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TRIGONOMETRIC STUDY FOR BOF LANCE TIP ANGLES WITH MULTI JETS

Abstract

In the present work, an analysis of geometric parameters of tip nozzles in operation was developed and extrapolations for futures situations were proposed. The main trigonometric relationships to evaluate the possibility of jet coalescence were determined. The results showed that the Primary Circle Diameter (PCD) is not affected only by the geometry of the nozzle, tips with 04 (four) nozzles and small angle with the vertical can promote coalescence and tips with more nozzles than four reduce this possibility. This work also presents a relationship between number of nozzles and angle between two adjacent nozzles. An important tool to determining conditions for development of new tips lance is proposed

Keywords:

BOF, tip lance, angle between adjacent nozzles, PCD, coalescence; angle nozzles with vertical, number nozzles.

1. Introduction

The operational conditions in BOF blow process to optimization of reactions depend the correct sizing of the tip lance responsible for the transfer of oxygen at supersonic speeds. For a multiple jet structure, Smith [1] presents a figure 1, which describes the flow field for a single jet of a nozzle with several nozzles for cases with 5 ° and 10 ° of inclination with respect to the center.

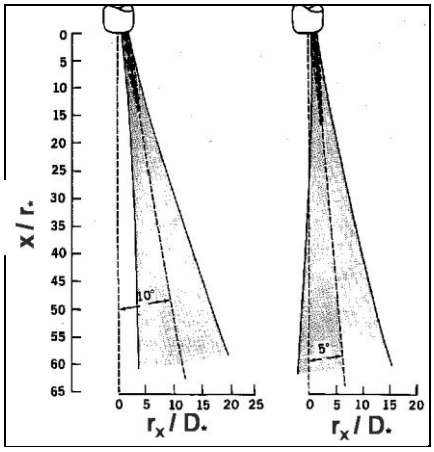

Figure 1: Comparison between jet slopes [1]

The nozzle exit center are approximately a center line diameter the lance this being a typical layout of many lances of 3 nozzles in operation. For 10° or bigger inclinations, the jet internal contour runs parallel with the centerline of the boom and the jets do not intersect. For the 5th case, the internal contour of the jet intersects with the centerline of the boom near 30 diameters below and the edge of the jets would intersect after reaching this point. This crossing is known as "coalescence of jets". Similar effect occurs as a function of the pressure in the stagnant reservoir, as shown in figure 2, by the jet impact diagram.

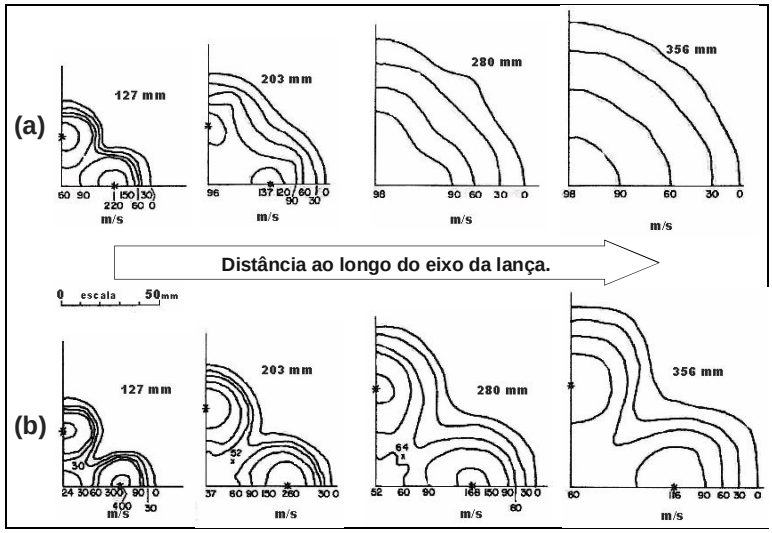

Figure 2: Impact diagram for all distances From the axis of the lance to the lance of 04 nozzles being: (a) 7,24x105 Pa e (b) 10,69x105 Pa [2]

The degree of coalescence increases with the drop in stagnant pressure. For higher pressures there is no complete coalescence and always some incidence of the four original jets

remains. Lee et al. [2] explain the phenomenon of jet coalescence by taking a view on the Y-Y direction plane, shown in Figure 3.

