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Design and Fabrication of Automatic Pneumatic Screen Printing Machine

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Abstract: ***Screen printing is a technique of applying a pressure of certain quantity of colouring agent into a specified surface to form a text and lot of development is taken place. Screen printing has application in Wedding cards, Stickers printing, T-shirts, Business cards and textile industries. A lot of innovation has been done by ink injection system, we have introduced pneumatic single acting valve which injects ink at period of time which is driven by compressor and controlled by Arduino board. Proximity sensors will detect the metal objects which cut off the gear motor which in turn stops the rotating worktable for printing action with help of squeegee. The Screen printing is done automatically by moving squeegee to and fro with help of pneumatic cylinder for its operation. Main intention of our project is to improve qualitative prints, by making it pneumatically operated cost and production time of printing is reduced.***

Keywords: Pneumatic single acting valve, Proximity sensors, Squeegee, Pneumatic Cylinder, Rotating worktable

1. Introduction

Printing is a process of reproducing text, or images typically with ink on paper using a machine. Screen printing is a stencil based process; it consists of closed non images and open image areas. It is based on the principle of squeezing the ink through the open area of screen on substrate. The squeeze is moved across the stencil screen which forces the ink through the mesh opening to wet substrate during to and fro motion of squeegee.

Screen printing technology is a way to optimize and obtain the most cost effective facility of applying and patterning different layer for hybrid electronic industry, paper printing industry and textile industry.

Most of the investigations are based on using of manual method of printing production, which consumes more time, non-uniform dispersion of emulsion on substrate and increase the printing time, process time results less production and reduces the mass production in small scale industry. where the vertical movement of the stencil frame and ink injection between the squeezes and to and fro motion of the squeeze rotation of worktable enhances the good printing quality, uniform dispersion of emulsion, printing time, process time and reduces the human effort with minimizing the cost.

2. Design Consideration

2.1 Cylinder 1force during Extension

Diameter =32mm, Stroke = 100mm,
Force = Pressure × $Area_1$ ($A_1 = 8.042\times10^{-4}\ m^2$)
F_1 (1) = 321.68 N (2.1)

2.2 Cylinder 1 force during Retraction

Bore ⌀ = 32mm,
Rod ⌀ = 10mm (Rod Area = $2.010\times10^{-4} m^2$)
$Area_2$= $Area_1$- Rod Area = $6.032\times10^{-4}\ m^2$
F_2 (1) = 241.28N (2.2)

2.3 Cylinder 2 force during Extension

Bore ⌀ = 20mm, Stroke = 200mm
Pressure = 4 bar =0.4 N/m^2
F_1 (2) = 125.66N (2.3)

2.4 Cylinder 2 force during Retraction

Bore ⌀ = 20mm, Rod ⌀ = 8mm
F_2 (2) = 105.55 N (2.4)

2.5 Measuring the friction between the screen and squeegee

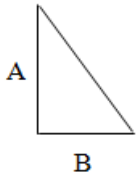
Total Resistance Force = Viscous Force + Sliding force

2.5.1 Viscous Force (F_1)

$F_1 = \eta \times A \times V/X$ (2.5)
η = Viscosity of fluid (emulsion) = $0.997 Ns/m^2$
V = Velocity of motion of squeegee=$0.039 ms^{-1}$
A=Area of contact =$8.96\times10^{-4}\ m^2$
X = Thickness of the fluid (emulsion) =.001

2.5.2 Sliding Resistance Force (F_2)

$F_2 = \mu \times (W+$ Initial Tension) (2.6)
μ= coefficient of friction = A/B =0.36
W = weight of squeegee =15g
Initial tension of screen = 0N



Total force = $F_1 + F_2$= 0.08 N
Power = Total force × Velocity =0.0455W (2.7)

2.6 Calculate the time for each 90^0 rotation of worktable

Radius of worktable = 450mm
Circumference of worktable=2×r×π = 2827.433mm
¼th Rotation of worktable=2827.433/4 = 706.85mm
Speed of motor= 45rpm = 0.75rps
Circumference of 40 mm wheel= 2rπ = 251.327mm
Rotation of wheel=0.75×251.327 = 188.49mm/s (2.8)
Time taken to ¼throtation of worktable=706.85/188.49
= 3.75seconds (2.9)

3. Materials Requirements

- A suitable stencil frame with polyester mesh.
- Double acting cylinders with compressor which is used in vertical and horizontal direction for stencil frame and squeegee respectively.
- A suitable squeegee with rubber at particular angle of cut section.
- Worktable made of wooden board.
- Single valve pneumatic actuated ink injection system, solenoids are used.
- Programmable Arduino board with inductive type proximity sensor.
- Gear motor drive with spring actuated brake wheel.
- Angle frames, rollers, ball bearings and shaft.

