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Effect of guiding plates in the turning on the uniformity of airflow distribution in the SCR system

Sheng Liu

School of energy and power engineering, Xi'an Jiaotong University, Xi'an 710049, (CHINA)

E-mail: 564725115@qq.com

ABSTRACT

In a Selective Catalytic Reduction (SCR) system, the nonuniform distribution of flue gas leads to the low utilization efficiency of SCR catalysts, which leads to great economic losses. Therefore, it seems quite important to improve the airflow uniformity in a SCR reaction tower. In this research, the velocity distribution of airflow in gas flue was measured in a small-scale SCR system, and the effect of different guiding plates on the airflow uniformity was shown in isovelocity graphs and was tested by Root Mean Square (RMS) values for engineering application.

KEYWORDS

SCR;
Uniformity of airflow distribution;
Guiding plate;
RMS.

INTRODUCTION

Due to the increasing burning of fossil fuels in furnaces, boilers, and diesel engines, various environmental problems have influenced human health heavily[1,2], especially the photochemical smog resulting from NO and NO_2[3]. Therefore, the Selective Catalytic Reduction (SCR) technology has been widely used in coal boilers to promote the reduction of NO*x*, and the expensive catalysts used in the SCR system have drawn much attention of researchers in recent years[4,5]. However, in the SCR system, the nonuniform distribution of flue gas decreases the utilization efficiency of catalysts, which leads to great economic losses.

Therefore, much research has been performed to investigate the flow characteristics in burners and boilers. Fan et al.[6] studied the flow field characteristics of over fired air for novel low NO*x* pulverized coal combustion technology by experiments, and the deflection characteristics, the velocity and root mean square (RMS) fluctuation velocity of OFA jet were obtained. Li et al.[7] measured the flow characteristics in the near-burner region of a low-NO*x* axial swirl burner with the use of a three-dimensional particle-dynamics anemometer in conjunction with a gas/particle two-phase test facility, and obtained mean velocities, root mean square velocities and particle volume flux profiles. Zhou et al.[8] carried out experimental and numerical study on the aerodynamic field in a tangentially fired boiler model of a 600MW unit, with emphasis on the flow fields in upper furnace and the gas velocity nonuniformity in horizontal flue gas pass. Chen et al.[9-11] investigated the gas/particle flow characteristics of double swirl flow burners with different structures using a three-dimensional PDA. For the centrally fuel rich burner, the mean radial velocities and tangential velocities are low in central recirculation zone and a zone of high particle-volume flux and large particle size is formed. Also, most of bigger particles are resident near the chamber axis and the residence time is prolonged.

Although there has been much numerical investigation and experimental research on the velocity distribution of flue gas in coal boilers and burners, little attention has been paid to the effect of the structure parameters of guiding plates in the turning on the velocity distribution of the flue gas in a SCR system. In this research, a small-scale experimental system was built up to explore the velocity distribution of a SCR system. Moreover, different guiding plates has also been studied to determine the suitable arrangement methods.

EXPERIMENTAL

The experimental system

The experimental system is as shown in Figure 1, and it is designed according to the SCR system of a 600 MW supercritical coal-fired boiler as the scale of 1:0.375. The inlet height of the model is 4 m and the inlet width is 10 m, so the inlet size of the experimental system here is 150 mm*375 mm. The size of the SCR reactor is 12 m*10 m*20 m (depth*width*height), and so the experimental system here is 450 mm*375 mm*750 mm. Air was blown into the inlet flue by an air blower, and flew into the catalysis layers by passing through two turnings. To ensure the uniformity of the airflow entering the first turning, grids of the section size of 15 mm*15 mm and the length of 200 mm were installed 1.5 meters after the inlet.

In the research, the equivalent length *Le* was used to mark the length of the straight section related to a guiding plate, and *Le* was the ratio of the length of the straight section to the equivalent diameter of the gas flue.

