Analytical Study on ZT Collecting Electrode

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Abstract: Analytical study on ZT type collecting electrode (ZT electrode) is conducted from theoretical and practical aspects. For theoretical aspect, distribution of field strength on surface of ZT electrode is studied against that on surface of flat plate collecting electrode (plate electrode) for different type of discharge electrodes. ZT electrode is advantageous over plate electrode for less deviation in distribution of field strength on electrode surface such that ZT electrode is also to be advantageous over plate electrode for less deviation in secondary current distribution on electrode surface. Consequently, ZT electrode is advantageous over plate electrode for less rapping force required for the same collection area. For practical aspect, the influence on distribution of field strength on electrode surface due to misalignment of discharge electrode is studied for ZT electrode against plate electrode. The results indicate ZT electrode provides a robust collecting system to withstand field problems from erection and operation without compromising the collection performance in terms of evener distribution of field strength on electrode surface against plate electrode. Flow dynamic performance is also studied for ZT electrode against plate electrode. Results indicate that ZT electrode has advantage to prevent rapping re-entrainment due to the convergent-divergent or divergent-convergent configuration. In cooperation with less deviation in secondary current distribution, ZT electrode has considerable advantage over plate electrode for rapping re-entrainment.

Keywords: ZT collecting electrode, electrical field strength, rapping re-entrainment, stagnation zone.

1 INTRODUCTION

ZT type collecting electrode (ZT) has zig-zag contour making up symmetric and asymmetric passages as shown in Fig. 1. Discharge electrodes (DE) in both passages are differently arranged of with respect to ZT contour. This study investigates ZT against the flat plate collecting electrode (Flat) focusing on the electrical field strength distributed on collecting electrode surface and the correspondent rapping force per a simplified model.

This simplified model calculates the maximum, medium and minimum electrical field strengths on ZT surface at location a, b and c respectively. The electrical field strengths at the correspondent locations on Flat surface are then calculated for comparison. Both 300 mm and 400 mm passage spacing are studied with both barbed and slinky wire DE. Area 1 is the linear collection area between locations a and b while Area 2 is the rest of linear collection area for both ZT and Flat.

2 DISCHARGE ELECTRODE IN POSITION

Table 1A and 1B show the comparison of electrical field strength on ZT and Flat surfaces with DE at correct position per Figs. 1 and 2.

F_0 and F_1 respectively represent the minimum electrical field strength on ZT and Flat plate surface required to have sufficient dust collection.

Taking F_0 equal to F_1 reveals that the deviation in electrical field strength on Flat is so significant that the necessary rapping force for Flat will be 1.2 to 1.5 times (barbed wire at 300 mm spacing) over that for ZT. Thus, considerable rapping re-entrainment is expected for Flat with rapping force at such magnitude. Otherwise excessive dust deposition will occur on Flat surface due to inadequate rapping

Table 1A Comparison with Barbed Wire

ITEM	F_{max}	F_{med}	F_{min}	Area 1	Area 2
ZT 300mm	$1.184F_0$	$1.076F_0$	$1.0F_0$	47%	53%
Flat 300mm	$1.716F_1$	$1.431F_1$	$1.0F_1$	47%	53%
	$1.29F_0$	$1.076F_0$	$-0.75F_0$	47%	53%
ZT 400mm	$1.115F_0$	$1.061F_0$	$1.0F_0$	45%	55%
Flat 400mm	$1.374F_1$	$1.245F_1$	$1.0F_1$	45%	55%
	$1.171F_0$	$1.061F_0$	$-0.85F_0$	45%	55%

