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Design and Fabrication of Pneumatic Robotic Arm

Prof.S.N.Teli [1] , Akshay Bhalerao [2] ,Sagar Ingole [2],Mahesh Jagadale [2] , Kiran Kharat [2].
[1] (Professor, Department of Mechanical Engineering , Saraswati College of Engineering , Kharghar, Mumbai University , India.)
shivanandteli@yahoo.com
[2] (Student, Department of Mechanical Engineering , Saraswati College of Engineering ,Kharghar, Mumbai University , India.)
akshaybhaleraocool@gmail.com , sagaringole608@gmail.com , jagadalemahesh95@gmail.com , kirankharatkk1996@gmail.com

***Abstract* - This project aims to Design and fabricate pneumatic arm for pick and place of cylindrical objects. The handling of materials and mechanisms to pick and place of objects from lower plane to higher plane and are widely found in factories and industrial manufacturing. There are number of pneumatic arms are available which consists of so many mechanisms hence becomes expensive. The designed pneumatic arm consists of two cylinders, a shaft works with lead screw mechanism capable of converting motion of piston to rotational motion of arm with help of using compressed air. The designed processes are carried out based on integrated information of kinematics dynamics and structural analysis of the desired robot configuration as whole. The highly dynamic pneumatic arm model can be easily set at intermediate positions by regulating the pressure using the flow control valve. It can be used in loading and unloading of goods in a shipping harbour as the movement of goods is done from lower plane to higher plane.**

***Keywords* – Pneumatic arm, Work volume, Cylindrical objects, Steel shaft A1 Cylinders, C-45 pistons, pilot valve, grippers.**

I. INTRODUCTION

1.1 Material Handling System

Material handling is a necessary and significant component of any productive activity. It is something that goes on in every plant all the time. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position and for the right cost, by using the right method. It is simply picking up, moving, and lying down of materials through manufacture. It applies to the movement of raw materials, parts in process, finished goods, packing materials, and disposal of scraps. In general, hundreds and thousands tons of materials are handled daily requiring the use of large amount of manpower while the movement of materials takes place from one processing area to another or from one department to another department of the plant. The cost of material handling contributes significantly to the total cost of manufacturing. Handling and storing materials involve diverse operations such as hoisting tons of steel with a crane; driving a truck loaded with concrete blocks; carrying bags or materials manually; and stacking palletized bricks or other materials such as drums, barrels, kegs, and lumber. The efficient handling and storing of materials are vital to industry. Fig 1 Material handling system The primary objective of a material handling system is to reduce the unit cost of production. The other subordinate objectives are reduction in manufacturing cycle time, delays and damage, Promotes the safety and improve working conditions, maintain or improve product quality Promote productivity, reduces tare weight, control inventory, promote increased use of facilities.

1.2 Pneumatics in Material Handling Pneumatic systems usually operate at much lower pressure than hydraulic systems do, pneumatics holds many advantages that make it more suitable for many applications**.** Because pneumatic pressures are lower, components can be made of thinner and lighter weight materials, such as aluminium and engineered plastics, whereas hydraulic components are generally made of steel and ductile or cast iron. Hydraulic systems are often considered rigid, whereas pneumatic systems usually offer some cushioning, or “give.” Pneumatic systems are generally simpler because air can be exhausted to the atmosphere, whereas hydraulic fluid usually is routed back to a fluid reservoir.

Pneumatics also holds advantages over electromechanical power transmission methods**.** Electric motors are often limited by heat generation. *Heat generation is usually not a concern with pneumatic motors* because the stream of compressed air running through them carries heat from them. Furthermore, because pneumatic components require no electricity, they don’t need the bulky, heavy, and expensive explosion-proof enclosures required by electric motors. In fact, even without special enclosures, electric motors are substantially larger and heavier than pneumatic motors of equivalent power rating. Plus, if overloaded, pneumatic motors will simply stall and not use any power. Electric motors, on the other hand, can overheat and burn out if overloaded. Moreover, torque, force, and speed control with pneumatics often requires simple pressure- or flow-control valves, as opposed to more expensive and complex electrical drive controls. And as with hydraulics, pneumatic actuators can instantly reverse direction, whereas electromechanical components often rotate with high momentum, which can delay changes in direction.