Measurement

The measuring points are as shown in Figure 1. The measuring layer consisting 6*3 measuring points is arranged 200 mm after the first turning. The width of the gas flue is 375 mm, and there are 6 rows of measuring points in the width direction, so the distance between every two rows is 54 mm; the depth of the flue is 150 mm, and there are three rows of measuring points in the depth direction, so the distance between every two rows is 38 mm.

The velocity of the airflow passing through measuring points were measured by a Testo-416 vane anemometer, whose range is 0-20 m/s and accuracy is ±5% in the temperature range of -20-50 ^{o}C.

In this research, RMS value is adopted to evaluate the velocity distribution, and the calculation formula is

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{V_i - \bar{V}}{\bar{V}}\right)^2} \quad (1)$$

where n is the number of measuring points, V_i is the velocity of the airflow passing through the measuring

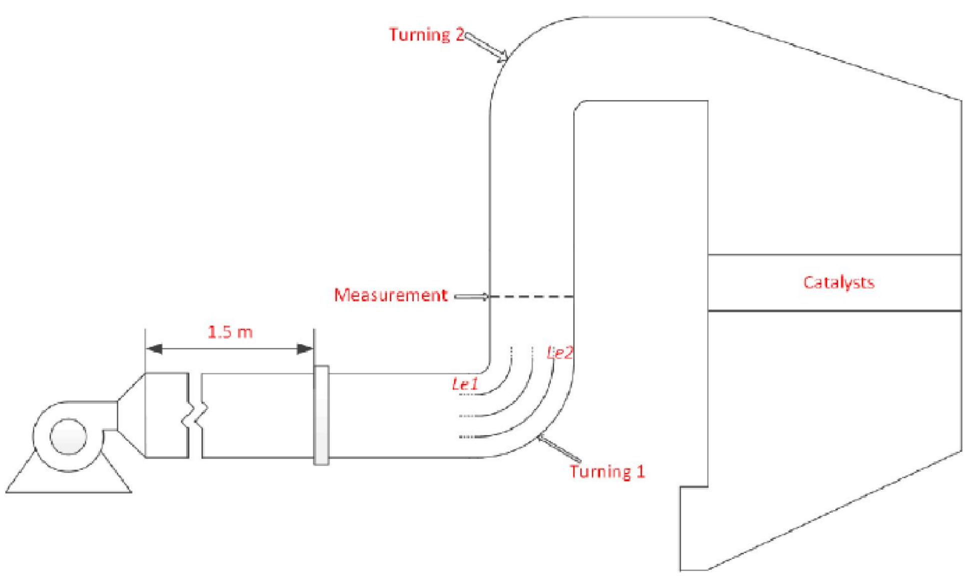

Figure 1 : The illustration the experimental system

point *i*, $\bar{V}$ is the mean velocity of the airflow.

RESULTS AND DISCUSSIONS

Effect of different amount of guiding plates

Different amounts of guiding plates with *Le1*=0 and *Le2*=0 were installed in the first turning, and the velocity distribution was shown in Figure 2. When there was not a guiding plate in the turning, the velocity of the second measuring layer was in the range of 2 m/s to 20 m/s, and it was extremely nonuniform. If one guiding plate was installed, the velocity range reduced to 4 m/s to 17 m/s; while if the amount of guiding plates increased to 2, the velocity range was 6.5-15.5 m/s. From them we could see, as the increase of the amount of guiding plates, the velocity distribution became more and more uniform. The result of installing three guiding plates verified the trend.

The velocity of 18 measuring points on the measuring layer was calculated to obtain the RMS value for every condition. It could be seen from Figure 3 that when there was 0 or 1 guiding plate in the turning, the RMS value was much higher than the standard of engineering application. The condition of installing two guiding plates was improved greatly, and three guiding plates helped to reduce the RMS value to 0.10, which was 78.9% lower than that of the condition without guiding plates. From the overall trend, installing guiding plates in turnings is very necessary, since it could significantly improve the flow distribution uniformity in the outlet of the turning, and increasing the number of the guiding plates could further improve the effects.

