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Design Optimization of Multi Vacuum Manifold for Semiconductor Industry

Taufik, R.S.*, Tan, S.T., Hambali, A., Tajul, A.A and Sivarao

Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Durian Tunggal, 76100 Melaka, Malaysia
*Corresponding Author: taufik@utem.edu.my +60 6 3316899

Abstract – *This paper presents the design optimization of multi vacuum manifold in gripping system for semiconductor industry. The objectives of this study were to investigate the parameter of designing manifold in vacuum system and analyze the results base on simulation software. The study was focused on the air flow in manifold system. The pressure drop, type of flow involved, and improper design were the factors that influenced the flow efficiency in manifold system. The study of multi vacuum manifold was carried out the design parameters involved such as various sizes of inlet, number of inlet used and the distance between the inlets used. The simulation was performed using CAD software to present the dynamic pressure and mass flow rates. Based on the simulation result, the design with the total cross section area inlets is less or equal to out resulted better value of velocity and suction pressure distributed in each inlet. In addition, the longer distance travels by fluid from inlet to outlet affects the result obtained. In conclusion, the new design of multi vacuum manifold for semiconductor industry was proposed. Copyright © 2012 Department of industrial engineering. All rights reserved.*

Keywords: *Design, simulation, multi vacuum manifold*

1   Introduction

It has increase the demand of semiconductor in output of electric and electronic sector to the market significantly. In 2007, the product of the electrical and electronic is the largest contributor to manufactured export with shared 58.9% [1]. The growth of semiconductor industry in industrial sector affects to development of automation technologies. These technologies are used in solving the problems of automated operation in machinery of assembly, handling, inserting the semiconductor products in order to increase the productivity in industries. Vacuum technology is the technology that is widely used in semiconductor industry for the purpose of handling and inserting electronic components.

There are many type of manifold are created by designer in for the use of drive and distribute the flow into each branch of the pipe network. In recently, there are many researchers are study on the parameters of the manifold in order to increase the efficiency of the flow in main and lateral pipes. There are various approaches and techniques have been described in vacuum manifold

system. The parameters design for two types of manifold such as end manifold and center manifold designs in the aspect of pressure distribution from the water pump to the lateral pipe [2]. Multi-port was used to present the cylindrical distribution manifold supplied with air from an upstream pipe whose internal diameter is identical to that of the manifold [3]. The combustion efficiency of the engine was performed by reducing the backpressure in the exhaust manifold [4]. Beside these researchers, there are many researchers still study on parameters of the manifold in one of the purpose of increasing the efficiency of flow.

Today, vacuum is involved in most every automated operation in most industrial sector. For semiconductor industries, almost all the machines are operated simultaneous with vacuum system such as pneumatic. A vacuum manifold is a vacuum tight distributing element, with the possibility of connection two or more vacuum chambers for simultaneous evacuation [5]. There are various of vacuum manifold designs have been used in semiconductor industries, such as in the end and center manifold design [2], linearly tapered and concave-down

contoured manifold design [6], and centralized and decentralized manifold design [7].

The current problem in industry is facing the utilization of multi vacuum manifold design, which occurs in the suction pad. The suction pad could not perform holding process all the items efficiently. There are various times taken to extract the air from the suction pad. Means the vacuum generated is not uniformly and the time taken is long until all the air is extracted.

In this study, design and analysis will be concerned on the study of multi vacuum manifold. The design aspect will be carry out in this study are the number of the inlets, diameter, and distances of inlets used in manifold design. For the analysis aspect, it will concern on velocity of flow and pressure distribution in vacuum manifold for various parameter design.

