CFD Analysis of a Noncontact Gripper with Rotor

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Abstract— *In this paper, a new non-contact gripper using a rotor is introduced and CFD analysis is done. This non-contact gripper creates a negative pressure that helps in lifting the object but does not allow the object to be lifted to come in contact with the gripper. Gripper with a rotor mentioned in this paper consumes minimum power when compared to other pneumatically activated noncontact grippers as it does not involve the use of compressors. The CFD analysis of the pressure variation at the top of work piece to be lifted is found and is validated.*

Keywords— non contact Gripper, CFD, rotor.

I. INTRODUCTION

End-effector of a robot interacts with the environment. The exact nature of end effector depends on the application of the robot. The end effector comes in contact with the object to be handled. Handling of food using contact end effectors leads to contamination. Preventing the end effector to come in contact with the food to be handled improves the hygiene standards [1]. In semiconductor industry, wafer comes in contact with the end effector repeatedly which lead to defective product. Surface scratching and static electricity is another disadvantage of contact gripper[2] which is the reason for introduction of non-contact end effectors as robotic arms. Pneumatic levitationis the use of flowing air to lift an object. It generates lesser heat. In this, air is used to create negative pressure, which creates an upward lifting force. The maintenance of a pneumatic gripper is lesser when compared to other grippers. Bernoulli gripper, the first and widely used pneumatic non-contact gripperworks on Bernoulli principle. Bernoulli gripper has a chamber with a central hole through which air is sent at high pressure to create central negative pressure.

Vortex gripper, which is also a non-contact gripper, has a chamber with a tangential nozzle that produces swirling flow and creating a central negative pressure[3][4]. It requires high amount of electrical energy to compress the air .There will be loss of energy as heat and friction between surfaces during working of compressor which leads to lesser efficiency.

In this paper we introduce a new gripper with minimum power utilization [5]. Instead of using a compressor and a tangential nozzle, a rotor is rotated at a fixed rpm with blades at a particular angle that creates the swirl flow. This creates central negative pressure and high pressure near walls of chamber which provides lifting as well as noncontact. Aim of the present work is to conduct CFD analysis and to find the pressure distribution due to swirl flow at the top of the work piece.

II. MECHANISM AND DESIGN

2.1. Mechanism

Rotor rotates at a fixed rpm using motor with servo mechanism. Rotor is inside a casing as shown in Fig1. Casing has a top cover with inlet holes. Rotor blades are curved at an angle of 10 degree to create a suction of air from the top inlet holes. This air is thrown to the walls creating a central negative pressure. This negative pressure creates an upward lifting force to lift the object. Centrifugal force pulls air from center to the wall of casing.

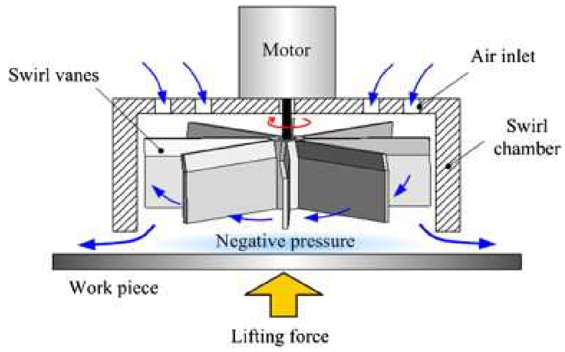

Fig.1: Schematic of gripper [1]

Air escapes from the bottom of the casing and creates the non-contact. Air enters through the inlet holes and leaves through the bottom of casing. Gripper is kept at a clearance distance with the work piece. In the present work, different clearance distances are considered to find pressure distribution at the top surface of the work piece. Optimization of design is beyond scope of the present work. A basic design [1] is considered and modifications of design are left as future scope of work.

2.2. Design

A basic design [5] is considered which includes Casing with inlet and outlet holes and Rotor. For CFD analysis, fluid domain is to be created from this design which is explained in the numerical part of this paper. A work piece is introduced at different clearance distance. This clearance distance is considered as the varying parameter for analysis.

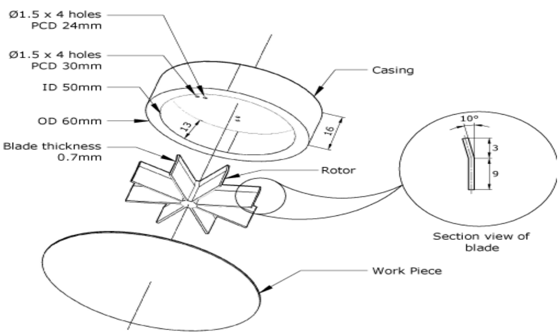

Fig.2: Design dimensions

Internal diameter of casing – 50mm
Number of air hole – 8
Blade thickness – 0.7mm
Blade angle – 10^o
External diameter of casing – 60 mm
Number of blades – 8
Blade diameter – 48mm
Diameter of air hole – 1.5mm

Enlarging the air hole diameter will increase the flow rate sucked. Variation of position of air holes also varies the suction rate. Variation of angle also varies flow rate. The maximum negative pressure appears in the central area. The material used is acrylonitrile butadiene styrene (ABS). Blades are arranged symmetrically around the center. The suction if stops will not keep clearance between the work piece and the casing.