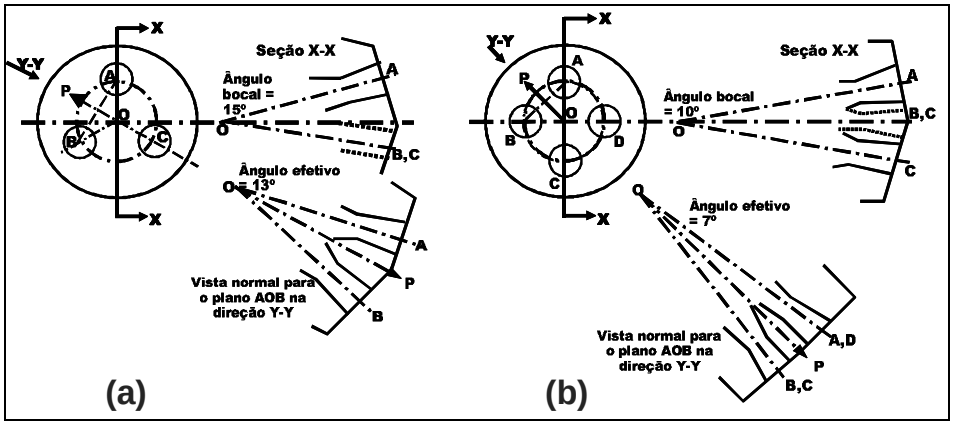

Figure 3: Effective angle between adjacent nozzles for: a) 03 nozzles and b) 04 nozzles [2]

The figure 3 show that the angle between axis of the nozzles is 26° for lance of 3 nozzles and 14° for lance with 4 nozzles. Thus, in this plane the effectives semi-angles (Spreading angles) are 13° and 7°, being smaller than the respective angles between the nozzles and the axis of the boom. The jet will interfere with other jet if your contour finds some other to long the OP line, the bisectrix the angle between axis nozzles. For lances with 3 nozzles, the jet contours diverge from one another in angle of +5,5° (13°-7,5°). With lances of 4 nozzles, this divergent angle is **–** 0,5 (7,0° -7,5°), meaning the negative sign that the jet-out effect should be somewhere along the OP line.

It is important the suction effect between adjacent jets that sucks the secondary air for the volume limits evaluated at the center of the boom. For this case, coalescence is by definition caused by the fusion of the jets, in premature stages, determining the most severe degrees of coalescence, with suction being only an effect (3-4). The present work has the objective of analyzing the relationship between multi jets nozzle angles of the current converters and proposing options for the future.

2. Methods and Materials

For this study, has compared multi nozzles tip of converters with production capacity between 30 the 330 tons scattered around the world.

In multi nozzles tip, has compared the influences: angle the nozzles with the vertical, angle between nozzles in relation the horizontal, angle divergent cone the nozzles, angle with relation the vertical of adjacent nozzles and PCD (primary circle diameter), as show the figure 4 above.