2 Materials and Method

There are three parameters that will concern in this study, distance between inlets used in manifold system, number of inlets used, and the size between inlet and outlet to be considered. Figure 1 shows the type of manifold used in study of vacuum manifold.
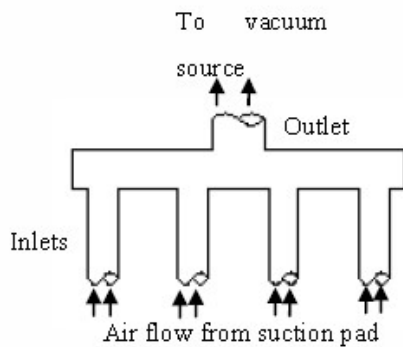

Figure 1. Vacuum manifold system

Three designs were generated for vacuum manifold system. The Figure 2 shows the distances used in three manifold designs. The distance between inlets of manifold (a) are far away to each other compare to manifold (b), and the distance between inlets of manifold are close to each other (c). These designs were used to study the relationship between the distances with the pressure distribution in manifold.
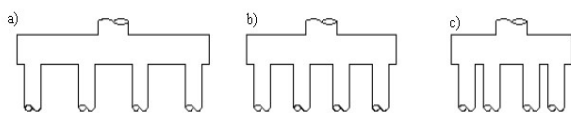

Figure 2. Distance between inlets in various designs

The sizes of inlet used in manifold design have a great affect for air flow through vacuum manifold system. According to Figure 2, the diameter outlet of each

design will be set constant and the size inlets of design (c), (d) and (e) were set from bigger to smaller, where $D_2>D_3>D_4$.
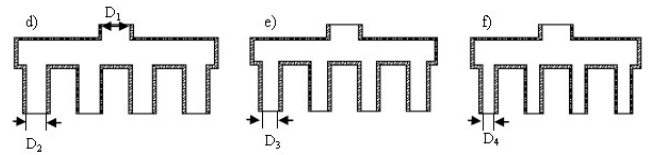

Figure 3. Number of inlets used in a same length of pipe.

Number of inlets used also one of the factors that will be used in design consideration in order to optimize the flow in manifold system. Figure 3 shows the various designs of numbers inlets used in this study. These designs were used to study on the efficiency of flow in manifold with different inlets used.

The manifold design which outlet is symmetric with the inlets will give uniformity result in pressure and velocity [4]. Therefore first model design created is shown in Figure 4 which contain with manifold block and 4 tubes with internal diameter of 7.5 mm. The diameter of outlet is 15 mm with the initial setup of 0.02 kg/s.
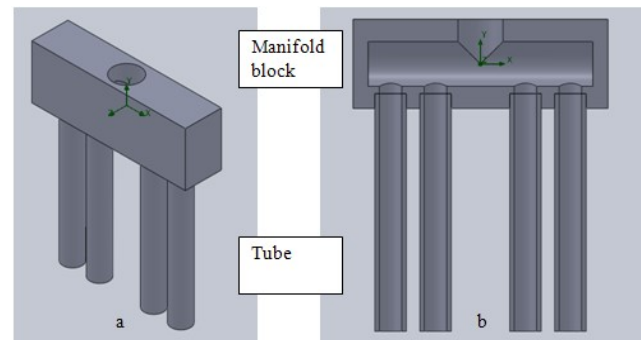

Figure 4. Multi-vacuum manifold with 4 inlets in (a) Isometric view, and (b) Cross section view

There are five groups of manifold parameters are developed and simulated with using SolidWorks, which are:
a) Number inlets of multi-vacuum manifold with constant diameter.
b) Size inlets with constant number of inlets.
c) Distance between inlets with constant number of inlets.
d) Multi-vacuum manifold with diameter base on A1=A2+A2.
e) Various sizes of inlets in a vacuum manifold.

In this study, the five groups of manifold parameters were identified as the critical parameter that influences the optimization of manifold design. The studies of air flow in the five groups manifold were presented using Solidworks.

