DESIGN AND DEVELOPMENT OF PNEUMATIC STEERING CONTROL SYSTEM FOR AUTOMOTIVE VEHICLES

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Abstract – *The emergence of technologies such as power steering has helped make driving less burdensome on drivers and increased the pleasure of driving. Power steering systems practically always make use of fluid pressure as a means of assisting the driver in turning the front wheels of the vehicle. The application of air pressure is the driving force behind the operation of pneumatic devices and equipment. Pneumatic systems are any tools or gadgets that make use of air in their operation. This type of apparatus runs at a high pressure. Compressed air is used to power an air-operated actuator, which is used to circulate the machine. The control has an instantaneous impact on the air. It was dispersed throughout the system via the tubes and valves. Two wheels, a pneumatic actuator, and a connection for power steering have all been part of this system, which is mounted on a frame. Every single wheel is attached to the shaft of the pneumatic actuator that controls them. The second wheel is connected to the first. Mounting the pneumatic cylinder stroke, which causes steering, is controlled by the direction control lever. The Pneumatic Power Steering System of the car makes driving it very simple, which are already fluid-powered and low-maintenance*

***Key Words*: Pneumatic actuators, Pneumatic Transmission of energy, Wheels, Pneumatic control valve, Links, Solenoid valve**

1. INTRODUCTION

Many tools and pieces of equipment, including automobiles, have pneumatic steering. Heavy machinery is frequently used as an illustration. Under direct or automatic control from control valves, high-pressure compressed air is supplied throughout the steering system to various pneumatic actuators and cylinders with the aid of hoses and tubes. Pneumatic drives are also simple and affordable[1]. Due to the pneumatic control system's reliance on compressed air, it must be made accessible in an amount and at a pressure appropriate to the system's capabilities [2]. An effective and secure way to automate a production line is to make pneumatically powered components. The project's scope included the creation and construction of a compressed air test platform that could duplicate a number of operations [3]. The airflow through the pipe in pneumatic systems is simulated using a linear differential equation based on Newton's second law, accounting for the inertial effects of the air, friction, and local pressure variations [4]. The dynamical link between the actuating forces and a PLSA's two main degrees of freedom, bending and steering, is directly determined using the general PLSAs [5]. The dynamical link between the actuating pressures and the two fundamental degrees of freedom of a PLSA, bending and steering, is derived using the General PLSAs in a parameter-independent manner [5]. The cyclical storage of exhaust air from a few outlets of an industrial-scale arbitrary pneumatic machine output is being expanded in order to improve the energy efficiency of pneumatic machines [6]. To automate the regulation of the proportionate supply of natural gas [7]. The combination of compressed gas energy storage and a nonlinear cam transformation mechanism results in the proposal of a novel isobaric compressed air storage system. Results indicate that this novel isobaric compressed air storage device performs well in terms of energy use and has favourable constant-pressure properties [8]. Multiple-joint, multi-DOF forceps manipulators have been developed by businesses and researchers to make doctors less employable [9]. The design and approval of a pneumatic push-pull actuator for vibration isolation, as well as the development of a unique control law for an autonomous vehicle [10]. An investigation of the dynamic features of systems using both experimentation and analysis [11]. The development of equations to describe the steering wheel's and the front wheels' two-degrees-of-freedom rotations around the kingpin [12]. This study suggests a H/ extension controller based on an active front steering system by combining the extension control into the H mixed sensitivity control regarding sensitivity f. The control's objective is to keep lanes open while adhering to a number of constraints, including actuator saturation of the steering system, an unidentified road's curvature, and an undetermined lateral wind force [13]. The force-balance idea and its use of pneumatic controls, the roles of temperature and pressure in these systems, and the usage of spring range to sequence valves and dampers are all covered [14]. According to the force-balance principle, the enclosure or chamber contains three apertures or ports: one for the supply air intake, one for the output of the control signal, and one for the exhaust [15]. Pneumatic control valve friction issues were somewhat frequent. The basic pneumatic control valve components, such as the valve positioner, valve actuator, and valve body, serve as the foundation for the new semi-physical model for sticky pneumatic control valves proposed in this study [16]. In terms of space efficiency, engine economy, and environmental friendliness, electric power steering (EPS) systems offer a number of advantages over conventional hydraulic power steering. To generate various steering sensations, lessen driver-exercised steering torque, and enhance return-to-center performance, an EPS control algorithm was developed [17]. All of the auxiliary systems typically seen in heavy-duty vehicles (such the power steering pump and air conditioning compressor) are engine-driven, which significantly restricts their performance. Engine speed influences energy consumption as well as outputs (such speed and temperature), even though most auxiliary requirements are unrelated to engine speed [18]. When used, electromagnetic solenoid valves' (SVs) fundamental properties—such as reliability, effectiveness, and remaining useful life (RUL)—regulate their operation in a safe and effective manner [19]. The design and mechatronic requirements for an electrical power steering simulator. In addition to being portable and modular, the simulator's architecture is as identical as it is possible to be, and its steering mechanism is comparable to that of a genuine car [20]. Using a linear quadratic Gaussian, the best control strategy for the tractor's semi-active suspension is created. The simulation makes use of a detailed automotive model as well as a hydro-pneumatic suspension system model created with Simulation X and MATLAB/Simulink [21]. The power-assisted steering system is an improvement in automotive dynamics that increases driver comfort by lowering steering effort and responding more swiftly than a traditional manual steering system.