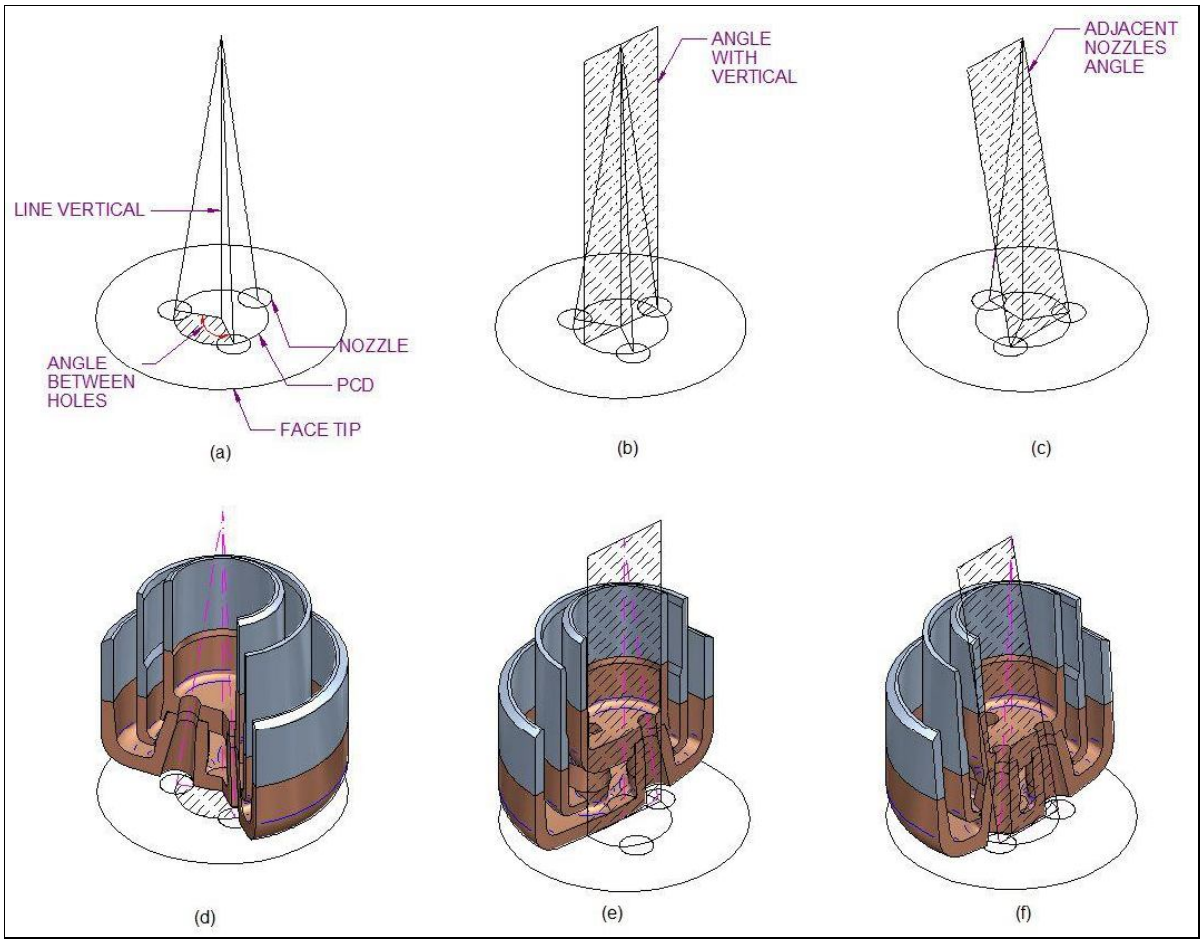

Figure 4: Existents angles in tips multi nozzles

Where: a) Represent the vertical line, angle between nozzles, tip face, PCD (primary circle diameter), nozzle, b) Represents the angle with vertical, c) Represents adjacent nozzles angle, d) Represents cut angle between nozzles, e) Represents cut vertical angle, f) Represents cut adjacent nozzles angle.

3. Results and Discussions

The nozzles number determines, inside the primitive circle diameter (PCD), an angle between nozzles with horizontal. This angle has influence in between adjacent nozzles angle and vertical angle. The figure 5 show the relation between nozzles number and tips angles operating in converter around the world and too an extrapolation of number of nozzles and angles.

In figure 5 (a), the axis "x" show the number nozzles and the axis "y" the between adjacent nozzles angle and the angle with vertical. It is possible to verify that same nozzles number there are different angles with vertical, but when is added the nozzles number is added too, the vertical angle. Inverse behavior occurs with between adjacent nozzles angle the have higher values and may contribute to the jet coalescence effect. Tips with 6 nozzles, are a special and peculiar case, because due the formation in relation the tip center and two adjacent nozzles, equilateral triangles are formed giving equal angles between the vertical and adjacent nozzles. After the tips of 06 nozzles, the vertical angles become higher than the adjacent angle, eliminating the possibility of coalescence due to the geometry. In function of the

existing designs, the correlation between angle with the vertical and adjacent nozzles was not significant.