3 Results and Discussion

3.1 Reference Design

The reference model of vacuum manifold was designed in the initial stage of design before further to study parameters. The manifold has a single outlet with 4 inlets and has the size of 15 mm diameter outlet and 7.5 mm diameter inlets. The size of inlets is referring to available size of tube on the market.
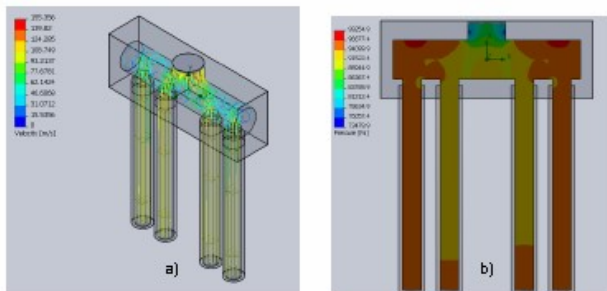

Figure 5. (a) Velocity flow at inside manifold, and (b) Pressure distribution at inside manifold

By referred to Figure 5, the flow trajectories shown at inlets have higher value of velocity and it is decrease before reach to manifold outlet. According to Bernoulli principle, the velocity of fluid will increase as the cross section area decreases, and the velocity will decrease as the cross section area increases. The velocity is decreased due to the cross section area of inlets are smaller than the cross section area inside manifold block, As shown in the Figure 5(a), the color of flow trajectories change from yellow to green and blue when went inside manifold block and the velocity increase again when close to the outlet. Based on the simulation result, the velocity in first inlet is 97.247 m/s and second and third inlet has higher velocity which is 104.577 m/s and 104.135 m/s. The inlets which were close to outlet have higher velocity and decreased as the distance become far from each other.

According to Figure 5(b), pressure distributed in second inlet and third inlet has low pressure (94995.82 Pa and 95047.11 Pa) compare to first and forth inlet which has pressure in 95824.36 Pa and 95859.23 Pa, respectively. It is found that the Bernoulli principle states an increase of fluid velocity occurs simultaneously on decreasing in pressure. Therefore, the pressure was affected by velocity generated. The low pressure occurs in second and third inlet is encouraging the fluid flow faster than other inlets.

For the mass flow rate, the first inlet and third have lower value compared to the inlet close to outlet. But the total mass flow rate of inlets boundary were equal to mass flow rate at outlet boundary, 0.02 kg/s. It is appeared that the result obtained is obeyed with conservation of mass principle. The main factor affect

the result of mass flow rate value is velocity of fluid pass through the inlets.

3.2 Number Inlets of Multi Vacuum Manifold with Constant Diameter

Figure 6 shows the chart of mass flow rate for the first study group. From the chart, 2 inlets vacuum manifold shows the highest value in mass flow rate in each inlet and follow by 3, 4, 5, 6, 7 and 8 inlets. As the number inlet increased, the mass flow rate is decreased simultaneously. Besides, the values of mass flow rate become inconsistence when the number inlets increased, which shown obviously in 8 inlets vacuum-manifold (0.002028, 0.002296, 0.002571, 0.003110, 0.003107, 0.002565, 0.002296 and 0.002027kg/s). All the designs were obey with mass conservation principle except 2 inlets vacuum manifold which the total inlet mass flow rate was 0.018kg/s compared to outlet mass flow rate value, 0.02kg/s. The velocity is the factor that affects the result in mass flow rate and pressure This phenomena can be explained by using mass flow rate equation, $m=\rho vA$, which velocity of fluid is inversely proportionally to area. Therefore, when the number inlet of manifold is added from 2 to 3 and so on, the velocity is dropped because of the total cross section area is increased.
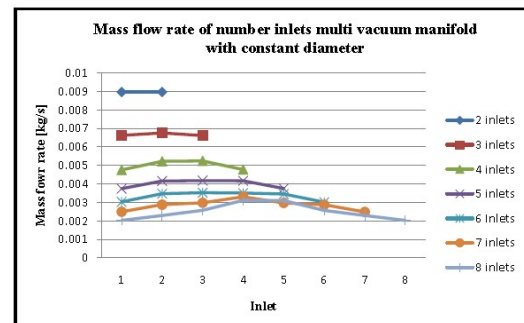