II LITERATURE SURVEY

Ted hesselrod,kakali sarkar ,P. Patric van der smagt .klaus schulten [1] The neural map algorithm has been employed to control a five joint pneumatic arm and gripper through feedback from two video cameras. The pneumatically driven robot arm (soft arm)employed in this investigation shares essential mechanical characteristics with the skeletal muscle systems.to control the arm 200 neurons formed a network representing a 3D workspace embedded in a 4D system of coordinates form two cameras for imterpolating nbetwenn positions.this was achieved through employment of a linear correction algorithm using the jacobian matrices mentioned above.

Tetsuya Akagi, Shujiro Dohta, Feifei Zhao, and Takahiro Fujikawa [2] A wearable actuator needs to be flexible so as not to injure the human body. The purpose of our study is to develop a flexible and lightweight actuator which can be safe enough to be attached to the human body, and to apply it to a robot arm and rehabilitation device. New types of flexible pneumatic actuator that can be used even if the actuator is deformed by external force have been developed in our previous studies. In this paper, a robot arm using the flexible pneumatic cylinder that can realize a natural flowing movement with multi-motion such as bending, expanding, and contracting is described.

G. Carducci Mario Massimo Foglia Angelo Gentile Nicola Ivan Giannoccaro A. Messina [3]This paper shows experimental results carried out considering a vision feedback obtained with a cheap cam mounted on the top of end-effector. This vision feedback is processed in order to localise the plant position along the movement plane of the robotic arm end-effector. A kinematical model of the robotic arm defines each actuator trajectory to lead end-effector to grasp the plant in the taking plane according to the vision feedback. All the control and localisation system was realised using a single commercial PC.

Swapnil Gurav, Chetan Bagul, Rahul Ramole, Pukhraj Patil [4] This paper deals with design and fabrication of end effectors of robot to perform pick and place activity. For material handling in industries robot with special purpose end effectors plays a great role to reduce cycle time and cost of production. The design of gripper is propelled by the requirement for grasping of sheet metal parts in stamping and fording industry. The design has focused on provincial general purpose gripper having kinematic and dexterousness similar to human hand (humanoid)

Kouichi Watanabe ,HisashiNagayasu ,NaokiKawakamil SusumuTachi1 [5] Thedesign and control of robots from the perspective of human safety is desired .We propose a Mechanical Compliance Control System as a new pneumatic arm control system.However ,safety against collisions with obstacles in a nonpredictable environment is difficult to insure inprevious system.The main feature of the proposed system is that the two desired pressure values are calculated by using two other desired values ,the end compliance of the arm and the end position and posture of the arm.

Dongjun Shin, Irene Sardellitti, Yong-Lae Park, Oussama Khatib, Mark Cutkosky [6] The increasing demand for physical interaction between humans and robots has led to the development of robots that guarantee safe behavior when human contact occurs. However, attaining established levels of performance while ensuring safety poses formidable challenges in mechanical design, actuation, sensing and control. To achieve safety without compromising performance, the human-friendly robotic arm has been developed using the concept of hybrid actuation.

Jose A. Riofrio and Eric J. Barth [7] The design of a free piston compressor (FPC) intended as a pneumatic power supply for pneumatically actuated autonomous robots is presented in this paper. The FPC is a proposed device that utilizes combustion to compress air into a high-pressure supply tank by using the kinetic energy of a free piston. The device is configured such that the transduction from thermal energy to stored energy, in the form of compressed gas, is efficient relative to other small-scale portable power supply systems.

Joachim Schr¨oder, Kazuhiko Kawamura, Tilo Gockel1, and R¨udiger Dillmann [8] studied Favorable characteristics of pneumatic actuators, such as high force-to-weight ratio and safe interaction with humans are very suitable for robotic applications. At the Center for Intelligent Systems at Vanderbilt University, pneumatic actuators are used in our humanoid robot, called Intelligent Soft Arm Control (ISAC) and have been subject in several papers in the past [1–4]. Due to the high nonlinearity of the system combined with the serial kinematics, a fast and robust control is necessary to achieve the desired motion.

Emanuel Todorov1, Chunyan Hu1, Alex Simpkins1 and Javier Movellan [9] Pneumatic actuators have a number of advantages over el ectric motors, including strength-to-weight ratio, tunable compliance at the mechanism level, robustness, as well as price. Their properties are in many ways similar to muscle properties, which further makes them a good choice for bio-inspired robotic designs.Contrary to popular belief, we found it surprisingly easy to work with these pneumatically-actuated robots and obtained high tracking performance.

