Design and Development of Industrial Suction Device using Compressed Air

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Abstract- *"Vacuum Producer" is a single stage design with inbuilt fittings for pneumatic connections without any moving parts. Vacuum producer works on a principle that compressed air is throttled as the air exits the nozzle and is discharged into the diffuser. This increased velocity of air lowers the pressure in the diffusion chamber. The volume of air within the closed vacuum system flows into the low pressure area of the diffusion chamber and is exhausted through the diffuser. This effect increases the vacuum level and evacuates most of the air within the closed vacuum system at supersonic speeds. This component is very small in size so can be fitted in pressure line anywhere and it is very cheaper as compared to vacuum pumps used in industries.*

Keywords- Compressor, Throttling, Pressure Drop, Vacuum production, Diffuser, Supersonic speed.

I. INTRODUCTION

In an automation industries vacuum is used for different purpose like material handling, plastic bags opening, vacuum forming, testing and inspection, vacuum conveying of powder sand granules. For these applications vacuum pump is used. But vacuum pump requires lot of space and it is very costly. 'Vacuum producer' is the solution for the above problem. It can produce vacuum using compressed air which is already available in the industry. It is very small in size so the problem of space can be solved and it is relatively very cheaper also.

It works on a principle that, when a fluid is passing through a pipe its velocity will increase as it passes through a converging cross section in according to the principle of continuity [14], while its static pressure must decrease according to the principle of conservation of mechanical energy [14]. Thus any gain in kinetic energy of fluid may occur due to its increased velocity through a converging cross section is balanced by a drop in pressure.

This paper is organized as follow, Problem statement is given in section II. The literature review and related work are presented in Section III. The design procedure, formulation and mathematical calculations for the vacuum producer is described in Sections IV and V respectively. Working of the vacuum producer is explained in section VI. Advantages and disadvantages are given in section VII. Finally, in Section VII, some conclusions are inferred. Acknowledgment and some references regarding the vacuum producer are given at the end of the paper.

II. PROBLEM STATEMENT

Now a day industries are becoming more automatic and reducing the labour work as much as possible Vacuum is very necessary in an automation industry lots of operations are depending upon vacuum. But a vacuum pump which is used to produce it is very costly and bigger in size. That is why a substitution for the vacuum pump is very important issue for automation industries.

There are so many attempts are done to find substitute for the vacuum pump like, to use a robotic arm, to use electromagnet, to use hydraulics. But all these have some limitation, so in these work we have tried to overcome all the limitations by designing the 'vacuum producer'.

III. LITERATURE SURVEY

Busaidi & Pilidis[1] studied different methods for the multistage centrifugal compressor which is used in industries. The wide stable operating range and the high efficiency have been the most two features that drive the selection of centrifugal compressor for any application. The new method is valid for both high and low flow coefficient applications. The obtained characteristics have been tested and validated against measured data. More accurate estimation for compressor efficiency and stability range. It is used to predict the efficiency at both design and off- design condition.

Peris & Corberan[2]studied how to reduce heat losses and increase the efficiency in compressor. Energy harvesting potential in the compressor heat losses. Model of thermoelectric module. Capacity modulation in refrigeration systems by the use of thermoelectric effect. COP improvement through the thermoelectric effect in refrigeration systems. In regular compressor operation, part of the supplied power is released in the form of heat losses to the environment, thus reducing the total efficiency of the system. The amount of energy lost to the environment depends on the working conditions and the size and technology of the compressor.

Dinh & Heo[4]studied performance testing of compressor in the aspect of aerodynamics. Blade tip ejection was introduced to a casing groove combined with tip injection in a transonic axial compressor with NASA Rotor37. A parametric study of compressor performances was performed using three-dimensional (3-D) Reynolds-averaged Navier–Stokes equations with the turbulence model. The application of a casing groove combined with tip injection and ejection was found to be effective in the simultaneous improvements of adiabatic efficiency, stall margin, and stable range extension without loss of the total pressure ratio of the transonic axial compressor, compared to the case with a casing groove with injection only, and a smooth casing.