2. WORKING PRINCIPLE OF PNEUMATIC STEERING CONTROL SYSTEM

Lifting air pressure from low to high is the main goal of a pneumatic power steering system. This can be done by reducing the airflow. Pushing the solenoid valve's lever to its left side allows air to flow through a pneumatic cylinder, as air compressors are typically positive displacement devices. There are five openings and three positions on this solenoid valve. There is one intake port, two discharge ports, and two venting apertures. In the two extreme positions, you can only modify the orientation, but in the middle, nothing changes in terms of its actual form. There are two wires that connect the actuator to the inlet and outlet ports (Cylinder). Through the actuator valve, pressurised air can enter the cylinder block's front end. The air pressure is used to drive the piston backwards during the recovery stroke. At the conclusion of the cutting stroke, air from the solenoid valve enters the cylinder block from behind. The control valve keeps the pressure steady while decreasing the available surface area. Consequently, the piston is subjected to a greater amount of pressure and is able to travel at a faster rate, resulting in a shorter return stroke. Two different types of compressors are used, one of which is a tiny air compressor and the other a larger, two-stage compressor unit. Compressed air is fed into the solenoid valve from the compressor. Solenoid valves are used to control flow in response to signals from a timing device. It is equipped with a motor, a pulley drive, a pressure regulator, and pressurised air tanks that can be used in a hurry. When the predetermined pressure is surpassed, the excess air is let out through a release valve. The compressor has a 10 HP engine and is designed to work at pressures of 145-175 PSI. When air enters the air fitter from the compressor, it is compressed. It's filtered out all the microscopic dust particles. Therefore, pneumatic systems are used to regulate the power steering.

3 PNEUMATIC STEERING CONTROL SYSTEM COMPONENTS:

1. Pneumatic Cylinder - Materials(STEEL, ALUMINIUM STAINLESS STEEL,BRASS etc..)
2. 5/2 double acting Solenoid Valve - Materials (Nylon, PVC,NICKEL PLATED BRASS AND STAINLESS STEEL)
3. Connectors - Materials(Polypropylene is a thermoplastic)
4. Hoses - Materials(Aluminium, plastic ,Rubber, pvc)
5. Suction Cups and Vaccum Generator - Materials(pvc plastic or neoprene mild steel)

3.1. PNEUMATIC CYLINDER/ACTUATOR :

Devices known as pneumatic cylinders are able to transform the potential energy of compressed air or gas into a mechanical motion that may then be used to drive one or more final control elements. As shown in Fig.1.