Tudor Deaconescu, Member, IAENG and Andrea Deaconescu, Member [10] The paper addresses the theoretical and experimental study of the operational behaviour of a fluidic driving system based on pneumatic muscles. A concrete application of pneumatic muscles is presented, namely two original non-anthropomorphic gripping systems with two jaws and integrated control system, developed by the authors. The presented solutions were selected upon analysis of several possible constructive variants, described in the paper, and represent an optimum as to both overall dimensions and performance

Ashraf Elfasakhany, Eduardo Yanez, Karen Baylo, Ricardo Salgado [11] The main focus of this work was to design, develop and implementation of competitively robot arm with en- hanced control and stumpy cost. The robot arm was designed with four degrees of freedom and talented to accomplish accurately simple tasks, such as light material handling, which will be integrated into a mobile platform that serves as an assistant for industrial workforce. The robot arm is equipped with several servo motors which do links between arms and perform arm movements.

Sho Maeda, Nobutaka Tsujiuchi1,, Takayuki Koizumi1, Mitsumasa Sugiura and Hiroyuki Kojima [12] developed a pneumatic robot arm driven by pneumatic actuators as a versatile end effector for material handling systems. The arm consists of a pneumatic hand and pneumatic wrist. The hand can grasp various objects without force sensors or feedback control. Therefore, this study aims to control the wrist motions to expand the hand motion's space. The hand mimics the human hand shape and can grasp objects that have different shapes and mechanical characteristics. The wrist has redundant degrees of freedom. This is useful when the robot moves to avoid obstacles

Grzegorz granosik, and johann borenstein [13] This paper introduces a new control method for pneumatic actuators, called "Proportional Position and Stiffness (PPS)" controller. The PPS method provides both position and stiffness control for a robot joint driven by a pneumatic cylinder with four ON-OFF valves. In addition, the proposed control system consumes much less compressed air than comparable strategies. These features make the PPS method highly suitable to applications on mobile robots.

Mohd Aliffa, Shujiro Dohtaa, Tetsuya Akagia, Hui Lia [14] The purpose of our study is to develop the flexible and lightweight actuator and apply it into a flexible robot arm. In this paper, the master-slave attitude control and the trajectory control of the flexible robot arm are proposed. This robot arm has three degree-of-freedom that is bending, expanding and contracting and will be applied into a rehabilitation device for human wrist. The master-slave control system which is proposed in this paper is necessary when a physical therapist wants to give a rehabilitation motion to a patient.

Che Soh, S.A. Ahmad, A.J. Ishak and K. N. Abdul Latif [15] Adjustable gripper for robotic system that is capable in identifying shape and size of an object is needed in many applications especially for picking and placing operation. This is due to some of the grippers' design are limited only to one specific shape or size that make picking and placing operation difficult The main objective is to design a robust gripper that can perform easier and faster picking and placing operation for multiple shapes and sizes objects. This adjustable gripper for robotic system can to improve the picking and placing operation in manufacturing field in producing more outputs without the needs to.

Yousif I. Al Mashhadany, Nasrudin Abd Rahim [16] Solar cell testers sort photovoltaic cells according to their electrical performance, tested under simulated sunlight. A variety of testers exist, but they all face a common challenge of handling cells that are very small and thin, which makes it difficult to transport the cells from the conveyer to the storage box. This paper presents a new design for a handling robot with vacuum end-effectors, which uses a PLC controller to govern the movement of the cells and the testing process. The design applies to solar cell testers for monocrystalline, polycrystalline, cadmium telluride (CdTe), and copper indium diselenide (CIS) cells.

Rakesh.N, Pradeep Kumar.A, Ajay.S [17] The paper proposes a cheap and effective method for design and manufacturing of a three degree of freedom revolute jointed robotic arm. The design process begins by specifying top–level design criteria and passing down these criteria from the top level of the manipulator's structure to all subsequent components. With this proposed approach the sequential design intents are captured, organized and implemented based on the entire system objectives, as opposed to the conventional design process which aims at individual components optimization.

Alexander Bierbaum, Julian Schill, Tamim Asfour and R¨udiger Dillmann [18] Robot hands based on fluidic actuators are a promising technology for humanoid robots due to their compact size and excellent power-weight-ratio. Yet, such actuators are difficult to control due to the inherent nonlinearities of pneumatic systems. In this paper we present a control approach based on a simplified model of the fluidic actuator providing force and position control and further fingertip contact detection. We have implemented the method on the microcontroller of the human hand sized FRH-4 robot hand with 8 DoF and present results of several experiments, including system response and force controlled operation.