Effect of *Le2*

Three guiding plates were installed in the first

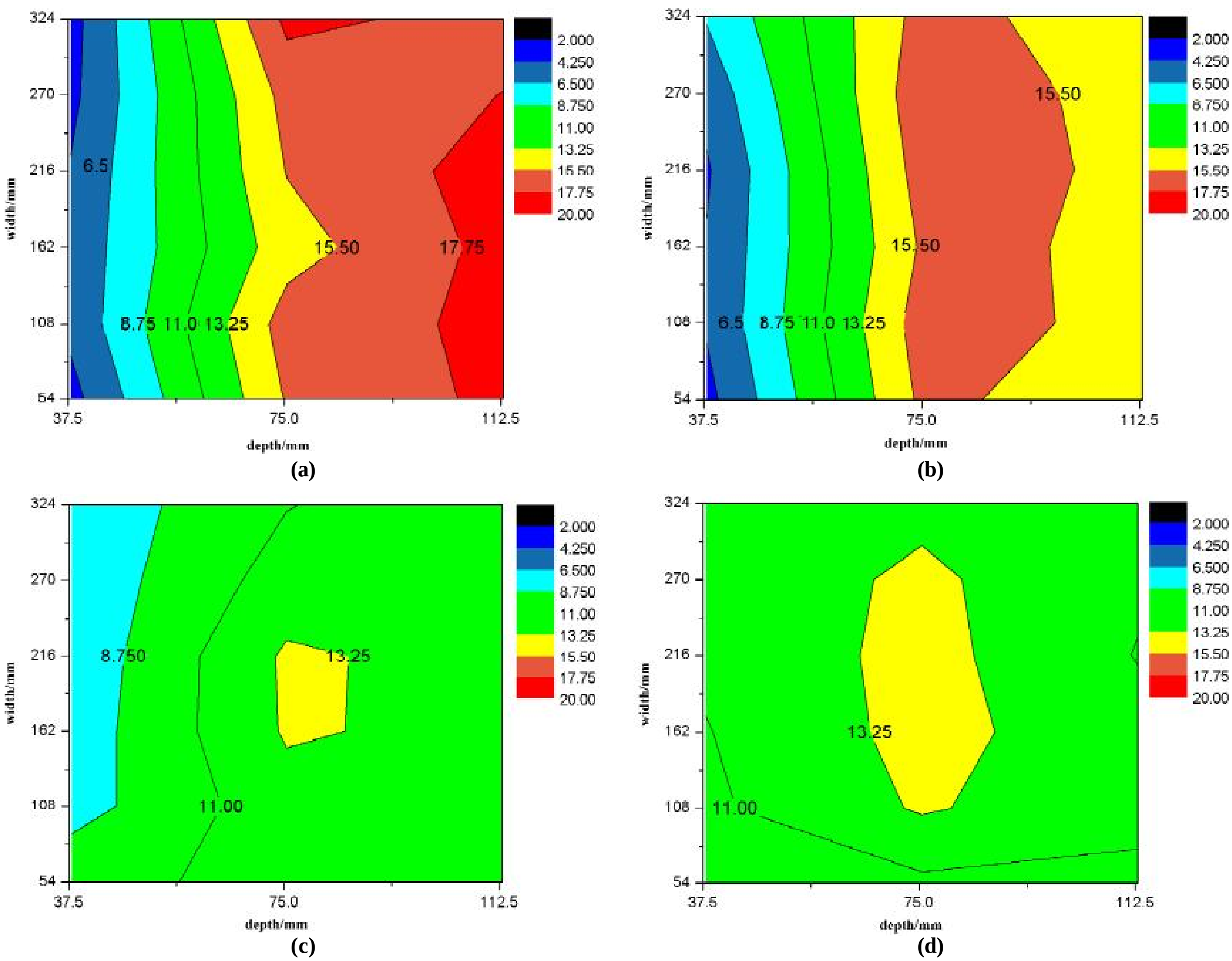

Figure 2 : Isovelocity graphs of different amount of guiding plates in the turning (a) 0 guiding plate; (b) 1 guiding plate; (c) 2 guiding plates; (d) 3 guiding plates