Figure 6. Mass flow rate of number inlets multi vacuum manifold with constant diameter

According to Bernoulli principle, high fluid velocity will lower the pressure in region flow pass through and encourage the air flow into manifold more faster than at higher pressure region. Based on the simulation result, it is shown that 2 inlets manifold have highest velocity and have the highest suction pressure (26514.74 Pa) among the designs in first study group. This value drop as the number inlets increase, which the maximum pressure distributed in 8 inlets is 2303.26 Pa. The inlets which are close to outlet have the better suction than inlets far away from center. The reasons that make the pressure drop are viscosity occur in between fluid and the wall of manifold, and the loss of fluid due to junction inside the manifold. Figure 7 shows the suction pressure distributed in each inlet of each design.
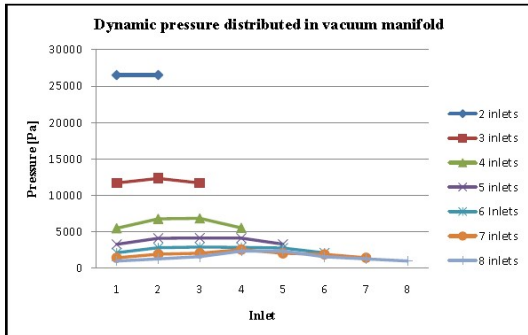
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Figure 7. Dynamic pressure distribution in vacuum manifold

3.3 Inlets with Constant Number of Inlets

Figure 8 show the mass flow rate for all 4 inlets manifold. From the chart, the mass flow rate distribution of each design have not significant different. The inlets diameter of 10 mm manifold shows the highest value of mass flow rate among the design in second study group, 5.55x10-3 kg/s while 6 mm diameter has the mass flow rate of 5.06x10-3kg/s.
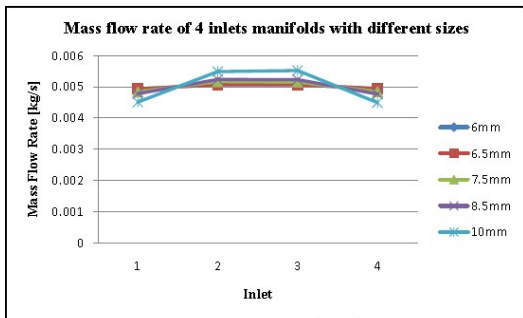

Figure 8. Mass flow rate of 4 inlets manifolds with different sizes

Among these designs, the smaller size of inlets the mass flow rates has more consistent compared to manifold with large size. Simulation result showed that for 6 mm diameter inlets manifold, mass flow rate in first inlet was 0.00494 kg/s and follow by 0.00506, 0.00506 and 0.00494 kg/s. For 10 mm diameter inlets manifold, mass flow rate for first inlet was 0.00451 kg/s while second inlet was 0.0050 kg/s. It is shown that the larger size used will have greater value and sudden drop for the side inlets. The velocity is decreasing as sizes of inlet increasing. Increasing size mean the cross section area is increase simultaneously.

It is found that the suction pressure also drops when the size inlets increase from 6 mm diameter to 10 mm diameter. The suction pressure drops to 2144.96 Pa while the suction pressure of 6 mm diameter of 18775.36 Pa.

3.4 Distances between Inlets with Constant Number of Inlets

The mass flow rates in this group were similar for all manifold design, because the cross section areas were approximated uniform. There are slightly dropped in mass flow rate value when the distances between inlet increases as shown in Figure 9. Compare the values in third inlet, the mass flow rates are 0.003038, 0.003011, 0.002992, 0.003094kg/s respectively from 12 mm distances to 20 mm distances, the difference were very small and can be neglected.
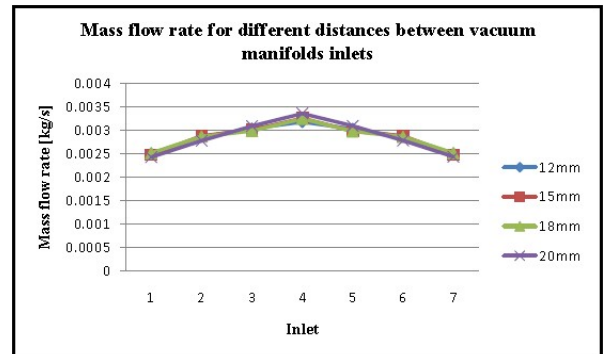