Pieter Beyl, Bram Vanderborght, Ronald Van Ham, Michaël Van Damme, Rino Versluys & Dirk Lefeber [19] This paper gives an overview of different robotic applications based on two compliant actuator technologies developed within the Robotics & Multibody Both actuators have built-in intrinsic compliance, which makes for two control parameters to be set, namely the equilibrium position of the actuated joint and the equivalent torsion spring stiffness. The increase of control complexity is countered by the added value of adaptable compliance.

B. Tondu S. Ippolito J. Guiochet A. Daidie [20] Braided pneumatic artificial muscles, and in particular the better known type with a double helical braid usually called the McKibben muscle, seem to be at present the best means for motorizing robot-arms with artificial muscles. However, fewer studies have concentrated on analyzing the integration of artificial muscles with robot-arm architectures since the first Bridgestone prototypes were designed. In this paper we present the design of a 7R anthropomorphic robot-arm entirely actuated by antagonistic McKibben artificial muscle pairs. The validation of the robot-arm architecture was performed in a teleoperation mode.

Gade S.V., Waghmare S.L. , Wagh P.R. , Baheti.A.S .[21] This paper deals with the study and review of Automatic Lubrication System which is based upon pneumatic. The conventional lubrication system consist of manual greasing to different greasing points . This system usually time consuming so downtime is more. Previously we have to shut down system for greasing. This project includes design and manufacturing of automatic lubrication system. Which allows to do greasing on regular time period and in adequate amount. This system also ensures safety to components and labour. It reduces manpower requirement for system lubrication. It ensures proper lubrication to the system.

Milind R. Shinde, V. N. Bhaiswar, B. G. Achmare [22] Normally the loading and unloading of work piece on lathe machine is done with manual interface. Our aim is to make it automatic and fast for better accuracy and improved performance. Robotic work cell simulation is a modeling-based problem solving approach developed for the design, analysis and offline programming of robotic work cell. This will increase the total productivity of machine where there is continuous operation and complete machine utilization. Use of Workspace LT software for designing the robotic components is very popular.

S. Premkumar, K.Surya Varman, R.Balamurugan [23] Robot manipulator is an essential motion subsystem component of robotic system for positioning, orientating object so that robot can perform useful task The main aim of our work is to collaborate the gripper mechanism and vacuum sucker mechanism working in a single pick and place robotic arm. This robot can be selfoperational in controlling, stating with simple tasks such as gripping, sucking, lifting, placing and releasing in a single robotic arm. The main focus of our work is to design the robotic arm for the above mentioned purpose. Robotic arm consists of revolute joints that allowed angular movement between adjacent joint.

S. S Dinde, Suraj M Kawale, Yogesh T Parkhe, Salman R Shaikh [24] Adjustable gripper for robotic system that is capable in identifying shape and size of an object is needed in many applications especially for picking and placing operation. This is due to some of the grippers' design are limited only to one specific shape or size that make picking and placing operation difficult. This adjustable gripper for robotic system can to improve the picking and placing operation in manufacturing field in producing more outputs without the needs to.

Xu Sun, Samuel M. Felton, Ryuma Niiyama, Robert J. Wood, and Sangbae Kim [25] In this paper, they introduce a novel self assembling method with a planar pneumatic system. Inflation of pouches translate into shape changes, turning a sheet of composite material into a complex robotic structure. This new method enables a flat origami-based robotic structure to selffold to desired angles with pressure control. It allows a static joint to become dynamic, self-actuate to reconfigure itself after initial folding.

III. OBJECTIVES AND METHODOLOGY

The main objective of our proposed work is Design and fabricate a pneumatic arm With Work volume 0.6 m3 With 1800 base rotation To pick and place cylindrical objects from lower plane to higher plane,by using Steel shaft Al cylinders,C-45 Pistons, manual operated pilot valve and grippers. The Project planning and methodology involved the following steps;

Study of existing pneumatic arms:

In this step we observed the existing material handling system in the market. We observed the mechanism of the holding the material, lifting and placing it on plane. For instance the working we observed was run by a couple of motors 3-4 pneumatic cylinders which was very expensive.

Selection of mechanism for threshing action:

By observing the existing material handling machines about how they displaces the metal/material we came to a conclusion of adopting a helical slot on shaft which will convert linear motion of lifting cylinder into rotational motion of arm.

Preparation of project plan:

In this stage we started preparing the machine design and the concept. The way our Arm would look was decided and studied thoroughly. The first conceptual plan is as shown and various changes were made to improve the performance and to make cost effective.