3.2. 5/2 DOUBLE ACTING SOLENOID VALVE :

The double-acting pneumatic actuators typically use the 5/2 and 5/3 solenoid valves for directional control. Single-coil 5/2 valves often use a return spring or pilot air when the power is cut. Double acting solenoid valves can be made from a variety of materials including nylon, PVC, nickel-plated brass, and stainless steel.As shown in Fig.2.

3.3. CONNECTORS :

In order to attach compressed air tools to a compressed air line, pneumatic connectors are employed. Pneumatic couplers make it easy to connect and disconnect tools from pressurised hoses and pipes. Connectors are constructed out of Polypropylene.

3.4. HOSES :

Compressed air travels through hoses, which are flexible tubes. Aluminum, plastic, rubber, polyvinyl chloride, and other synthetics are all common choices for hose manufacturing. As shown in Fig.4.

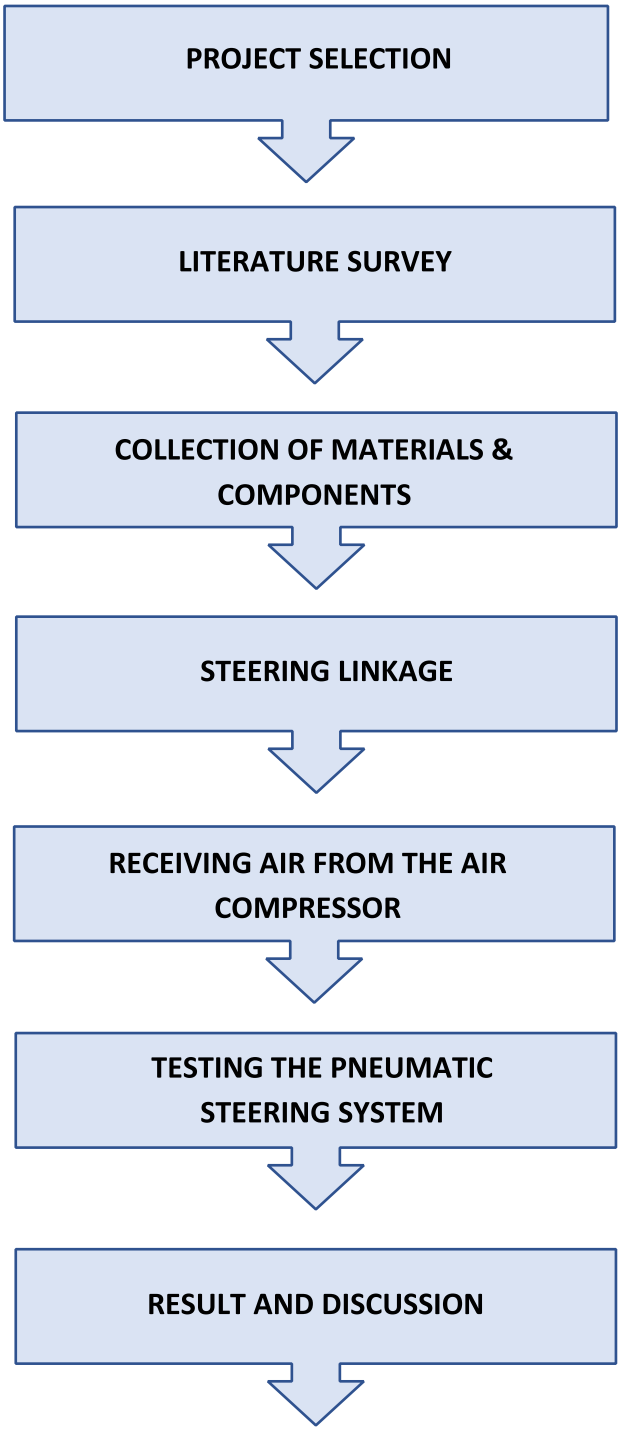
3.5 AIR COMPRESSOR :

Compressed air comes from a machine called an air compressor. In accordance with Fig.5. These storage tanks have pressure-relief valves installed in case of an explosion.

The equation Vr = 14.7(QrQC) Pmin can be used to calculate the reservoir's optimal size.