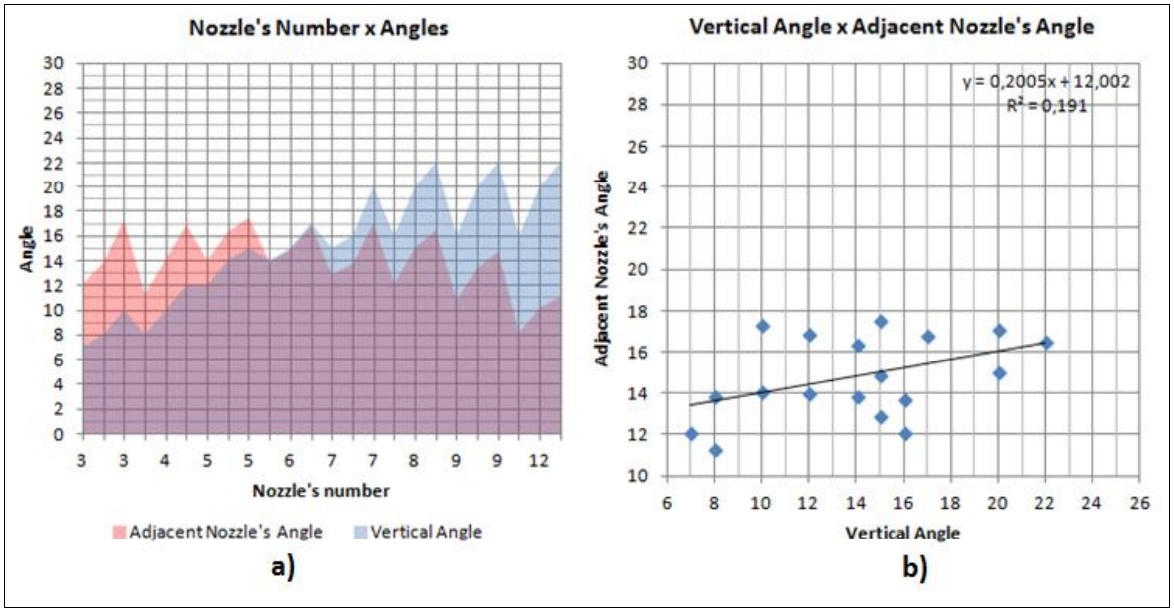

Figure 5: Lance tip in operation around the world and new designs

Where: a) Represent the relation between number nozzles and angles. b) Represent the relation between vertical angle and angle between adjacent nozzles.

The figure 6 shows typical nozzle configurations in the plants and extrapolations.

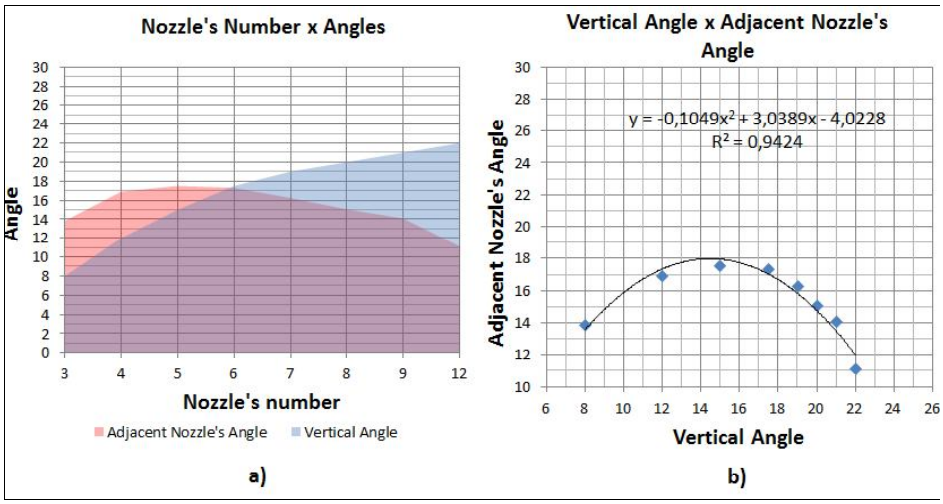

Figure 6: Typical tips and news designs

Where: a) Represent the relation between number nozzles and angles. b) Represent the relation between vertical angle and angle between adjacent nozzles.

It is important to verify again, the geometrical peculiarity the tip with 6 nozzles, having the same vertical inclination with angle between adjacent nozzles. Nozzles below 06 nozzles have angle with vertical less than the angle between adjacent nozzles and potentially the possibility of jet coalescing occur. Nozzles above 06 nozzles have inverse behavior, eliminating the possibility of jet coalescence even though they are hypothetical cases, since in fact there are no such configurations in operation in the converters.

With the selection of typical configurations by number of nozzles, it is possible to note the parabolic behavior with a good correlation between the nozzle angle with the vertical and the angle between adjacent nozzles. The values were extrapolated to the value of 22º, while the current practice of the converters is in the angle of 17º, considering 0.5º of variation.

The figure 7 show the comportment fixing the vertical angle with nozzles in 17 degrees.

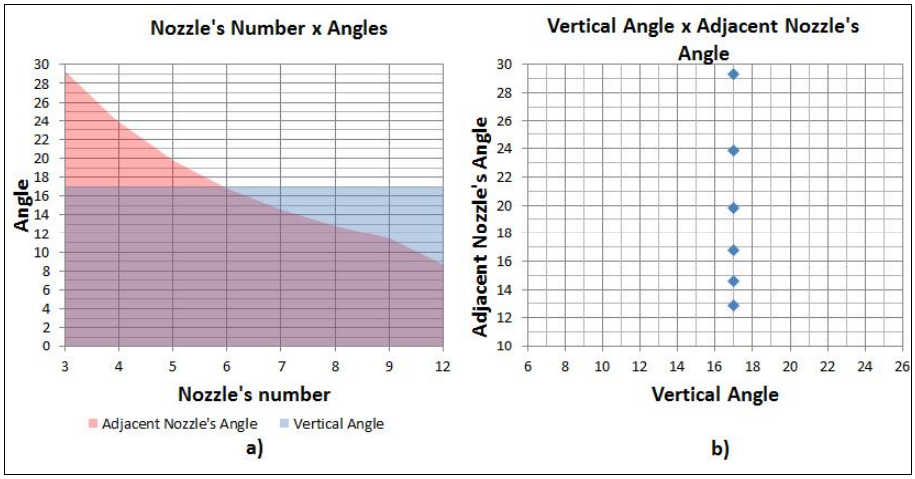

Figure 7: Tips 17 degrees with the vertical

Where: a) Represent the relation between number nozzles and angles. b) Represent the relation between vertical angle and angle between adjacent nozzles.