Selection of appropriate materials:

Selection of appropriate material is necessary to build an efficient system where both performance and cost were accountable. The materials were selected such that it would withstand vibrations and varying load acting on it. Materials used to build the system were almost mild steel and nylon-cotton for belt.

Design calculations and 3D Modelling:

calculations were carried out for design of shaft, arm, griping cylinder and lifting cylinder. Accordingly 3D model of the components were prepared using Modelling Software CREO 2.0. The 3D model of components and the Assembly model gave the dimensional pictorial view of the Pneumatic arm which was to be fabricated.

Fabrication and Assembly of the Machine:

After preparing the 3D model of the machine using CREO 2.0 operations like Arc Welding, Drilling, Boring, Step turning, Threading, Grinding, Sheet metal cutting, and mounting of bearings were carried out. The full arm was assembled using permanent fastening like welding and temporary fastenings like bolt and nuts. Various components are used in the fabrication of Pneumatic arm are listed below

2.1 Pneumatic cylinder

Double acting cylinder is considered to be as a main actuator in any pneumatic systems. Double acting cylinders are more expensive than single acting cylinders, but double acting cylinders are superior than the single acting cylinders by any other important measure. Double acting cylinders are faster and stronger. In industrial applications, single acting cylinders are also used if possible, but when speed and force are important double acting cylinder are employed. Applications include opening and closing doors, taking things off conveyor belts and putting things on conveyor belts.

2.2 Direction Control Valve

A 5/2 way direction control valve, from the name itself has 5 ports equally speed and 2 flow positions. It can be used to isolate and simultaneously bypass a passage way for the fluid which for example shoud retract or extend a double acting cylinder. There are variety of ways to have this valve actuated. A solenoid valve is commonly used, a lever can be manually twist or pinch to actuate the valve, an internal or external hydraulic or pneumatic pilot to move the shaft inside, sometimes with a spring return on the other end so it will go back to its original positions when pressure is gone, or a combination of any of mention above. Figure 2.2 5/2 Direction Control Valve In the Illustration given, a single solenoid is used and a spring return is installed in the other end. The inlet pressure is connected to (P)1. (A)2 could possibly be connected to one end of the double acting cylinder where the piston will retract while (B)4 is connected to the other end that will make the piston extend. The normal position when the solenoid is de-energized is that the piston rod is blocking (B)4 and pressure coming from (P)1 passes through (A)2 that will make the cylinder normally retracted. When the solenoid is energized, the rod blocks (A)2 and pressure from (P)1 passes through (B)4 and will extend the cylinder.and when the solenoid is de-energized, the rod bounces back to its original position because of the spring return. (E)3 and (E)5 is condemned or used as exhaust.

2.3 Flow control valves

A pneumatic system, energy that will be used by the system and transmitted through the system is stored as potential energy in an air receiver tank in the form of compressed air. A pressure regulator is positioned after a receiver tank and is used to position out this stored energy to each leg of the circuit. A pressure regulator is a normally open valve. With a regulator positioned after a receiver tank, air from the receiver can expand through the valve to a point downstream. As pressure after the regulator rises, it is sensed in an internal pilot passage leading to the underside of the piston. This piston has a large surface area exposed to downstream pressure and for this reason is quite sensitive to downstream pressure fluctuations. When downstream pressure nears the present level, the piston moves upward pulling the poppet towards its seat . The poppet, once it seats, does not allow pressure to continue building downstream.

IV.CONCLUSION

The design and fabrication of pneumatic arm for pick and place is completed with economic and effective considerations. It is controlled by manually flow control and direction control valves.P n e u m a t i c arm movement and rotation is done by pneumatic cylinder using a helical slot mechanism. The gripper is also a pneumatic actuator which holds objects which are rectangular in shape. The maximum pay load is yet to be calculated and total weight of arm is 25kgs. The model is expected to lift objects of atleast 10 kgs weights.

V. REFERENCES

[1] Ted hesselrod,kakali sarkar ,P. Patric van der smagt .klaus schulten “neural network control of a pneumatic robotic arm” , January 1994 .

[2] Tetsuya Akagi, Shujiro Dohta, Feifei Zhao, and Takahiro Fujikawa, “ Development and Attitude Control of Flexible Robot Arm Using Flexible Pneumatic Cylinder with Simple Structure”, 2001.

