

## Uniformity of Two-phase Flow Distribution in Curved Round Distributor

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**Abstract.** Distributor plays a major role on uniformity of the fluid flow distribution through multiple channels, particularly in two phase flow. Uniformity and low pressure drop are the major issue which shall be solved. This study emphasized on the shape of branching points for two phase flow distributor to minimize mal-uniformity and pressure drop. The present distributor, the merge pipe distributor was developed to curved round distributor models with three types of reducer namely; curve reducer, T-reducer and straight reducer. The work was done thru investigating the performance of merge pipe distributor and comparing it to the performance of developed distributors. The analyses were performed through CFD modeling by using Fluent@ software, the two dimensional approach and high superficial velocity. It was founded that, the merged pipe distributor has tended to lack uniformity of phase distribution and slightly lower pressure drop than curved reducer distributor. While the curve round distributor models with T-reducer has exhibited better performance due to smaller pressure drop and optimum phase uniformity.

**Keywords:** two-phase flow, distributor, uniformity, reducer.

### 1. Introduction

The lack of two-phase flow uniformity on the distributor is a major problem especially in the multiple channels. If the mal-distribution occurred, the performance of heat exchangers and other industrial devices tend to decreases. In order to achieve even distribution, several works have been done and developed since constructal theory for fluid flow was constructed by Bejan [13], adopted from natural phenomenon. The fluid flow path between one point and a finite-size volume (an infinite number of points) is optimized by minimizing the over all flow resistance when the flow rate and the duct volume are fixed. The optimizing step begin from the smallest block which have array of small duct to bigger block which have bigger ones and continue toward bigger block ones. Optimizing couldn't be done inversely.

Based on constructal theory, such distributors design and model had been derived. The early was ramified fluid distributor by Tondeur et al. [11]. Lou et al. [10] optimized multi-scale structures of distributors which dichotomic tree configuration. Lou et al. [9] had coupled constructal distributors/collectors with a mini cross flow heat exchanger (MCHE) to solve the problem of flow mal-distribution. Fan et al. [8] proved that blocking one or two outlets of one branch will generally decrease the uniformity of the flow distribution.

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Miguel [5] developed constructal equation of dendritic structures distributor for fluid flow both Laminar and turbulent. Vascular design of constructal structures with low flow resistance and non-uniformity was designed by Cho et al. [6]. Ramos-Alvarado et al. [3] investigated constructal flow distributor as a bipolar plate for proton exchange membrane fuel cells. The uniformity in flow distributors having novel flow channel bifurcation structures has been studied by Liu et al. [4].

Almost of all foregoing studies have not involved two-phase flow in particular, whereas is not a few systems involve it, as in evaporator and condenser. The uniformity of phase distribution in them is absolutely urgent. If the phase distribution is uneven then the performance of it will decrease significantly, moreover in a T-junction bifurcation, where the gas phase tends to occupy the upper space while the liquid occupy lower channel space. T-junction bifurcation must be designed accurately to prevent phase separation and to minimize pressure drop, it will be supported by this work which is still little researcher studying on it.

Al-Rawashdeh et al. [2] had designed and tested the barrier-type distributor for two-phase flow. His work was intended to mix gas and liquid flows at the entrance of each of the parallel channels uniformly, before enter distributor. Accordingly, it was only be implemented in the chemical process reactor. In the evaporator and condenser, the phase was complicated to maintain and control. Therefore, it must be gained the breakthrough to maintain uniformly of phase throughout the channels downstream of distributor. There isn't an easy matter since two-phase flow pattern vary uncertainly.

Aziz et al. [1] have conducted a research by designing merge pipe distributor with lower-upper parallel row configuration of channels bifurcation tested horizontally, incline and vertically. The experiments were done by various gas and liquid superficial velocity. They concluded that the uniformity phase distribution is increase parallel to increasing superficial velocity of gas and or liquid. Likely, at high superficial velocity the phase pattern develops to annular flow in which easily divided evenly. There is the remaining problem which has not been solved yet mal-uniformity on low superficial velocity on both gas and liquid phase. Here is very important to develop other forms of distributors to overcome the problems.

The objects of present study are to investigate mal-uniformity of phase distribution in merge pipe distributor, to design new distributors enhancing uniformity and to analyse their performances as well as to find the best design.

## 2. Design and Analysis

### 2.1. Design

Three types of distributor are developed in this study, namely curved round distributor with; curve distributor reducer, T-reducer and straight reducer, Figure 1. The development was inspired by the extending research of multiple structural bifurcation channel based on constructal theory, Bejan [13] which solely leads to organizing structural of bifurcation. There are few researchers who focus on the shape of branching points which greatly affects the non uniformity of phase in the downstream of the distributor.