In figure 7 fixing the vertical angle in 17 degrees and varying the nozzle number the angle behavior between adjacent nozzles remains the same, but thus allowing the possibility of jet coalescence larger with the smaller number of nozzles.

The figure 8 show the influence the primitive circle diameter (PCD) for tip conditions with 6 nozzles and angles with vertical in 17 degrees.

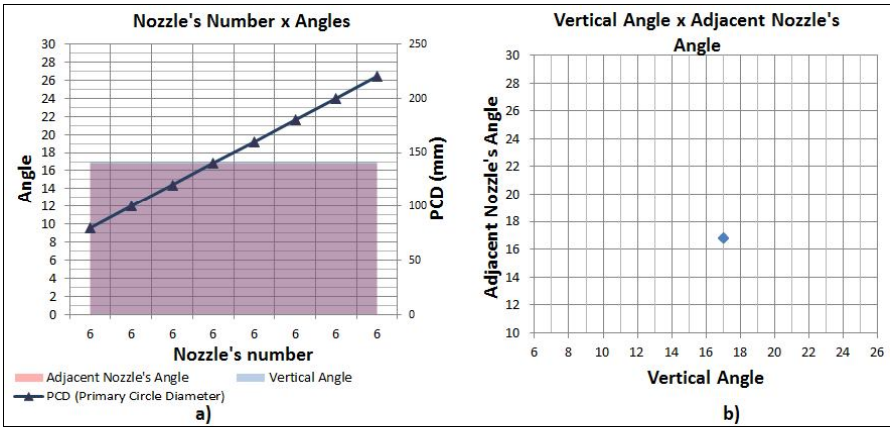

Figure 8: Tip 6 nozzles 17degrees with vertical

Where: a) Represent the relation between number nozzles PCD and angles. b) Represent the relation between vertical angle and angle between adjacent nozzles.

In figure 8 is possible to verify that the PCD have not influence about the angle with vertical and angle between adjacent nozzles, but in function the divergent nozzle exit angle can influence in jet coalescence, because until now, was not verified the effect the divergent nozzle exit angle. Can be verified in figure 8 the peculiarity of tip with 6 nozzles, which presents the same angle between vertical and angles between adjacent nozzles.

The figure 9 introduce the angles dispositions between adjacent nozzles, angles between nozzle in tip face , angle with vertical and primary circle diameter (PCD) for the condition of tip with 6 nozzle and angle of 17,5 degrees with vertical.

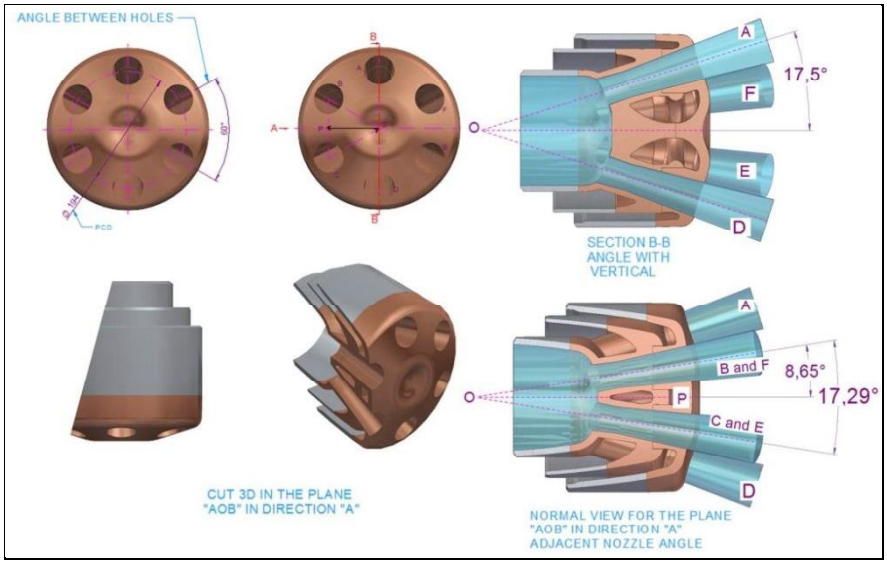

Figure 9 Tip with 6 nozzles with the vertical

It may be noted that in this plane this effectives semi-angles are 17,5 degrees, being greater than the respective angles between the nozzles and the axis lance which are 8,65 degrees. Thus, the effect of coalescence is avoided, as shown in figure 10.