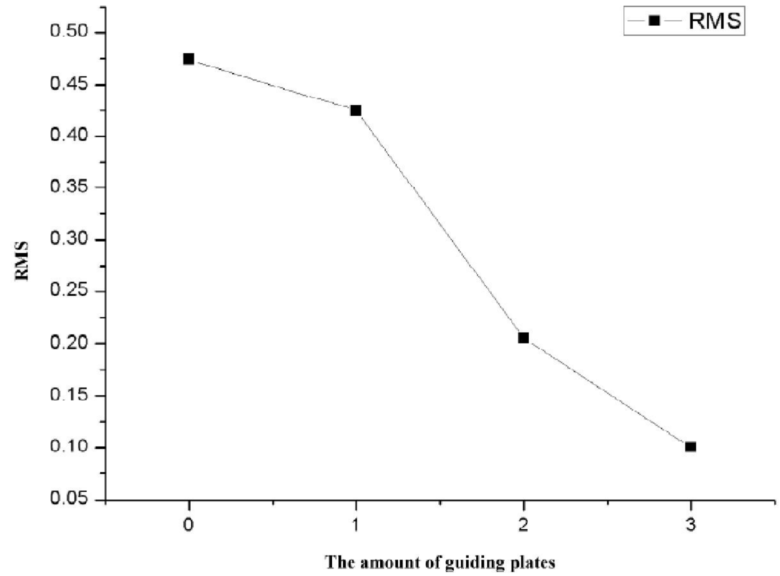

Figure 3 : RMS values of different amount of guiding plates in the turning

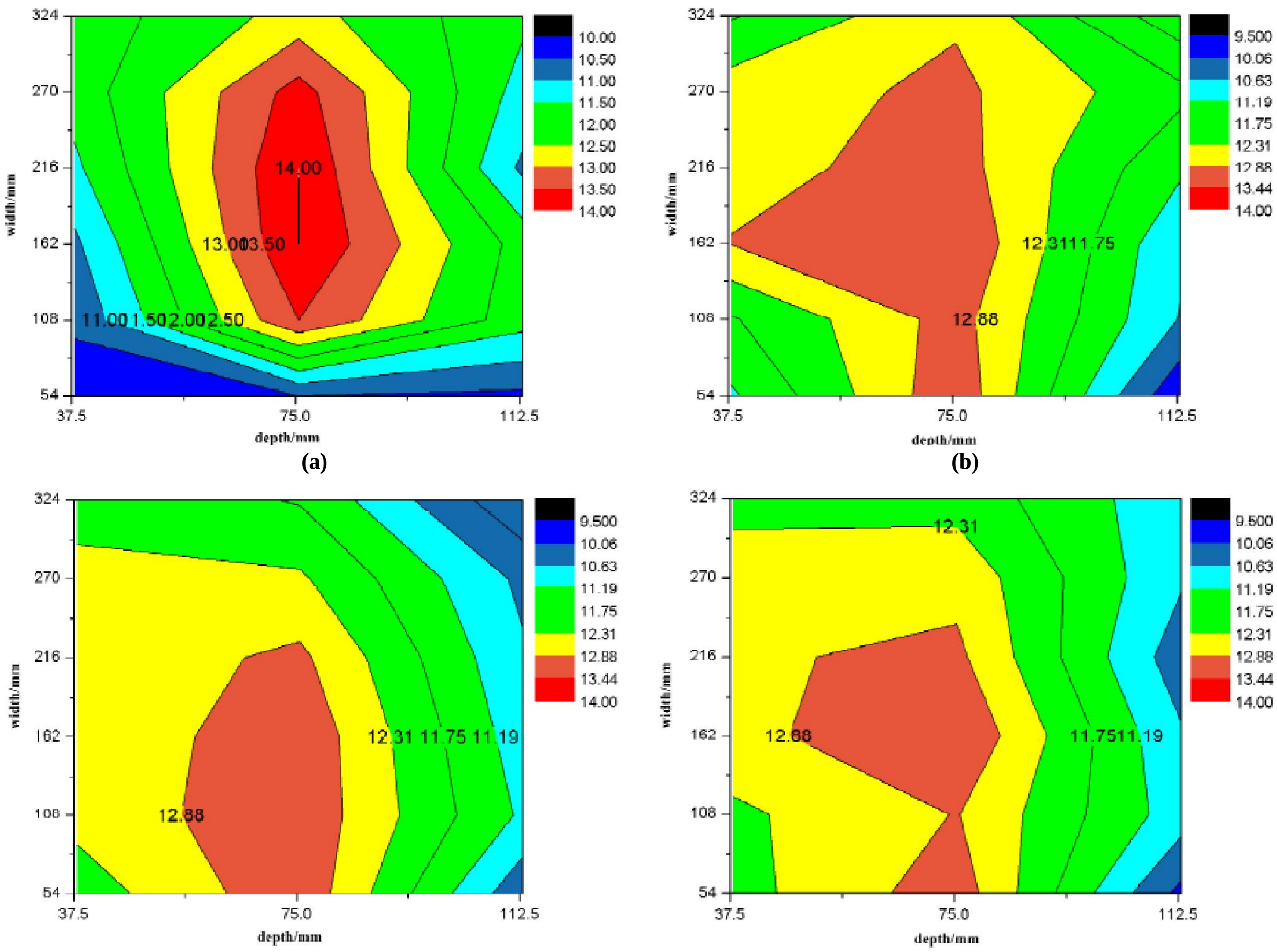

Figure 4 : Isovelocity graphs of *Le2* of guiding plates in the turning (a) *Le2*=0; (b) *Le2*=0.1; (c) *Le2*=0.2; (d) *Le2*=0.3

turning, and *Le2* was separately 0, 0.1, 0.2 and 0.3. The three plates divided the gas flue into four prismatic parts equally, and the isovelocity graphs were shown in Figure 4. Under the condition of *Le2* being 0, the highest velocity on the second measuring layer was 14 m/s, and the lowest was 10 m/s. When

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Le2 increased, the highest velocity reduced to about 13 m/s, and the area of the lowest velocity decreased more or less, which showed that the straight sections had positive effects on the velocity distribution.