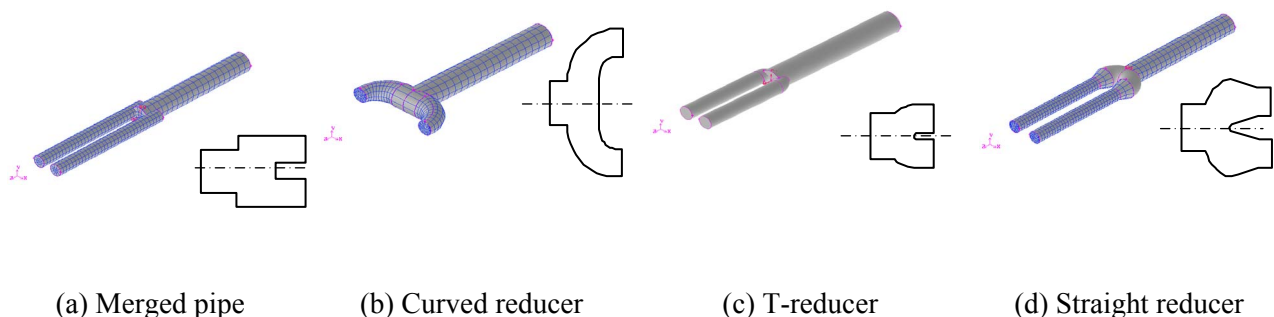


Fig. 1: Types of distributor

The study was begun from analyzing mal-uniformity of phase distribution along merge pipe distributor, in which it was simplified to two dimensional on centre plane devising distributor two part symmetrically, Figure 2. The trend of flow characteristic on the main channel cap was similar to characteristic of flow over rectangular aerofoil, Mannini et al. [7], as sown on Figure 3. Despite the both of Figure 2 and 3 are different

flow condition, in which the first is internal flow and the others are external flow, but the stream line is tend to similar. The similarity assumption has been done on analyzing compressor blade aerodynamically, Gresh [12]. As sown on Figure 2, that the stream line change from symmetrically into asymmetrically by a little increasing rake angle  $\alpha$  (equal to increasing angle of entrance velocity vector). It can be deduced that the stream line around symmetrical body is strongly influenced by entrance velocity angle. Similarly, if the velocity vector angle reaching main channel cap surface is fully parallel, the flow will be divided to upper and lower channel equally. Unfortunately, it is easy for single phase flow not for two-phase flow. Both of fluids in two-phase flow have different density and velocity as wall as phase distribution. The velocity vector of each fluid varies along channel. However, division of phase around lower and upper channel tend to uniform in annular and disperse flow pattern since the phase distribution spread quit evenly along channel and the stagnation area on the cap surface promotes to rearranging phase uniformity. Even though uniformity could be enhance by increasing stagnation area, the sharp edge of cap surface promotes stream line separation in which spoil phase uniformity. Accordingly, the phase uniformity shall be enhanced by appending stagnation area and curvature shape along distributor aerodynamically as aerofoil profile.

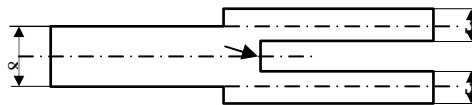


Fig. 2: Two dimensional merged pipe distributor

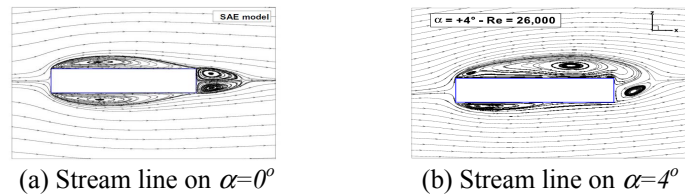


Fig. 3: Flow around rectangular aerofoil, Mannini et al.[8].

The last three of designed distributors was varied by large, narrow and moderate of stagnation area respectively. The study was performed through CFD modelling by using Fluent<sup>®</sup> software, the 2d approach for iterating efficiency and high superficial velocity as well as merge pipe distributor as base line. The performance parameters which have been investigated were distribution of; phase, velocity and pressure through distributor. The boundary conditions are; superficial velocity of water inlet and air inlet are  $U_L = 1\text{ m/sec}$ ,  $U_G = 10\text{ m/sec}$  respectively and both pressure outlet,  $P_o = 100\text{ Pa}$ .