3.1 Stencil frame

Figure 1: Stencil frame

Stencil technique is employed in screen printing which uses a tightly woven mesh screen coated in a thin layer of emulsion to reproduce the original image .These stencils are usually made out of thin 100-500nm low stress SIN in which apertures are defined by various lithographic techniques.

The screen tension was in the region of 2– 3.3 N/mm, the off-contact was 0.9–1.5 mm .for this type of adhesive paste.

3.2 Double acting cylinders

Figure 2: Double acting cylinders

There are two pneumatic double acting cylinders which uses air as a working medium and the stroke length of working medium is 100 mm and 200 mm respectively. One of the cylinders is used for the movement of stencil frame in vertical direction and other one for movement of squeegees in horizontal movement which can vary as per our requirement and printing quality.

3.3 Compressor

Figure 3: Compressor

An air compressor is a device which increases the pressure of the air by converting power supplied into potential energy stored in pressurized air.

3.4 Squeegee

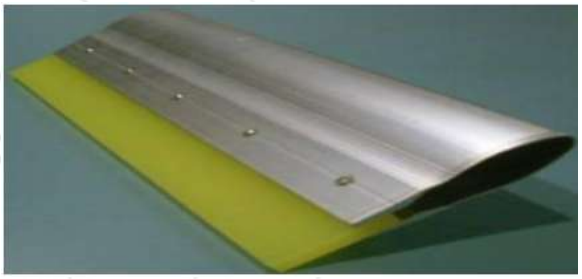


Figure 4: Squeegee

These are aluminum plate fixed with rubber which squeezes the ink through the mesh to print on the substrate. The dimension of the squeegee varies from 1 inch to A5 inches. Different types of squeegee are triangle cut and square cut type. We introduced two squeegees one which spread the ink uniformly on the stencil frame during forward stroke and squeezes the ink while return stroke by another squeegee.

3.5 Worktable

Figure 5: Worktable

Worktable is made up of wooden board of diameter 900mm, which is mounted on a plate with a shaft. In order to avoid the hobbling of the shaft the rollers are used.

3.6 Ink injection system

Figure 6: Ink injection system

This is a single acting pneumatic valve which works at a pneumatic pressure of 3.5 to 7 bar.it works at a fluid temperature range of -10^{o} to 180^{o}which injects ink at a period of time.

3.7 Arduino board

The Arduino Uno is a small, complete, and breadboard-friendly board based on the AT mega328 (Arduino Uno 3.x) orATmega168 (Arduino Uno 2.x). The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

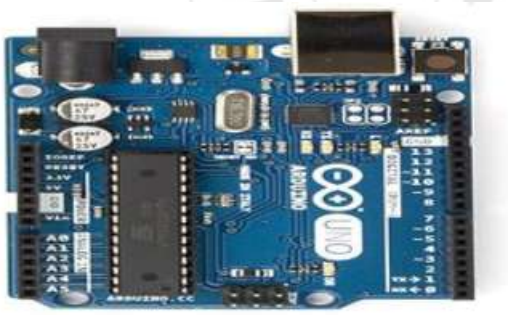


Figure 7: Arduino board

3.8 Proximity sensors

Figure 8: Proximity sensors

Sensor which are able to detect nearby object without any physical contact. Here, the inductive type is used for metal target which is NPN style. These type of sensors are widely applied in measuring.

3.9 Gear motor

Figure 9: Gear motor

The 12V DC Geared Motor can be used in variety of robotics applications and is available with wide range of RPM and Torque. The gear motor is used for rotation of worktable because 4 sheets are placed per cycle.

3.10 Ball bearing

Figure 10: Ball bearing

The deep grove ball (6206) bearings are simple in design, non-separable, capable of operating at high and even very high speeds which can withstand loads. These are inserted inside the bush which provides smooth and frictionless rotation of worktable.