4 METHODOLOGY:

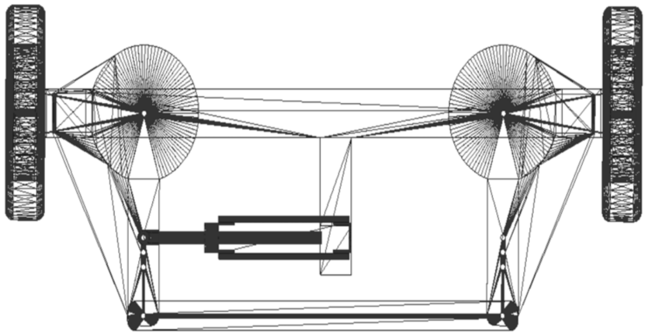
When it comes to low-cost mechanisation, pneumatic is a preferred medium, especially for repetitive or sequential operations. Power (or energy) and control can be supplied through compressed air systems, which are already present in many businesses and buildings (although equally pneumatic control systems may be economic and can be advantageously applied to other forms of power). The main advantages of an all-pneumatic system are often its low cost and ease of use, the latter of which requires almost no maintenance. Furthermore, it may have massive social benefits. The steering system uses pneumatics or some other form of energy transmission to accomplish the given task. To do work, it is necessary to apply kinetic energy to a resistive object, which causes the object to move over a distance. Compressed air is utilised to store potential energy in a pneumatic system. Pneumatic systems convert potential energy stored in compressed air into useful work force when the air is released for expansion (kinetic energy and pressure). Pneumatic transmission of work energy requires strict regulation and management at all times. No useful work will get done unless restraints are applied, and machine users risk injury if they aren't. Using valves, energy transmitted by pneumatics can be easily regulated.



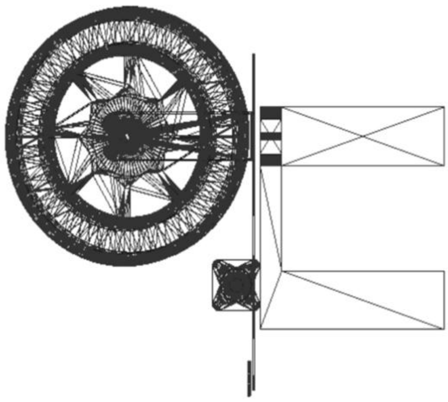
Methodology of Pneumatic Power Steering system

5. 3D design

The wheels, pneumatic actuator, and frame, among other components, may be seen in the front view of the pneumatic power steering system. .... As shown in the figure.6



Wheels, a pneumatic actuator, a frame, and other components make up the pneumatic power steering system's right view. according to the figure.7



6. FEATURES OF PNEUMATIC POWER STEERING SYSTEM:

1. Manageable in size.

2. Easy to operate.

3. Simple in construction.

4. Maintenance cost low and easy.

5. During operations, less time is needed.

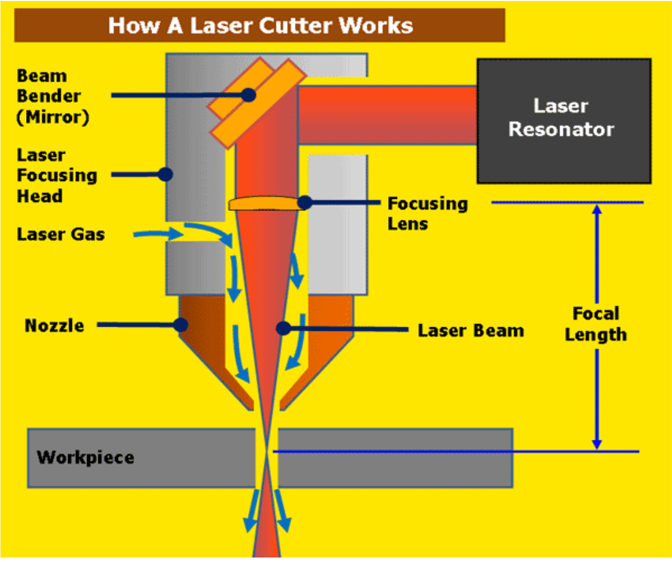
6. Less Effort Required

7. FABRICATION OF PNEUMATIC POWER STEERING SYSTEM:

7.1Laser Beam Machining (LBM):

Lasers can be put to many different tasks. For instance, they can be utilised in the cutting of metal plates. When applied to plate materials like mild steel, stainless steel, and aluminium, laser cutting provides pinpoint accuracy, superior cut quality, a narrow kerf width, a restricted heat impact zone, and the ability to carve intricate shapes and microscopic holes.