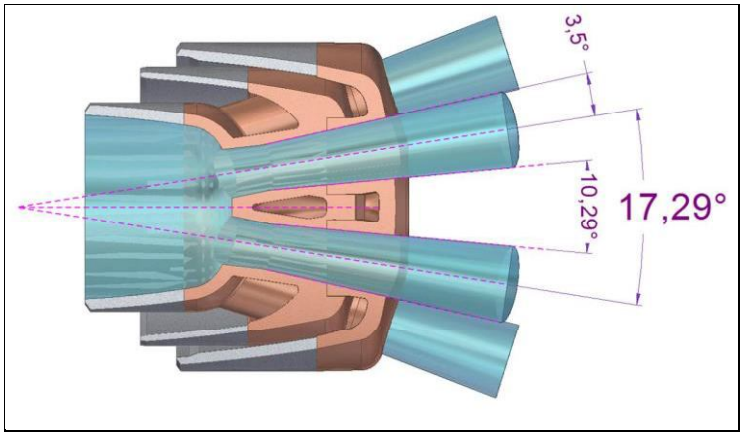

Figure 10 Tip without show coalescence effect

The figure 11 exhibit the graphic that show the influence the primary circle diameter (PCD) for jet coalescence of a tip with 3 nozzles and 8 degrees with vertical.

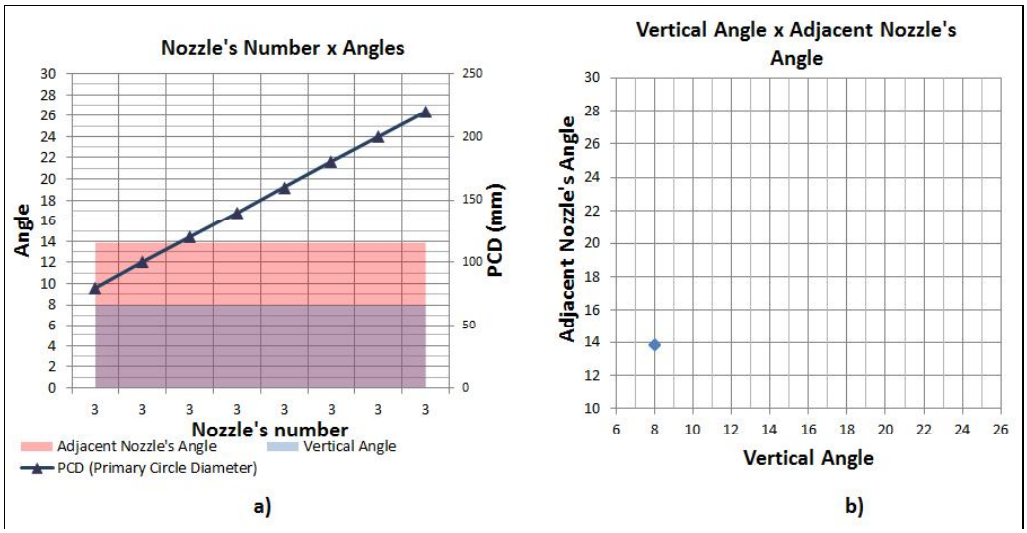

Figure 11 Tip 3 nozzles

Where: a) Represent the relation between number nozzles, PCD and angles with vertical. b) Represent the relation between vertical angle and angle between adjacent nozzles.

In figure 11 shows that independent of dimension the PCD, the angle between adjacent nozzles remains the same and the value is higher than the nozzle angle with respect to vertical, and the effect of jet coalescence may occur.

As an example in figure 12, was utilized a tip 3 nozzles in operation at industry. The angles with vertical are 10 degrees and the divergent nozzle exit angle of 22 degrees. It may be noted that the angle between adjacent nozzles is higher than the angle with the vertical, then the effect of jet coalescence occurred, as shown in the figure 13 below.

