PC: Pulverized coal
B.A. : Bed Ash
S.A. : Secondary Air

REFERENCES

(1) S. Kavidass G.L. Anderson G.S. Norton, Jr. *"Why Build a Circulating Fluidized Bed Boiler to Generate Steam and Electric Power"* - POWER-GEN Asia 2000.

(2) John Kang, Ron Beverly, Dan Porter, JEA and Bill Leach, Imersy *"Reducing Ash Agglomeration in JEA's CFB Boilers"* October 1, 2012.
(3) C. Agresta, F. Oegema, R. Sorrenti "*Development and application of an innovative dry bed Ash extraction system for fluidized bed combustion Boilers"* 12th ICCS – November 2003