Table 1B Comparison with Slinky Wire

ITEM	F_{max}	F_{med}	F_{min}	Area 1	Area 2
ZT 300mm	$1.141F_0$	$1.026F_0$	$1.0F_0$	53%	47%
Flat 300mm	$1.604F_1$	$1.376F_1$	$1.0F_1$	53%	47%
	$1.166F_0$	$1.026F_0$	$-0.73F_0$	53%	47%
ZT 400mm	$1.128F_0$	$1.094F_0$	$1.0F_0$	42%	58%
Flat 400 mm	$1.329F_1$	$1.196F_1$	$1.0F_1$	42%	58%
	$1.215F_0$	$1.094F_0$	$-0.84F_0$	42%	58%

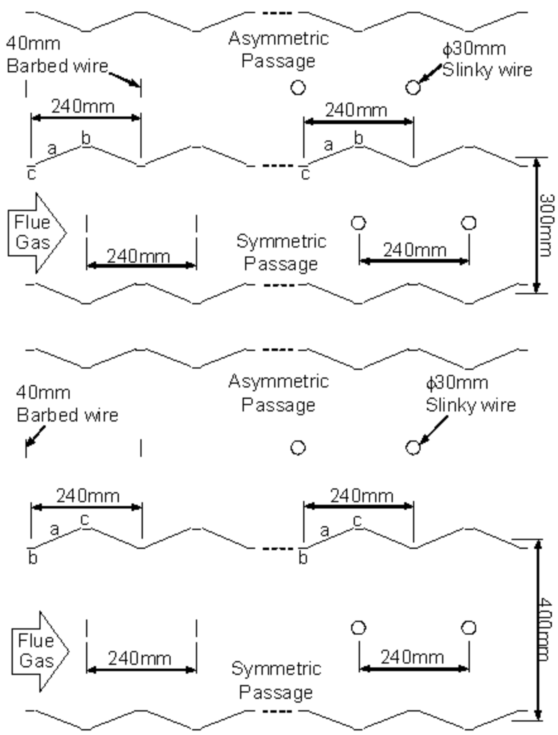

Fig. 1 ZT with Barbed and Slinky Wire

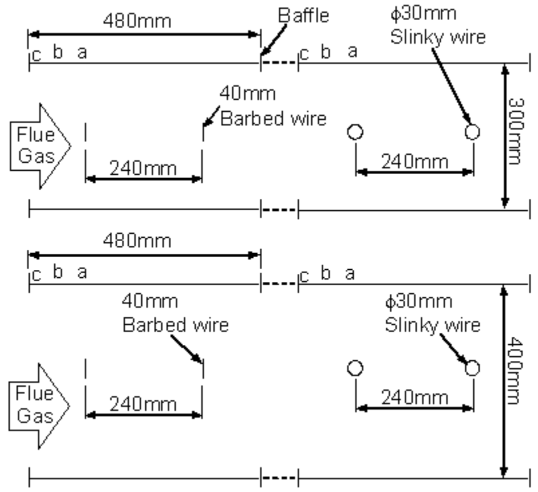

Fig. 2 Flat with Barbed and Slinky Wire

Taking electrical field strength at location b as the same for both ZT and Flat reveals about 15% to 27% reduction in electrical field strength at Area 2 on Flat. Therefore the dust collection efficiency of Flat will be significantly affected and rapping re-entrainment problem still exists because of such reduction in electrical field strength at Area 2.

3 DISCHARGE ELECTRODE OFFSET

Table 2A and 2B show the comparison of electrical field strength on ZT and Flat surfaces with DE misalignment for offset 15 mm and 20mm within passages at 300 mm and 400 mm duct spacing respectively per Figs. 3 and 4. It is to note that this study only deals with the condition with increased electrical field strength due to DE misalignment. Likewise, F_0 and F_1 respectively represent the minimum electrical field strength on ZT and Flat surface required to have sufficient dust collection.