## 2.2. Analysis

All distributors are mostly occupied by air, Figure 4, while the water occupy in near wall area, because phase supply to distributor is mostly vapour. The curve reducer distributor type exhibit the highest uniformity followed by T-reducer, straight reducer and merged pipe respectively. The uniformity level is characterized by maintaining of annular flow pattern with thin water layer around wall, the pipe circumference. This underlines that increasing stagnation area drives phase rearranging further preserve annular flow pattern and uniformity distribution. Unfortunately, almost of all of fluid particle passing through stagnation area is decelerated reducing the outlet phase velocity. Consequently, the most of fluid particle on curved reducer distributor convert their kinetic energy to pressure energy. This produces problem while the distributor connected to channels of heat exchanger or others.

Conversely, the minimum stagnation area keeps phase velocity on high level so as the highest phase velocity is on T-reducer distributor followed by straight reducer, merged pipe and curved reducer, respectively, Figure 5. The converted kinetic energy to pressure energy is proportional to velocity difference along distributor as well as channel. While T-reducer distributor performance tends to have better performance, but if the model is expanded to the three dimensional analysis, the performance shall drop due to significantly additional stagnation area.

The attractive velocity distribution is depicted on merge pipe distributor, in which the phase velocity upper channel is higher than lower channel and the stream line separated on both upper and lower edge of main channel cap. Perhaps, the distinction of phase velocity is caused by buoyancy effect and sharp edge cap resulting separation. The separation promotes turbulence and vortex.

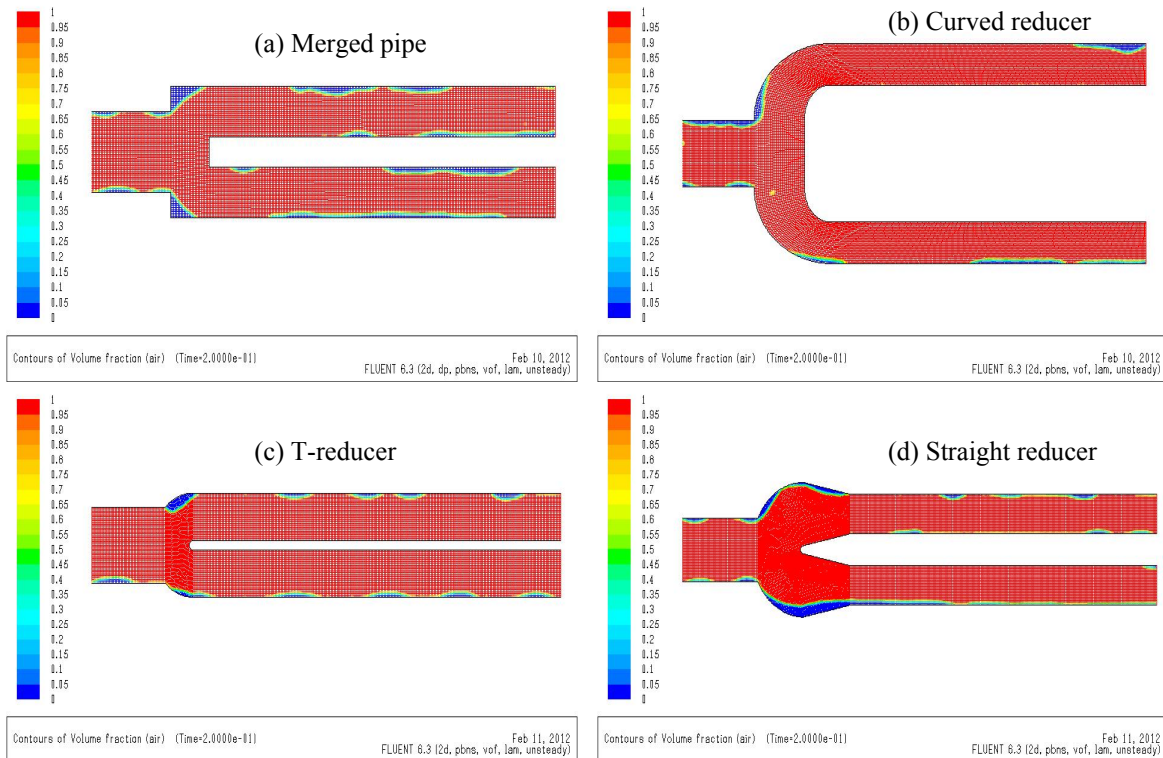


Fig. 4: Phase distribution.