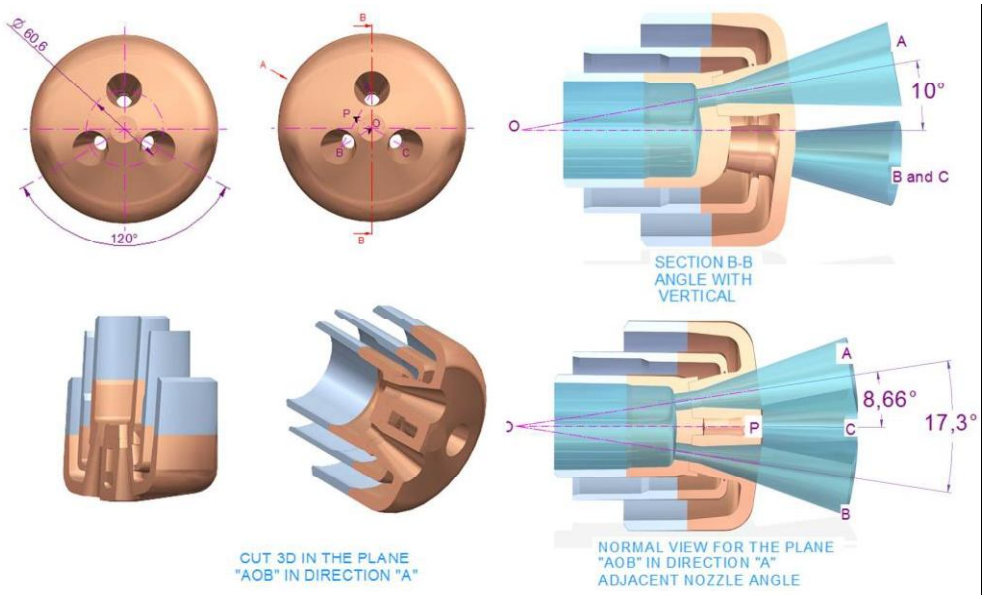

Figure 12 Tip 3 nozzles 10 degrees with vertical

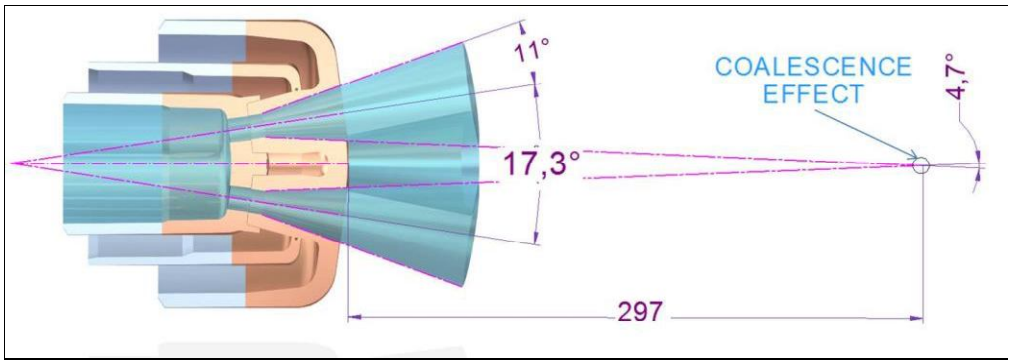

Figure 13 Verification of jet coalescence to nozzle with 3 nozzles 10 degrees with vertical.

In order to verify the influence of the divergent exit angle on the effect of coalescence, the values were collected of tips in operation. The result is shown in figure 14.

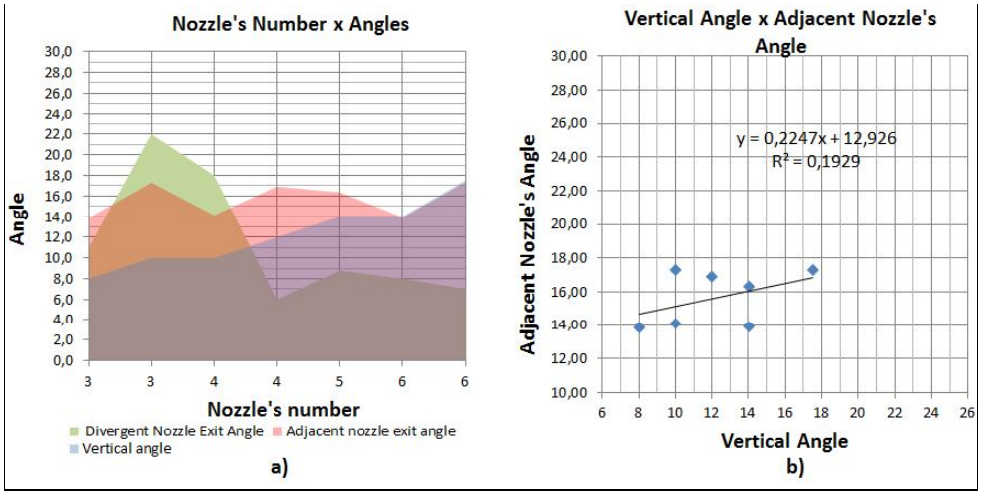

Figure 14 Tips in operation all the world

Where: a) Represent the relation between number nozzles, angles with vertical and divergent nozzle exit angle. b) Represent the relation between vertical angle and angle between adjacent nozzles.