IGES file of the model is transferred to CFD software.Air is the fluid for analysis which is taken from atmosphere and so the inlet boundary conditions will be the properties of atmosphere. The gripper is placed in the atmosphere and rotation of blades causes entry of air inside the casing. Analysis is started after extracting the fluid volume. An airenvelope which is a large fluid space is created with non-merge condition with the gripper body and fluid region is extracted refer fig 3 and 4.

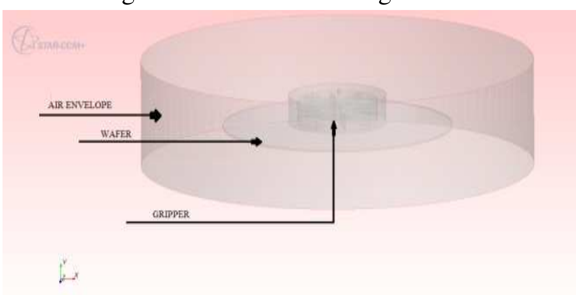

Fig.3: Introduction of air envelope

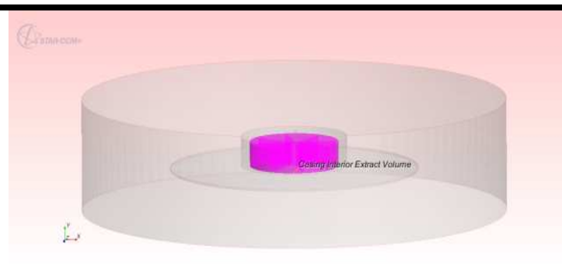

Fig.4: Extract volume

2.2.1. Mesh condition

Polyhedral elements were selected and prism layer mesh model is used with a core volume mesh to generate orthogonal prismatic cells next to wall surfaces or boundaries.8,99,227 cells are obtained after meshing (fig 5) for 0.4 mm clearance distance.

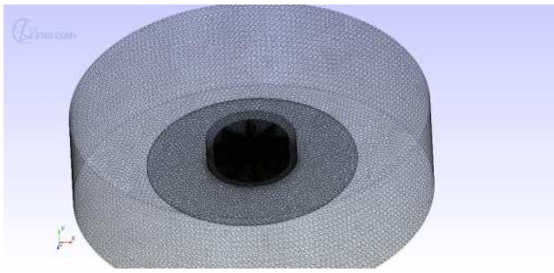

Fig.5: Polyhedral mesh

2.2.2. Physical Boundary Conditions

It includes mentioning the physics of the problem. This problem includes air flow at higher velocity which is rotational (swirl). The physics of the problem is given below

Calculation Conditions	Selected Model
Space	Three dimensional
Time	Steady
Flow	Segregated flow
Material	Gas
Equation of state	Real gas
Viscous regime	Turbulence
Reynolds average turbulence	k-Epsilon model

2.3. Results And Discussions

Results of experimental analysis are taken [5], and are compared with CFD analysis. Pressure at the top surface of the work piece is noted. Different horizontal and vertical section planes are created along the casing and pressure distribution is noted for different clearance distance.

Pressure Distribution

The analysis of 1mm clearance distance and 0.4mm clearance distance is done and is compared with the experimental details.

0.4mm clearance distance- Distance between wafer and casing is 0.4mm .Pressure above the work piece is found out and graph is plotted along the diameter of the work piece. The variation of pressure is found to be a parabolic curve as in experimental method. Pressure at the central region is lower than the periphery. Along the gap, due to viscous impedance, the pressure slightly goes up and comes down. Use of different turbulence models is left as future scope of work. Variations of pressure along different sections are found.

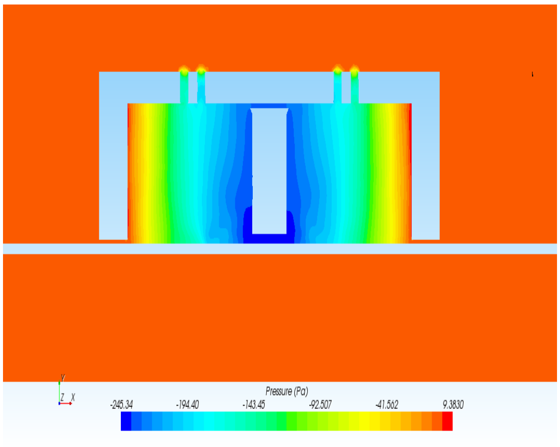

Fig.6(a)