Figure 9. Mass flow rate for different distances between vacuum manifold inlets

It is shown that the manifold with 20 mm distances between inlets has the highest value of suction pressure compare to other designs. The pressure distributed in the 20 mm distances shows the pressure of 1364.98, 1793.56, 2258.97 2689.66 Pa from first inlet to forth inlet. In addition, the manifold with 12 mm distances shows the value of 1412.71, 1861.12, 2101.2101.21 and 2311.23 Pa from first inlet to forth inlet.

3.5 Multi-Vacuum Manifold with Diameter Base on $A_1=A_2+A_2$

By creating the designs using $A_1=A_2+A_2$, the mass flow rate result shows more uniform and consistence distributed in each inlet. By referring to Figure 10, the 3 and 4 inlets vacuum manifold have a very obvious value drop in the first inlet and last inlet while the 5, 6, 7 and 8 inlets have approximate similar mass flow rate in each inlet. Means, by controlling cross section area of inlet, the result becomes more uniform and consistence. The 7 inlets vacuum manifold illustrated the mass flow rate value of 0.0027, 0.0028, 0.0029, 0.0028, 0.0029,0.0028, 0.0027 kg/s. Compared with Figure 5.1 in the first group, this group have a better mass flow rate result and sum all the mass flow rate of inlets are equal to total mass flow rate of outlet, 0.02kg/s.
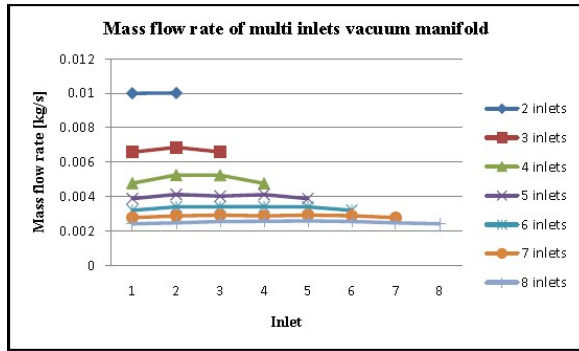
Figure 10. Mass flow rate of multi inlets vacuum manifold

It is found that the velocity distributed in each inlet of multi vacuum manifold. The maximum velocity showed by 2 inlet were 116m/s and followed by 3 inlets to 8 inlets which have 106, 106, 112, 108, 111,121m/s respectively. All of these values were distributed in the range of 100 to 120 m/s. It is shown that the velocity inversely proportional to cross section area. Hence, the cross section area of the inlets to be constant and the result shows a very consistence value of velocity to each design. For the outlet manifold, the cross section area was 176.71 mm^2. Table 1 shows the total cross section area for all the inlets of different design in this study group. Since all the total area does not excess the value of 176.71 mm^2, therefore the system can perform its velocity at maximum capacity value.

Table 1.Total cross section area

Inlet	2	3	4	5	6	7	8
Cross section area (mm^2)	157	170	176.68	166	170	166	157

It is found that the suction pressure in each design has higher value of pressure in the range of 5000 Pa to 10000 Pa. The maximum value of 2 inlets vacuum manifold was 8145 Pa and followed by 3 inlets to 8 inlets which have the value of 6784P a, 6787 Pa, 7588 Pa, 7071 Pa, 7537 Pa and 8864 Pa, respectively. As the number inlets of manifold increased, the inlets which distributed far away from the outlet will have the lower pressure than close to center. The longer distance traveled by fluid makes the pressure drops due to viscosity of fluid and the different cross section area.