In Figure 16 it can be observed that nozzles between 3 and 4 nozzles have divergent exit angles between 14 degrees and 22 degrees and can present jet coalescence. Nozzles with more than 5 nozzles present the maximum value of 14 degrees of divergent exit angle. The combination of the adjacent nozzle angles with the divergent outlet angle is one of the determinants for jet coalescence, as shown in figure 15.

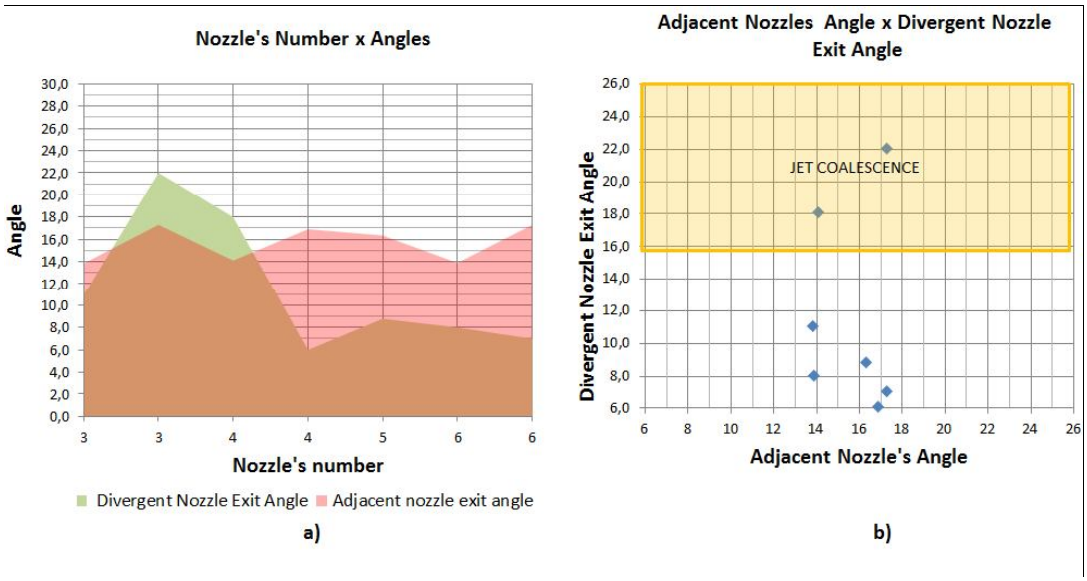

Figure 15 Tips in operation all the world

Where: a) Represent the relation between number nozzles, angle between adjacent nozzles divergent nozzle exit angle. b) Represent the correlation angle between adjacent nozzles and divergent nozzle exit angle.

Figure 15 shows that there is no correlation between the angles, but it shows that nozzles, when the angles of the divergent outlet are greater than the angle between adjacent nozzles, will promote jets that will undergo the effects of coalescence.

It should be noted that the nozzle geometry is influenced by other parameters, notably the pressure of the stagnant reservoir, the higher its value, the greater the tendency to reduce the divergent outlet angle. There is the influence of the furnace environment at high temperatures as well as the combustion and post-combustion reactions that occur during the blow [5-6], as well as the jet velocity, and these matters are not deepened in this study. In the same way that the angle of divergent outlet of the nozzle is strongly influenced by the flow desired by each melt shop as well as the need to promote the necessary cooling of the nozzle. These topics were not the subject of this study, focusing only on the trigonometric characteristics of the nozzles.

4. Conclusions

The main conclusions of the study were:

1. The Primitive Circle Diameter (PCD) not have influence in coalescence effect;
2. The combination the angles of adjacent nozzles with divergent nozzle exit angle and vertical angles are crucial for coalescence jet;
3. The greater the angle of divergent outlet nozzle, the higher the possibility of When angle between two adjacent nozzle exceeder the vertical angle will occur the coalescence;
4. Tips studied until 4 nozzles, when combined with smaller vertical angle and larger divergent nozzle exit angle may occur coalescence;
5. Tips studied above 5 nozzles, the coalescence effect get more difficult to occur

Acknowledgments

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