Most people know that "LASER" refers to Light Amplification by Stimulated Emission of Radiation. The laser beam is a narrow, intense shaft of light with a certain colour and wavelength. In a standard CO2 laser, this phenomenon happens in the infrared portion of the light spectrum, making it invisible to the naked eye. From the laser resonator, which produces the beam, the beam's diameter is about 3/4 of an inch; this is about the same diameter as the beam as it travels along the machine's beam path. It may first be reflected off of a series of mirrors called "beam benders" before being focussed onto the plate. The laser beam is guided through a nozzle's bore before it reaches the plate. Through that nozzle bore is also coming a compressed gas like oxygen or nitrogen.



7.2 HAND HACKSAW:

A hacksaw has small, sharp teeth and was first and foremost designed for cutting metal. Similar saws, called bow saws, are also used to cut wood.

Hacksaws, a type of hand saw, typically have a C-shaped frame that compresses a blade. Hacksaws like these have pins on the handle (often shaped like a pistol grip) that secure a short, disposable blade. The frames may be adjustable so that different sized blades can be used. A screw or other mechanism is used to maintain tension on the thin blade.Like most frame saws, hacksaws include a blade that can be adjusted so that the teeth face either toward or away from the handle, allowing the saw to be used for cutting on either the push or pull stroke. When sawing horizontally downward while holding the work in a bench vice, the hacksaw blade is often placed so that the cutting edge is facing front.

7.3 DRILLING :

Drilling is a form of cutting where a circular hole is bored out of a solid object using a drill bit. Typically, the drill bit is a revolving, multi-pointed cutting tool. The bit is pressed against the workpiece while spinning at speeds of several hundred to several thousand revolutions per minute. This pushes the cutting edge toward the workpiece by removing chips (swarf) from the hole while it is being drilled.

When drilling into rock, it is common practise to spin the bit, however this does not necessarily result in a circular cut. A drill bit is often hammered rapidly into the hole several times to form the hole. Top-hammer drills have hammering mechanisms on both the inside and the outside of the bit, allowing for drilling in both directions (down-the-hole drill, DTH). Drifter drills, often known as horizontal drilling rigs, are specialised tools used to bore horizontal holes.

7.4 LATHE TURNING :

Turning is a type of machining in which a cutting tool (usually a non-rotary tool bit) moves along a helical toolpath as the workpiece rotates. Tools' axes of motion are essentially linear, even if they may be along a straight line, a sequence of curves, or an angle (in the non-mathematical sense). Conventionally, the term "turning" is used to refer to the process of creating external surfaces via this cutting action, while the term "boring" is used to refer to the process of creating internal surfaces via this same fundamental cutting action (that is, holes of various types). As a result, the term "turning and boring" is used to describe a broader group of (roughly analogous) lathing operations.

7.5 ARC WELDING

Arc welding is a method of combining metals in which electricity is used to provide enough heat to melt the metal, which is then allowed to cool and congeal as a joint. By striking an electric arc between an electrode and the base material, a welding power supply liquefies the metals at the welding spot. Direct current (DC) or alternating current (AC) can be used, and either disposable or permanent electrodes can be used. Welding areas are typically shielded using gas, mist, or slag. Arc welding procedures can be fully automated, semi-automated, or performed by hand. Although technique wasn't widely adopted until after World War II, arc welding's origins may be traced back to the second half of the 19th century. It is still an essential process in the making of steel structures and vehicles.