3.11 Solenoid valve

Figure 11: Solenoid valve

A solenoid valve is an electromechanically operated valve which controls the flow of liquids or gases. The 5/2 solenoid valve with push in fittings is bolted on to a function plate which is equipped with a port P and a silencer.

The solenoid valve is reversed when voltage is applied to the solenoid coil (1-4) and brought back in to initial position (1-2) by the return spring when the signal is removed. The switching status is shown by an LED in the terminal housing.

4. Circuit Diagram

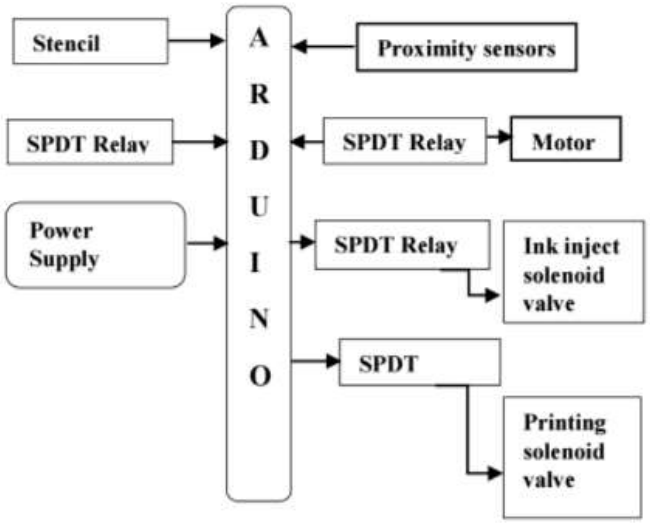


Figure 12: Circuit diagram

Pin specification

- Pin 08 - Ink injection relay output
- Pin 10 - Stencil relay output
- Pin 09 - Squeegee output
- Pin 11 - Motor relay output
- Pin 07 - proximity sensors
- Proximity sensor- metal detect – output as 10V
- Proximity sensor - not detect-ground

5. Working Principle

The working of the components of screen printing is as explained below:

- The paper is placed on the rotating work table with 90°each. The pressure of compressor is set to 4 bar.
- The motor relay is switched on to rotate the worktable till the proximity sensor detects the metal screws, which is fixed under the worktable for 90°
- The power supply is cut-off once the proximity sensor detects the metallic objects.

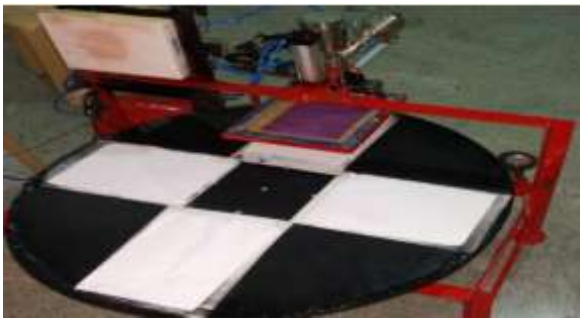


Figure 13: Overall assembly of Machine

- The stencil frame (vertical pneumatic cylinder) activated by 5/2 solenoid valve, which vertically moves down and position on the substrate of the worktable.
- The pneumatic ink injection system is actuated by 3/2 solenoid valve, which injects the ink between the squeezes.
- The squeeze (horizontal pneumatic cylinder) is activated by 5/2 solenoid valve results in spreading of the ink during forward stroke. Meanwhile, squeezing the ink during return stroke by pre-set pressure.
- Once printing is done the solenoid activates the stencil frame (vertical pneumatic cylinder) results in stencil frame moves up and the cycle is repeated.

6. Flow Chart

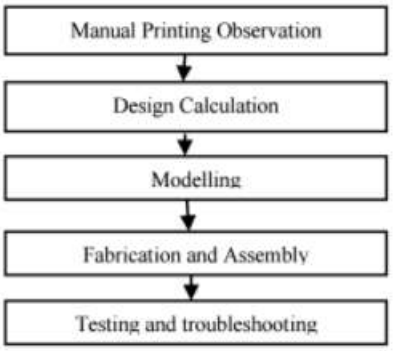


Figure 14: Flowchart

7. Results and Discussions

7.1 Off Contact compensation with respect to Screen Tension

The objective of the project was to design and fabricate automatic pneumatic screen printing machine.

Table 1: Off Contact compensation with respect to Screen Tension.