Zhang & Xu[7] studied hydraulic and thermal characteristics of metal. Receiver is a core component of dish solar thermal power generation system, which absorbs the concentrated beam of solar energy, converts it to heat, and transports solar heat to the heat engine with minimized heat loss. Heat pipe receivers for dish solar thermal power generation system has been widely concerned because of the efficiency and reliability. For the complex conditions of high and variable heat fluxes, it is important to choice a wick with excellent hydraulic and thermal characteristics.

Trebuna & Simcak[9] studied during their operation the pipes of gas compressor stations are influenced by dynamic impacts caused by operating equipments as well as flowing media. Due to the occurrence of excessive vibrations on output pipes of turbocompressor after its modernization, experimental vibration analysis of the output pipe of turbocompressors was realized, which included modal analysis and vibration measurements during operating of turbocompressor. Objects of measurements were two compressors of the same type. The aims of the measurements were to determinate a source of an excessive vibration and proposal of measures leading to reducing vibration to an acceptable level defined by a relevant standard.

Zhang & Dong[11]studied how to save energy in whole compressed air system. This paper describes an integrated instrumentation system for the volumetric-concentration measurement of biomass/coal/air three-phase flow in a pneumatic conveying pipeline. The system combines electrostatic sensors with capacitive sensors and incorporates data fusion techniques. First, the flow regime is identified through the Hilbert marginal spectrum of the electrostatic sensor output signal. Then, under certain identified flow regimes, the dual regression analysis method is applied to work out the biomass concentration and the pulverized coal concentration.

Jana & Das[14]studied different aspects of flow of fluid through venturemeter. The present work reports the influence of a venturimeter on liquid–liquid phase distribution during upflow through a vertical pipe. The optical probe technique has been adopted for the characterization of flow. The experiments have indicated the flow pattern transitions to occur at lower velocities at the downstream region of the venturi. The pressure drop readings across the venturi have been used to estimate the mass flow rate of the mixture by using suitable models for the different patterns.

Tanyildizi & Eren[15] studied different techniques for manufacturing of venturimeter. In this work, a simple and cheap production technique for the liquid and gas flow meters widely used in industry is presented. The technique is concerned with the production of the flowmeter case and simply employs the relative equilibrium property of a liquid in a container rotating with constant angular velocity. The liquid used is a special chemical solidifying during the process. Naturally, a tube with a paraboloidal inner surface is obtained and this tube can be used as the flow meter case. A comparison of the flow rate computations shows that flow meters with paraboloidal inner surfaces thus obtained provide, in fact, a slightly better approximation than the usual flow meters with conical inner surfaces.

IV. DESIGN PROCEDURE OF VACUUM PRODUCER

The design should be optimum so that it can produce maximum vacuum. To achieve optimum efficiency, based on the available inputs, propose a model and analyse using software.

Block diagram:-

'Vacuum Producer' works on the effect of venturimeter. As the cross sectional area of the pipe is decreasing velocity of the fluid (Compressed air) increases to a very large extent. Due to which pressure drop occurs. Using this pressure drop vacuum is produced. The proposed model as compared to vacuum pump Lighter, smaller and cheaper. Based on the working conditions the proposed model will work efficiently. Vacuum producer can be connected in pressure line wherever required. The following diagram shows the connection of the component in the pressure line of the compressor.

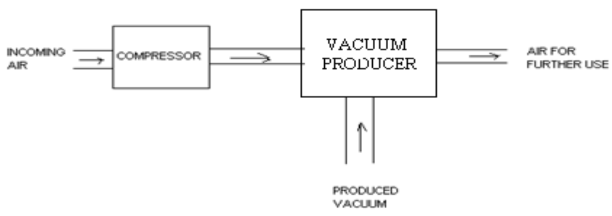

Fig.I. Block diagram of set up

Venturimeters have been used to measure the volume flow along a pipe for many years. The fluid flowing in the pipe passes through a section which is called as "throat". The throat has a smaller cross sectional area than other parts of the pipe. Assuming that the compressed air flow speed is constant, the velocity of the fluid through the throat is higher than the other sides of the pipe. From the continuity law we can infer that, the velocity of fluid and pressure increases in the converging pipe and decreases at diverging pipe. So, the flow rate can be calculated with the measured pressure and pipe parameters. The limiting case of the Venturi effect is when a fluid reaches the state of choked flow, where the fluid velocity approaches the local speed of sound. In choked flow the mass flow rate will not increase with a further decrease in the downstream pressure environment.