[3] G. Carducci Mario, Massimo Foglia ,Angelo Gentile ,Nicola Ivan, Giannoccaro A. Messina, “Pneumatic robotic arm controlled by on-off valves for automatic harvesting based on vision localization” ,January 2005

[4] Swapnil Gurav, Chetan Bagul, Rahul Ramole, Pukhraj Patil, 5 Prof. Sneha Bire , “ Review on design and fabrication of pneumatic gripper for material handling”, Feb 2008.

[5] Kouichi Watanabe ,Hisashi Nagayasu ,Naoki Kawakami 1and Susumu Tachi , “Mechanical Compliance Control System for A Pneumatic Robot Arm”, August 20-22, 2008.

[6] Dongjun Shin, Irene Sardellitti, Yong-Lae Park, Oussama Khatib, and Mark Cutkosky “Design and Control of a Bio-inspiredHuman-Friendly Robot”, 2009.

[7] Jose A. Riofrio and Eric J. Barth “ Design of a Free Piston Pneumatic Compressor as a Mobile Robot Power Supply”.2009

[8] Joachim Schr¨oder , Kazuhiko Kawamura , “ Improved control of a humanoid arm driven by pneumatic actuators” Feb 2010.

[9] Emanuel Todorov, Chunyan Hu, Alex Simpkins and Javier Movellan , “ Identification and control of a pneumatic robot” , 2010.

[10] Tudor Deaconescuand Andrea Deaconescu , “Pneumatic Muscle Actuated Gripper”, March -2011.

[11] Ashraf Elfasakhany, Eduardo Yanez, Karen Baylon, Ricardo Salgado, “Design and Development of a Competitive Low-Cost Robot Arm with Four Degrees of Freedom”, November 2011.

[12] Sho Maeda, Nobutaka Tsujiuchi. Takayuki Koizumi ,Mitsumasa Sugiura and Hiroyuki Kojima , “Development and control of pneumatic robotic arm for industrial fields”, June 2012.

[13] GRZEGORZ GRANOSIK, and JOHANN BORENSTEIN “ Minimizing Air Consumption of Pneumatic Actuators in Mobile Robots”.2012

[14] Mohd Aliffa, Shujiro Dohtaa, Tetsuya Akagia, Hui Lia , “Development of a simple-structured pneumatic robot arm and its control using low-cost embedded controller”. 2012.

[15] Che Soh , S.A. Ahmad, A.J. Ishak and K. N. Abdul Latif, “Development of an adjustable gripper for robotic picking and placing operation”, DECEMBER 2012.

[16] Yousif I. Al Mashhadany, Nasrudin Abd Rahim , “Design of a Pneumatic Robotic Arm for Solar Cell Tester System by Using PLC Controller”, January 2013.

[17] Rakesh.N, Pradeep Kumar.A, Ajay.S , “Design And Manufacturing Of Low Cost Pneumatic Pick And Place Robot”, 8, AUGUST 2013

[18] Alexander Bierbaum, Julian Schill, Tamim Asfour and R¨udiger Dillmann , “Force Position Control for a Pneumatic Anthropomorphic Hand”,2013

[19] Pieter Beyl, Bram Vanderborght, Ronald Van Ham, Michaël Van Damme, Rino Versluys & Dirk Lefeber , “ Compliant Actuation in New Robotic Applications”.Feb 2014.

[20] B. Tondu ,S. Ippolito,J. Guiochet ,A. Daidie , “A Seven-degrees-of-freedom Robot-arm Driven by Pneumatic Artificial Muscles for Humanoid Robots” ,2014

[21] Gade S.V. , Waghmare S.L. , Wagh P.R. , Baheti.A.S “Review of Automatic Lubrication in pneumatic system”, 2015.

[22] Milind R. Shinde, V. N. Bhaiswar, B. G. Achmare ,“Designing a suitable robotic arm for loading and unloading of material on lathe machine using workspace simulation software” ,Jan-2016.

[23] S. Premkumar,a, K.Surya Varman,b, R.Balamurugan, “Design and Implementation of multi handling Pick and Place Robotic Arm”, March 2016.

[24] S . S Dinde, Suraj M Kawale, Yogesh T Parkhe, Salman R Shaikh , “International Journal of Advanced Research in Computer Science and Software Engineering” ,4, April 2016.

[25] Xu Sun, Samuel M. Felton, Ryuma Niiyama, Robert J. Wood, and Sangbae Kim , “Self-folding and Self-actuating Robots: a Pneumatic Approach”,2016.