Trial	Screen Tension (N/mm^2)	Off Contact (mm)
1	1.6	1.74
2	2	1.4
3	2.2	1.3
4	2.4	1.2
5	2.6	1.1
6	2.8	1.05
7	3	1.1

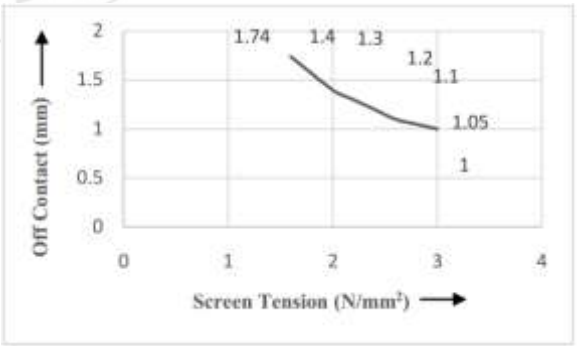


Figure 15: Off Contact compensation with respect to Screen Tension.

In this case graph shows that, the off-contact has to be increased according to squeegee force has not been changed, the paste is being printed with the same pressure, and due to the modified off-contact the elastic force resulting from

screen deflection and the paste adhesion has the same force condition as at the initial screen tension and off-contact.

7.2 Comparison of off-set printing and digital printing.

In this case graph shows that, if volume of production increases cost per unit page decreases in case of offset printing, digital printing cost remains same. Hence it is suitable for mass production.

Table 2: Comparison of off-set printing and digital printing

No of copies	Cost per Page (off-set)	Cost per page (Digital)
200	1.2	0.79
400	0.8	0.62
600	0.55	0.55
800	0.45	0.54
1000	0.3	0.50

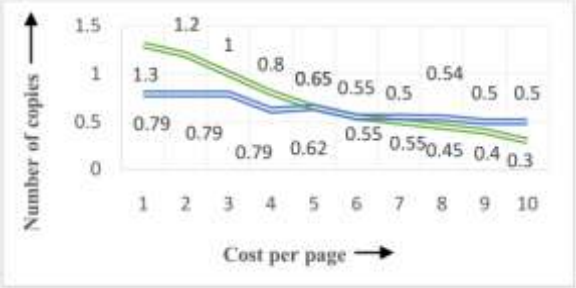


Figure 16: Comparison of off-set printing and digital printing

7.3 Variation of printing quality and thickness of paper

Table 3: Variation of printing quality and thickness of paper

Sl. No	Thickness of paper (mm)	Printing quality
1	0.01	1-No Printing
2	0.02	2-Good Printing
3	0.04	3-Better Printing
4	0.05	4-Best Printing
5	0.1	5-Best Printing

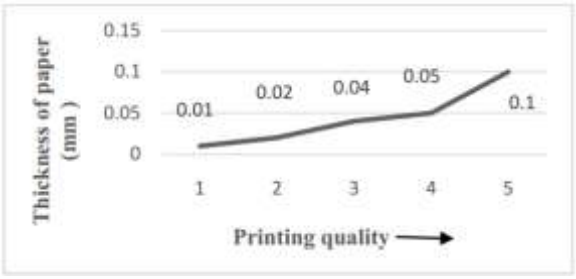


Figure 17: Variation of printing quality and thickness of paper

In this case graph shows that thickness of paper increases printing quality also increase. In graph at 0.05 mm best quality is obtained and greater the value of thickness printing quality also increases.

8. Applications

Printing is a wide variety of applications; some of the applications is mentioned as below,

- Printing wedding cards, visiting cards.
- Printing animations, pictures on textiles.
- Printing on balloons, decals, medical devices.
- Printed electronics including circuit board printing.
- Product labels, signs and display and snowboard graphics.

9. Conclusion

In this paper, we have shown a model for screen printing machine which mainly works on pneumatic system.

In this paper we concluded that designed model eliminates the manual printing method by adopting completely automated pneumatic actuation system. It reduces the printing time and processing time, the dispersion of emulsion can be reduced.

The pressure can be variable for printing good quality prints; hence it can be adopted for small and medium scale industry. The different colour of print can be obtained by use of single colour at a time.

This model reduces the human effort and makes the process easy to perform.

10. Future Scope

In future we want to work with machine to find out more cost effective and use of multicolour printing on paper. Optimize the reduction of printing time and process time. We can adopt the mechanical programmed software for printing textiles/paper on different position. This would help in mass production in large scale industry results in economic growth.

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