8. CONCLUSION

We've determined that the pneumatically powered steering mechanism is an exceptionally unique and easy method of controlling the vehicle. This pneumatic steering system is easy to operate in both small and large trucks. This is a form of protection for both the present and the future. This pneumatic steering system frees up more space for the air bag to perform its function.

REFERENCES

[1] "Pneumatic Power Steering" Parth Lad, Vaibhav Wani, Pranit Mehata (2014) ,2349-5162

[2] " Design And Implementation Of An Energy Monitoring Physical Systyem In Pneumatic Automation,"2000,Kyle Abela, Paulrefalo, Emmanuel Francalaza

[3] "Modeling And Optimization For Pneumatically Pitchiner Connected Suspensions Of A Vehicle "(2018),Hengija Zhu, James Yang, Yunqing Zhang

[4] "A Unified System Identification Approach For A Class Of Pneumatically-Driven Soft Actuators"(2001), Xiaochen Wang, Tao Geng,Yahya Elsayed, Chakravathini Saaj, Constant in a Lekakou

[5] J.S.Leszczynski, D. Grybos,"Compensation (2019),For The Complexity And Over-Scaling In Industrial Pneumatic Systems By The Accumulation And Reuse Of Exhaust Air"32

[6] Osinski Yuriy, Danilov Vadim (2019)"Oscillatory Step Rotary Pneumatic Drives In Gas And Transmission Systems

[7] Hu Wang, Zhengren Tong,Xin Dong,Wei Xiong,David Sk.Ting,Rupp Carriveau,Zhiwen Wang(2021)Design And Energy Saving Analysis Of A Novel Isobaric Compressed Air Storage Device In Pneumatic Systems,3,139-141

[8] Katsuhiko Fukushima(2021) A Pneumatic Rotary Actuator For Forceps Tip Rotation

[9] M Damira, M Abou-Alia, A Damirb (2021) Pneumatic Non-Contact Measuring System For In-Process Dimension Measurements

[10] Christiangraf , Rudiger, Kieneke(2010)"Pneumatic Push-Pull Actuator For An Active Suspension,74,112-114

[11] Masato Abe(2015).Steering System And Vehicle Dynamics,5.1,139

[12] Anh-Tu Nguyen, Chouki Sentouh, Jean-Christophe Popieul(2016).Takagi-Sugeno Model-Based Steering Control For Autonomous Vehicles With Actuator Saturation,49,206-211.

[13] Wanzhongzhao, Milan, Chunyanwang, Zhilingjin, Yufang Li(2019),"Extension Stability Control Of Automotive Active Front Steering System"

[14] Montgomery,R. Mcdowall.(2008)"Pneumatic Controls Fundamentals Of Hvac"180,17-25.

[15] Li Tang, Lei Fang, Jaindong Wang , Qunil Shang (2015). "Modeling And Identification For Pneumatic Control Valves With Stiction"1244-1249,48-28

[16] Ji-Hoon Kim, Jae-Bok Song (2002). Control Logic For An Electric Power Steering System Using Assist Motor, 447-459, 12-3.

[17] Emilia Silvas, Eric Backx, Theo Hofman, Henk Voets (2014)" Design Of Power Steering Systems For Heavy-Duty Long-Haul Vehicles"3930-3935,47-3.

[18] Santosh V.Angadi, Robert L.Jackson (2022). A Critical View On The Solenoid Valve Reliability, Performance And Remaining Useful Life Including Its Industrial Applications.36-14

[19] L.Nehaoua, A.Marouf, J.J.Santin, P.Pudlo, M.Djemai (2016). Towards An Electrical Power-Assisted Steering Simulator: Modeling Specifications. 86-62

[20] Kyuhyun Sim, Hwayoung Lee, Ji Won Yoon, Sung-Ho-Hwang(2016). Effectiveness Evaluation Of Hydro-Pneumatic And Semi-Active Cab Suspension For The Improvement Of Ride Comfort Of Agricultural Tractors.69, 23-32

[21]B.U.Raja Ramakrishna, S. Murali(2021).Design And Modelling Of Emergency Power Steering System For Heavy Vehicles,101,10-15