3.6 Sizes of Inlets in a Manifold

When using the different sizes in a design, the mass flow rate becomes inconsistence as shown in Figure 11. The designs with the same size for all inlets will have consistent and uniform. The mass flow rate for 7 mm diameter inlets were approximated similar except the first inlet and last inlet. When there were 2 sizes used, the mass flow rate suddenly dropped, particularly for small size. For the size 5 mm, 6 mm and 7 mm sizes used in a design, the larger size will have greater mass flow rate than the small size. In any case, the total mass flow

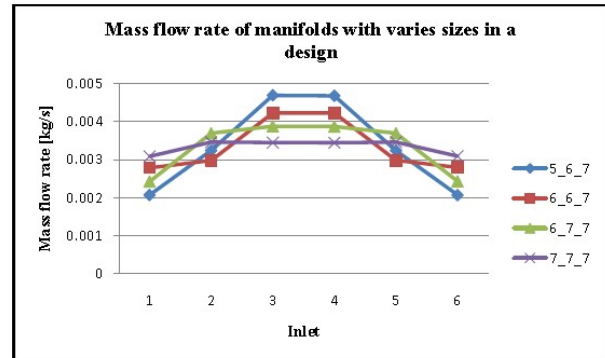rate of inlet for all design equals to mass flow rate of outlet.

Figure 11. Mass flow rate of manifold with varies sizes

It is shown that the manifold with 1 size has the lowest velocity among the design models in this study group. For the design uses 2 sizes (2 of 6 mm and 4 of 7 mm diameters used), it is slightly increased for each inlet compared to preview design. It increases when 4 of 6 mm diameters were used. The design with 5 mm, 6 mm and 7 mm diameter shows the highest among the design. Since the velocity is inversely proportional, therefore the size of the design is decreased; it will increase the velocity simultaneously. But the values obtained were not consistence for all inlets of the design.

Table 2.Total cross section area

Group	Mass flow rate	Velocity	Suction pressure	Overall consistency
Reference design (4 inlets manifold	0.0051 kg/s	104.57 m/s	6.6 kPa	Good
Number inlets of manifold, constant diameter	Drops as total inlets increases	Better. 2 and 3 inlets		Good
Size inlets, constant number of inlets	Drops as the size increases	Size of 6 and 6.5 mm have better result		Good
Distance between inlets, constant number of inlet	Drops as the distance increases	Range of 12 to 18 mm distances have better result		Less
Multi-vacuum manifold, diameter based on $A_1=A_2+A_2$	Drops as the diameter increases	All designs have better result than reference design		Good
Various size of inlets in a vacuum manifold	Drops as the number varies sizes used increase	Size of 5, 6, and 7 mm have better result		Less

Table 2 shows the best design parameters that can be accomplished. The total cross section area inlets were equal or less than total cross section area of outlet (to maintain value of velocity and pressure at high level). The better distances between inlets were in the range of 12-15 mm to reduce inconsistence occurring to inlets. Among the 5 groups of design parameter generated, the result showed that the vacuum manifold which designed in group 4 (multi-vacuum manifold with diameter base on $A_1=A_2+A_2$), and 8 inlets vacuum manifold was the better design with size of 5 mm diameter and 15 mm distance between inlets.

4   Conclusion

The design and simulation of multi vacuum manifold has been presented for the semiconductor industry. It is shown that the cross section area was the main factors that affecting final result such as suction pressure and velocity distributed. The distance was another factor that affects the result obtained at final stage. The velocity and pressures distributed to each inlet were maintained at high value if the cross section of inlets decreases as the number of total inlets increases. It is concluded that the better parameter to be considered in this study were total cross section area with the inlet was less or equal to cross section area, distance between inlets were in the range of 12 mm to 18 mm with the size in between 5 mm to 7 mm diameter. Hence the design with 8 inlets, 7.5 mm diameter, and 15 mm distances between inlets showed the best design in this study.

Acknowledgements

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