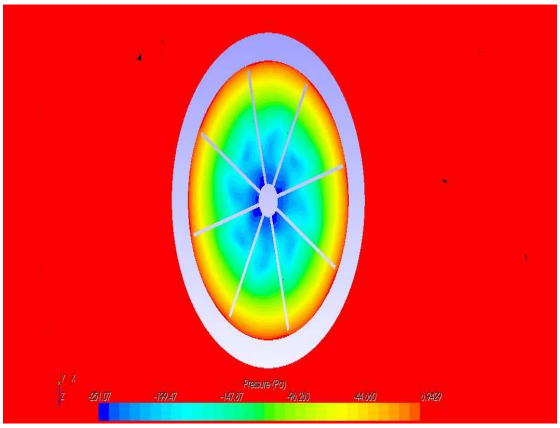

Fig.6 (b)

*Fig.6(**a**):Pressure at vertical section through center of casing , (**b**) Pressure at Pressure at horizontal section through center*

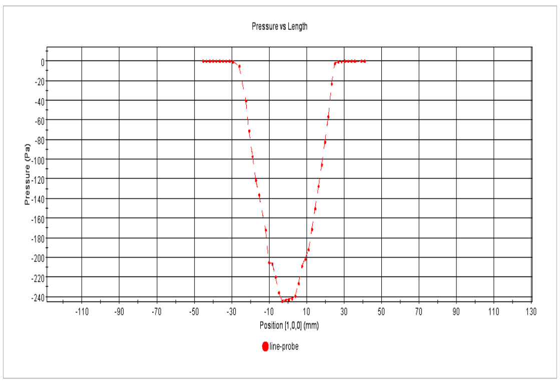

Fig.7(a)

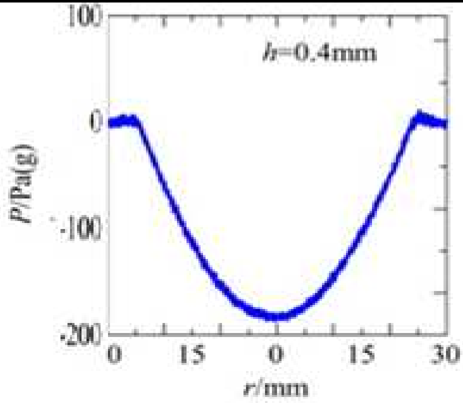

Fig.7(b)

*Fig.7(**a**):CFD Result 0.4mm, (**b**): Experimental Result 0.4mm[1]*

The reults of the 0.4mm clearence distance and 1mm clearence distance from the two graphs gives the detail that the experimental data is validated using CFD analysis. In experimental analysis , due to the quality of the pressure tap and sensors, there is a fluctuating result. That is not present in CFD analaysis . Central small fuctuation is due to thickness of the shaft. The force analysis from the prsessure data is left as future scope of work.This force analysis gives study of gravity effect of the body to be lifted.

III. CONCLUSION AND PERSPECTIVES

In this paper , CFD analysis of a non contact gripper with a rotor , rotating at 8000 rpm is done. The rotation of air has a tendency to rotate the object. This can be prevented by using number of grippers arranged in a circular symmetry with altenate grippers rotating in opposite direction. Pressure distribution from CFD analysis is validated using experimental analysis[5] for different clearence distance . This gripper utilises minumum power when compared to other non contact grippers as it has no compressor. Fluctuating rotor velocity produces fluctuating pressure at the top of workpiece. To prevent this , a servo motor which can maintain the rpm at 8000 is used. Force can be found out using this pressure. If the upward force is greater than the weigt of the body, the body gives a stable levitation.

REFERENCES

[1] *S.Davis_et.al.,* .An end effector based on the Bernoulli principle for handling sliced fruit and vegetables , Robotics and Computer-Integrated Manufacturing, Volume 24, Issue 2, 249-257, 2008

[2] *Xin Li, et.al* , Computational Fluid Dynamics Study of a Noncontact Handling Device Using Air-Swirling Flow, Journal of engineering mechanics ASCE /, 137:400-409, June 2011

[3] Xin Li, et.al, Analysis of vortex levitation , Experimental thermal and fluid science, Volume 32, Issue 8,1448-1454, Sept 2008

[4] *QWu et.al,* Experimental and numerical study of vortex gripper with a diversion body, Journal of mechanical engineering science, 194-201, 2011
[5] *Xin Li n* et.al., Development of a new noncontact gripper using swirl vanes ,Robotics and Computer-Integrated Manufacturing 29,63–70, 2013
[6] *Vincent Vandaele ,et.al* , Non-contact handling in microassembly: Acoustical levitation, Precision engineering, Volume 29, Issue 4, 491-505, 2005
[7] *E. Toklu et.al,*.Modeling of Radial Flow on a Non-Contact End Effector for Robotic Handling of Non-Rigid Material , Journal of applied research and technology, ISSN 590-596, 2012
[8] *S. Jain, and Y. Deshpande* , CFD Modeling of a Radiator Axial Fan for Air Flow Distribution, , World Academy of Science, Engineering and Technology 71, 2012