Numerical treatment:-

Bernoulli's equation[14] is used to design the venturimeter as it deals with the pressure and velocities in a pipe at two sections.

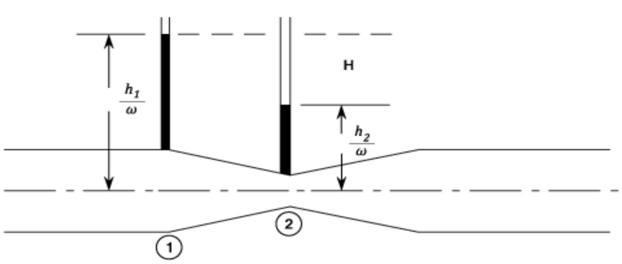

Fig.II. Venturimeter[14]

$$\frac{p1}{w}+\frac{v1^2}{2g}=\frac{p2}{w}+\frac{v2^2}{2g}$$

Applying Bernoulli's equation at stations 1 and 2:

$$\frac{v2^2-v1^2}{2g}=\frac{p1-p2}{w}$$

For a meter with the above arrangements of manometers, the quantity flowing is given by:

$$Q = a * v$$

$$\frac{v2^2-(\frac{a2v2}{a1})^2}{2g}=\frac{p1-p2}{w}$$

$$v2=\frac{1}{\sqrt{1-(\frac{a2}{a1})^2}} * \sqrt{2g(\frac{p1-p2}{w})}$$

$$v2 = constant * \sqrt{2gH}$$

$$H = (\frac{p1-p2}{w})$$

$$Q = a2v2 = a2\sqrt{2gH}$$

Where.. v= velocity of fluid,
p=pressure of fluid,
w=specific weight,
H= head of the venturimeter,
a= cross sectional area,
g= acceleration due to gravity

V. WORKING OF VACUUM PRODUCER

Compressed air is given as an input to the vacuum producer. All connections are already given in the component itself so there is no need of extra connections. Compressed air enters the inlet section at velocity and pressure V1 and P1 respectively. After some length cross sectional area of the pipe is decreased so that the velocity and pressure of the air changes to the increased values V2 and P2. Here the velocity becomes much more than that at the entry of the component. As the air reaches some required values the cross sectional area of the component again increases to previous value. Here pressure drop occurs and at that area one hole is made which is used to produce vacuum. This hole is connected to a pipe. At the end of this pipe again connection is give at which a suction cup can be connected. This suction cub is used as an output device which will suck the object. It can hold the object until the compressed air is passing through the vacuum producer. As the passing air stops through the component, it drops the component at same time. This can be done by using solenoid valves which can ON and OFF the supply of compressed air to the vacuum producer. If it is going to be used for the mass production at which the same task has to be performed thousands of time , in such cases microcontroller can be used to operate the solenoid valve which will then control the input of the vacuum producer. At the other end compressed air goes out of the vacuum producer at which silencer is fitted to reduce the noise made by the compressed air at while expanding to the atmosphere.

VI. ADVANTAGES

There are lots of advantages of vacuum producer. Some of them are as follow.

- No need of vacuum pump already available compressor can be used to produce vacuum.
- No moving parts , so the maintenance is very less.
- All connections are inbuilt so no need of external fittings.
- It is very lightweight so can be fitted anywhere in the pressure line.
- Very small in size so that industry space can be saved.
- Component cost is very less as compared to vacuum pump.

VII. CONCLUSION

In this work, Vacuum Producer is proposed to replace a vacuum pump in an automation industry. This component can perform every task which a vacuum pump can perform like material handling, plastic bags opening, vacuum forming, testing and inspection, vacuum conveying of powder sand granules. Although the task performed are same, the size and cost of the component is very small as compared to vacuum pump. So finally this component can successfully replace the currently used vacuum pump of the industry. Like vacuum producer there are lots of inventions and improvements need to be done. So that an industry become more automated and accuracy and productivity can be increased.

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