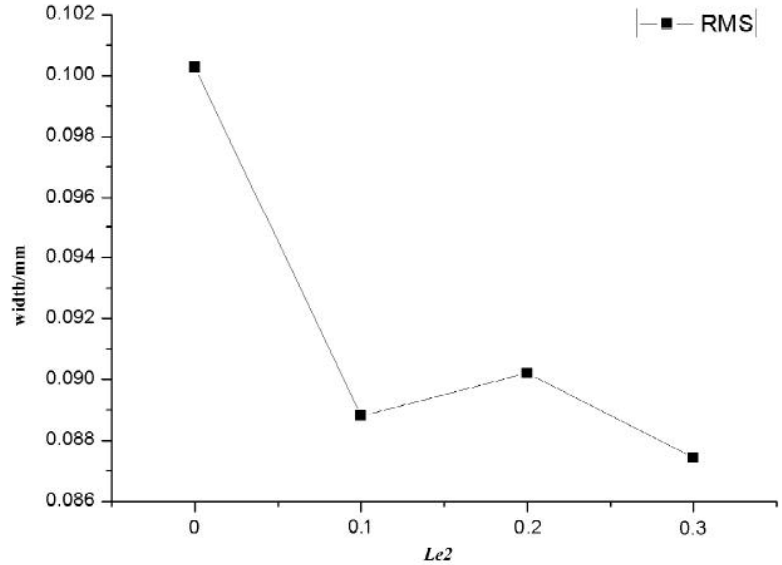

Figure 5 : RMS values of *Le2* of guiding plates in the turning

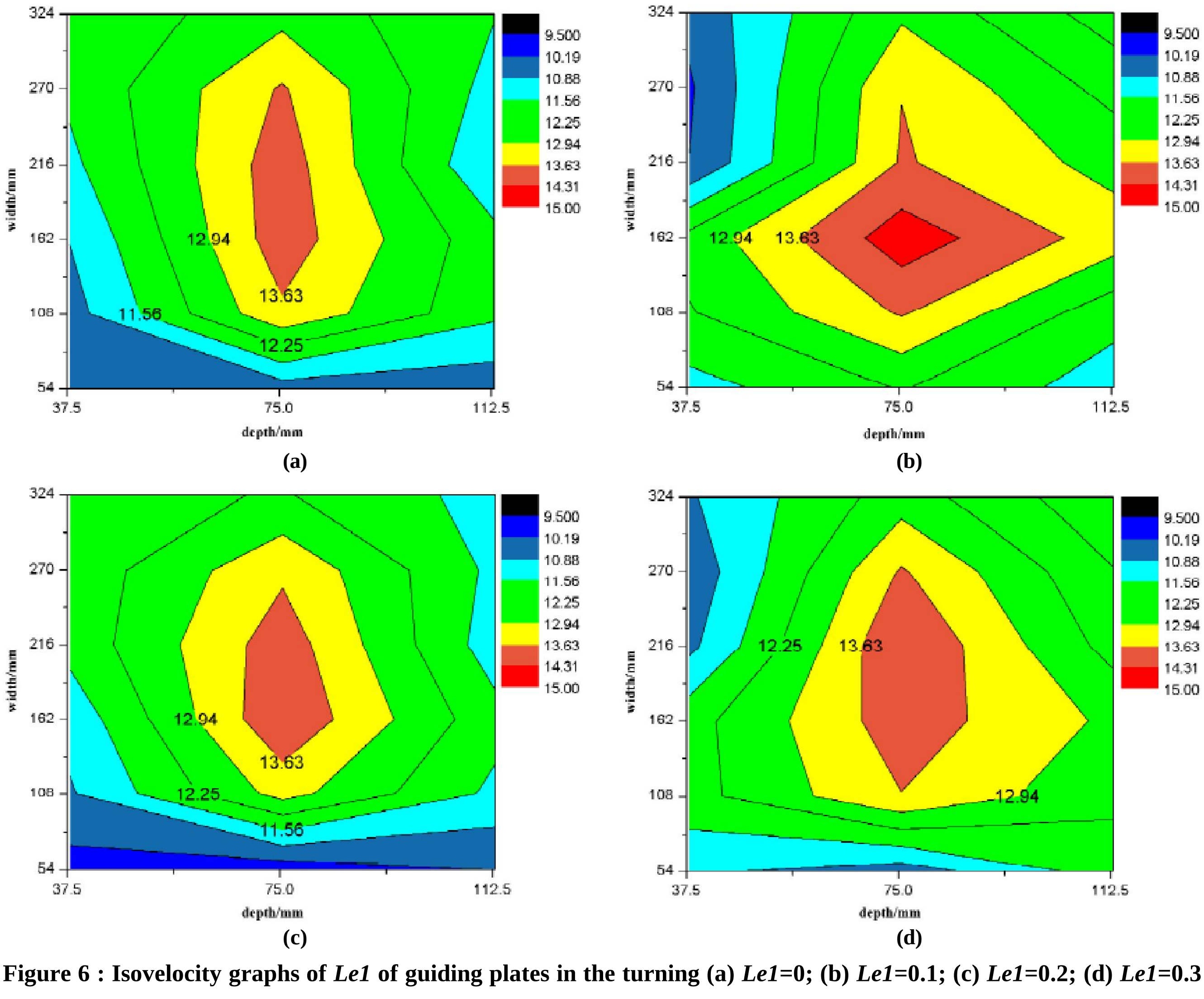

Figure 6 : Isovelocity graphs of *Le1* of guiding plates in the turning (a) *Le1*=0; (b) *Le1*=0.1; (c) *Le1*=0.2; (d) *Le1*=0.3