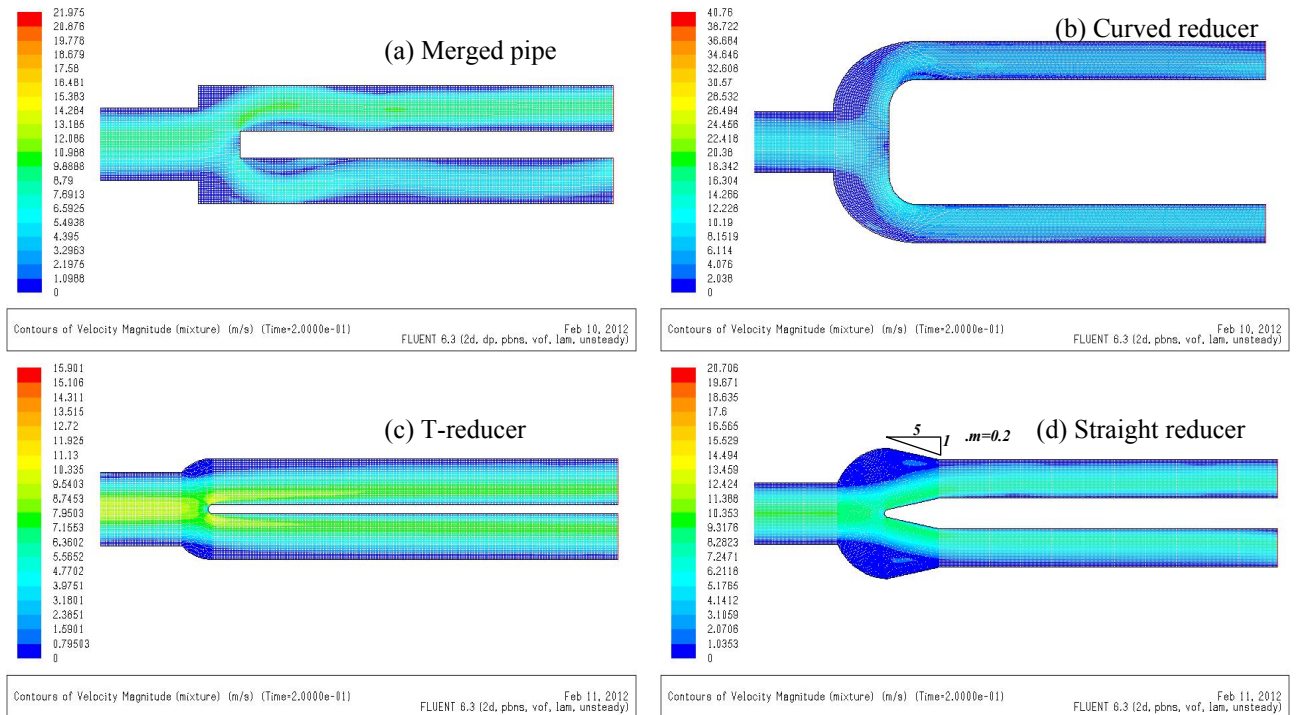


Fig. 5: Velocity distribution.

Furthermore, the uniformity of flow distribution is fall off. Since the analysis is based on laminar flow approach, the effect of turbulence was not appearance. Instead of turbulence, the oscillating gas flow through channel was exhibited. Accordingly, this shall be appended viscous modelling on CFD parameter. It is inferred that the curvature shape distributor could shift separation back, as shown on velocity distribution of curved round distributor which almost no phase oscillates within channels. It is evidence that the curved round distributor designed aerodynamically as aerofoil contributes to increase uniformity of two flow distribution along distributor.

Furthermore, the static pressure distribution along junction, Figure 6, approves forgoing analysis. The curved reducer distributor has the highest average static pressure followed by merged pipe, straight reducer and T-reducer, respectively. In the curved reducer distributor the most of kinetic energy is converted to pressure energy. The fluid particle/phase relaxes to uniform indicated by uniform pressure distribution and pumped to channels by its pressure energy. The process generates high pressure drop, destroying its performance. The merge pipe distributor has static pressure slightly lower than curve reducer distributor. The uniformity pressure distribution is disturbed by sharp edge of main channel cap raising the air to upper channel and oscillating it as well as the water come down to lower channel promoting static pressure jump to high level at 4 mm under centre line. The straight reducer distributor indicates low static pressure, in which kinetic energy loss is reduced significantly and the phase uniformity is better than the second one. There is negative static pressure in both lower and upper side of junction, in which the fluid is accelerated from stagnation condition to channel. In this case, it has to be carefully to design straight reducer, if the slope of reducer is big enough ( $m > 0.2$ ), the pressure loss could drop dramatically. The best performance is exhibited by T-reducer distributor in which the phase distribution is more uniform than others due to the uniformity of phase distribution, lower energy kinetic loss and lower pressure drop. However, the design must be enhanced the owing to existing static pressure jump as well as the large stagnation area while expanded to 3d model.