Table 2A Comparison for offset Barbed Wire

ITEM	F_{max}	F_{med}	F_{min}	Area 1	Area 2
ZT 300mm	$1.263F_0$	$1.154F_0$	$1.0F_0$	42%	58%
Flat 300mm	$2.0F_1$	$1.7F_1$	$1.0F_1$	42%	58%
	$1.176F_0$	$1.154F_0$	$-0.6F_0$	42%	58%
ZT 400mm	$1.30F_0$	$1.162F_0$	$1.0F_0$	56%	44%
Flat 400mm	$1.473F_1$	$1.284F_1$	$1.0F_1$	56%	44%
	$1.333F_0$	$1.162F_0$	$-0.8F_0$	56%	44%

Table 2B Comparison for offset Slinky Wire

ITEM	F_{max}	F_{mid}	F_{min}	Area 1	Area 2
ZT 300mm	$1.179F_0$	$1.099F_0$	$1.0F_0$	49%	51%
Flat 300mm	$1.824F_1$	$1.495F_1$	$1.0F_1$	49%	51%
	$1.22F_0$	$1.099F_0$	$-0.7F_0$	49%	51%
ZT 400mm	$1.15F_0$	$1.066F_0$	$1.0F_0$	35%	65%
Flat 400mm	$1.411F_1$	$1.345F_1$	$1.0F_1$	35%	65%
	$1.118F_0$	$1.066F_0$	$-0.75F_0$	35%	65%

Taking F_0 equal to F_1 reveals that the significant deviation in electrical field strength on Flat for offset DE. The necessary rapping force for Flat will be 1.15 to 1.6 times (barbed wire at 300mm spacing) over that for ZT. Similarly considerable rapping re-entrainment is expected for Flat with rapping force at such magnitude or excessive dust will deposit on Flat surface due to inadequate rapping.

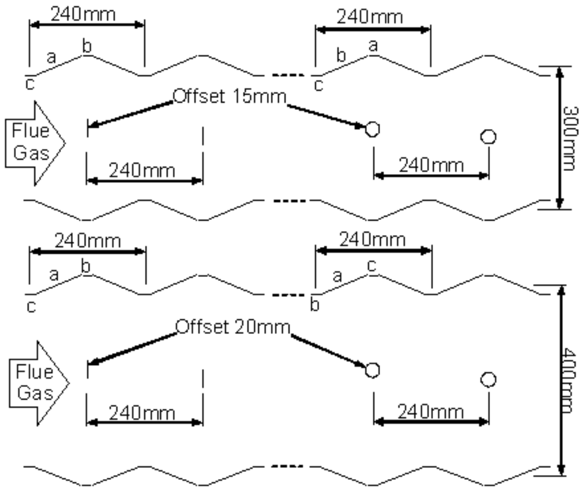

Fig. 3 ZT with Offset DE

Taking electrical field strength at location b as the same for both ZT and Flat reveals that 20% to 40% reduction in electrical field strength occurs at Area 2 on Flat. Such significant reduction in electrical field strength will substantially lower the dust collection efficiency of Flat Area 2 and consequently rapping re-entrainment will become ever severe.

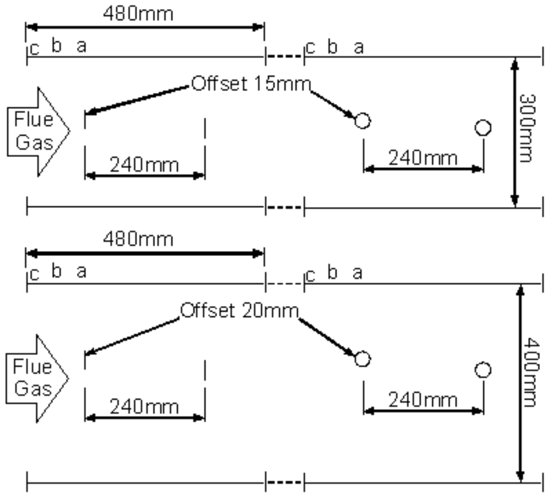

Fig. 4 Flat with Offset DE

It is to note that ZT and slinky wire DE result in the smallest increase in the maximum electrical field strength due to offset DE.