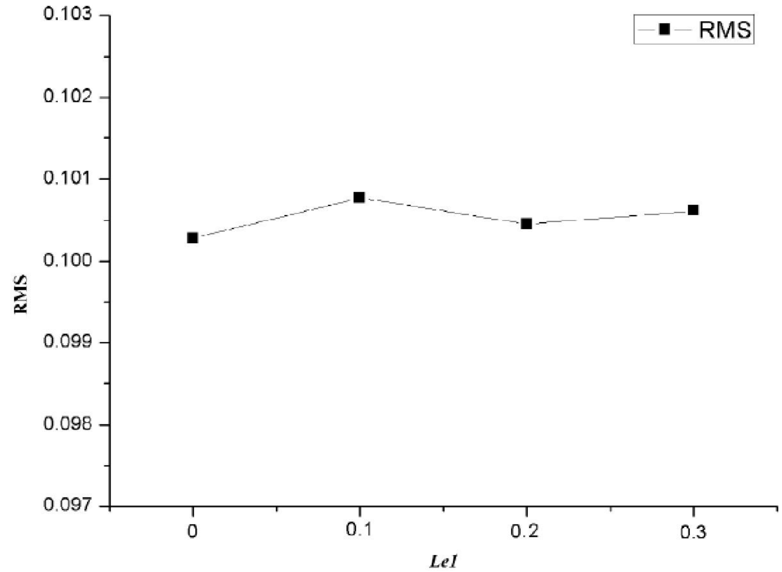

Figure 7 : RMS values of *Le1* of guiding plates in the turning

To analyze the effect of *Le2* further, we calculated the velocity data of the 18 measuring points and obtained the RMS value of each condition (Figure 5). It could be seen that the RMS value decreased greatly as straight sections were installed. Compared with the RMS value under the condition of *Le2* being 0.1, the RMS value under the condition of *Le2* being 0 was 12.9% higher, while that under the condition of *Le2* being 0.2 was 1.6% higher and that under the condition of *Le2* being 0.3 was 1.6% lower. The RMS value under the conditions of *Le2* being 0.1, 0.2 or 0.3 was low enough to meet the need of engineering, and the difference between them was not great.

Effect of *Le1*

To investigate the effects of *Le1*, three guiding plates were installed in the turning, and *Le1* was separately 0, 0.1, 0.2 and 0.3. The three plates divided the gas flue into four equal parts, and the isovelocity graphs were shown in Figure 6. As we could see, there was not much difference between the four conditions, and the velocity was in the range of 9.5 m/s to 15 m/s. under the condition of no straight sections installed, the area of high velocity distribution was relatively small, but the area of low velocity distribution was relatively large. Equipped with imported straight sections, the area of high velocity increased, but the low velocity took up less area. Therefore, no conclusion could be obtained directly from the graphs of the cold tests, further analysis was processed to get the RMS value.

From Figure 7 it could be seen that when straight sections were installed in the inlet of guiding plats the RMS value increased a little, which means that the velocity distribution became nonuniform. Moreover, when *Le1* increased from 0.1 to 0.3, the value fluctuated and all were higher than than that of *Le1* being 0. The RMS value under the condition of *Le1* being 0.1 was 0.5% higher than that under the condition of *Le1* being 0, and the RMS value under the condition of *Le1* being 0.2 was 0.3% lower than that under the condition of *Le1* being 0.1. By comparing all the RMS values, we could find that the RMS values under different conditions were 1% relatively different. From the results above, it is not recommended to install straight sections into the inlet of guiding plates.

CONCLUSIONS

Different amount of guiding plates were installed in the first turning. When there was 0 or 1 guiding plate in the turning, the RMS value was much higher than the standard of engineering application. The condition of installing two guiding plates was improved greatly, and three guiding plates helped to reduce the RMS value to 0.10. From it we could see, as the increase of the amount of guiding plates, the velocity distribution became more and more uniform. Therefore, installing guiding plates in turnings is very necessary, since it could significantly improve the flow distribution uniformity in the outlet of the turning, and increasing the number of the guiding plates could further improve the effect.

In the turning, installing straight sections to the outlet of guiding plates could improve the velocity distribution, but the length of the straight section did not have much effect on the uniformity. However, installing straight sections to the inlet of guiding plates could not improve the velocity distribution, so it is not recommended to install straight sections into the inlet of guiding plates.

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