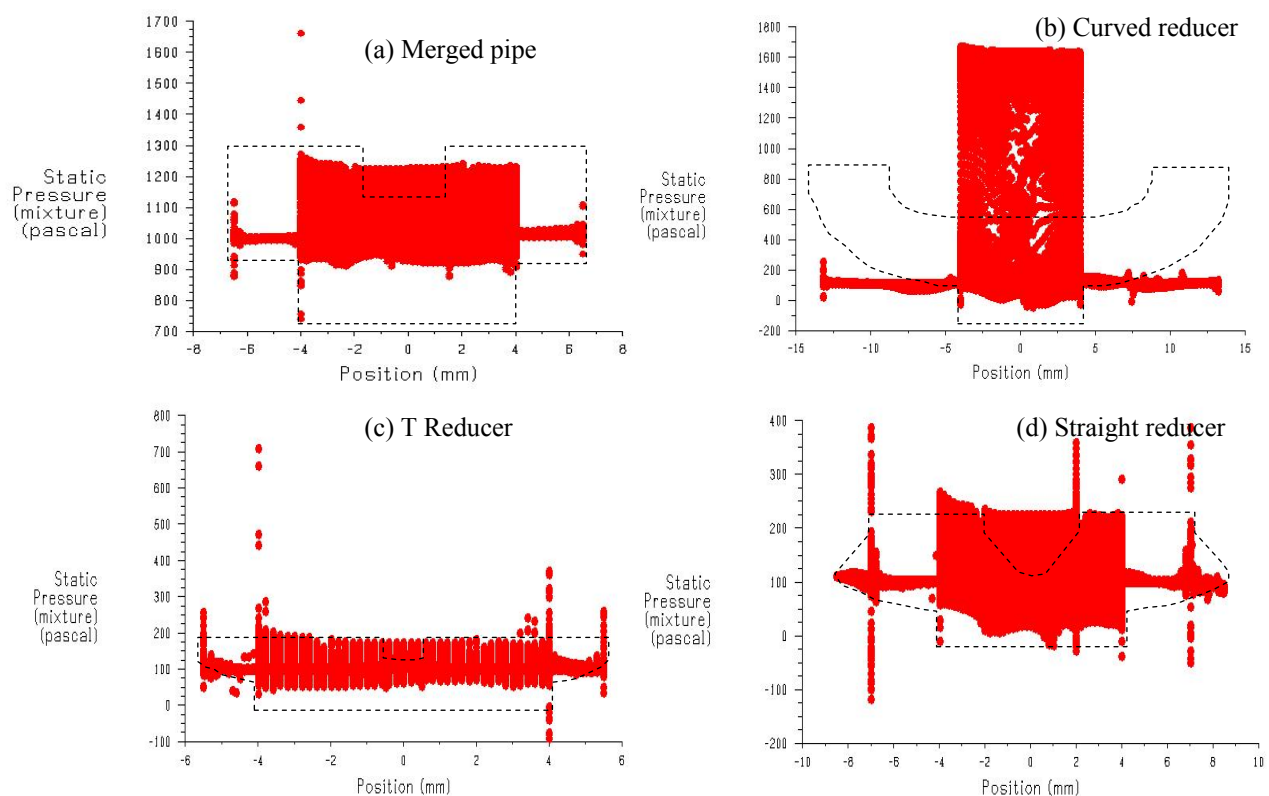


Fig. 6: Pressure distribution through junction.

### 2.3. Conclusion

The curved reducer distributor has the best uniformity of phase distribution, conversely has the highest pressure drop. While the merged pipe distributor has the lack-uniformity of phase distribution due to stream line separation on sharp edge of main channel cap, but has lower pressure drop than curve reducer distributor. The straight reducer and T-reducer exhibit the optimum condition but both of them have to be enhanced their

design. The straight distributor must be reduced stagnation area and optimized reducer slope. The T-reducer shall be narrowed the stagnation area while developed to 3d design.

The design development should refer to aerofoil contour by using aerodynamics or hydrodynamics theory. The CFD modelling is recommended to append viscous effect to detail turbulence phenomenon. The best modelling have to expand to 3d modelling analysis for perfection design.

### 3. Acknowledgement

The first author is gratefully to Directorate General of Higher Education, Ministry of National Education and Cultural of Indonesia as financial support.

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