4 RAPPING RE-ENTRAINMENT

Table 1A, 1B 2A and 2B clearly indicate the advantage of ZT over Flat for the homogeneity of electrical field strength distributed on collecting electrode surface. This advantage becomes more obvious when offset DE is taken into consideration. ZT is also advantageous over Flat for the homogeneity in secondary current distribution when Area 1 and Area 2 are taken into account [1].

Hence ZT requires less rapping force determined by the maximum electrical field strength over collecting electrode surface compared with Flat. Consequently ZT is advantageous over Flat for less rapping re-entrainment that is mainly determined by the maximum magnitude of rapping force [2].

Further, ZT and slinky wire DE is a good combination for less rapping force required by the maximum electrical field strength on collecting electrode surface in conditions that DE is either in position or offset. The combination of ZT and slinky wire DE is a robust system from practical aspect of electrostatic precipitator (ESP) operation since DE offset is common for ESP in service.

5 FLOW DYNAMIC PERFORMANCE

Flat commonly uses a baffle at both inlet and outlet as shown in Figure 2 for producing a stagnation zone along collecting electrode surface in order to prevent the rapping re-entrainment. However, such baffle is known to have a limited effective downstream distance when the flue gas velocity is over a level [3]. Thus, rapping re-entrainment is the major contributor to poor collection performance of ESP.

ZT does not have a baffle. Huang's study [4] indicates that a flow separation occurs near the inlet of a divergent channel for turbulent flow when half angle of such divergent channel reaches 7.5 degrees. Hence, the divergent section of ZT with half divergent angle over 20 degrees provides a considerable stagnation zone for preventing the rapping re-entrainment along both divergent and convergent sections. A schematic diagram of stagnation zone along ZT surface is shown in Figure 5. The stagnation zone covers most of collecting area of ZT so as to effectively prevent the rapping re-entrainment.

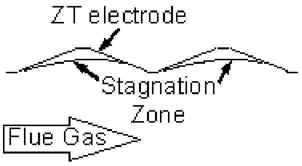

Fig. 5 Schematic Stagnation Zone along ZT

Huang's study also indicates in turbulent flow the particle deposition rate at channel wall is poor in a divergent channel with half angle of 7.5 degrees due to the increased migration distance as a result of divergent channel when the image charge force is under certain level. However, Sun's study [5] indicates that a convergent channel yields good particle deposition rate at channel wall due to the reduced migration distance as a result of convergent channel even when image charge force stays at a relatively low level.

Thus, it is understood that ZT utilizes the advantages of both convergent and divergent channels not only to further reduce the rapping re-entrainment but also to enhance the re-capture of re-entrained dust due to rapping. As for the asymmetric passage of ZT, it is understood that DE better be placed at inlet convergent section as shown in Figure 1 for better dust collection rate per Sun's study.

6 CONCLUSIONS AND SUGGESTIONS

The electrical field strength on both ZT and Flat electrode surface is studied with barbed and slinky wire DE in correct and offset conditions. The flow dynamic performance of ZT is also studied. The conclusion for ZT compared with Flat is summarized as follows:

[1] ZT has less deviation in the electrical field strength along collecting electrode surface.

[2] Thus ZT is believed to be advantageous for less deviation in the secondary current distribution along collecting electrode surface.

[3] ZT needs relatively less rapping force required by the maximum electrical field strength along collecting electrode surface.

[4] Consequently ZT produces relatively less rapping re-entrainment due to relatively less rapping force required.

[5] ZT is more robust than Flat against DE misalignment that is a common problem in ESP erection and operation.

[6] ZT has better flow dynamic performance per the divergent- convergent configuration so as to prevent the rapping re-entrainment.

[7] Convergent section of ZT facilitates the re-capture of

dust re-entrained due to rapping.

[8] Following suggestions are made according to the result of this study:

[9] Study of flow velocity distribution within a ZT passage to verify the stagnation zone.

[10] Study of secondary current distribution on ZT surface per different type of DE.

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