Development of an Integrated Tyre Inflation System

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ABSTRACT

The volume of automobiles on the streets is increasing day by day. It is a known factthat driving on underinflated tyres can adversely affect a vehicle's performance, and thus it is a primary safety concern. Vehicles with underinflated tyres are mostly associated with handling problems that result in significant numbers of highway accidents and fatalities. Under-inflation is also a primary cause for early tyre breakdown and poor tread life, which shortens tyre life, resulting in increased maintenance costs. In addition to contributing to safety hazards and maintenance costs, driving on underinflated tyres can significantly decrease fuel economy. Therefore, the proper monitoring and regulation of tyre pressure can increase tyre life, reduce fuel consumption and would result in improved handling and ultimate safety. The proposed design would bring out a highly efficient and integrated tyre inflation, would supply the necessary air to the tyres as and when required during vehicle motion.

KEY WORDS: Compressed air, Piston Actuated Valve (PAV), Cam Profile.

1. INTRODUCTION

Proper tyre inflation improves fuel economy, reduces braking distance, improves handling and increases tyre life, while under inflation creates overheating, excessive tyre wear and can lead to accidents. Approximately 3/4 of all automobiles operate with at least one underinflated tyre. The main causes of under inflation are natural leakage, temperature changes and road hazards. Drivers typically do not check tyre pressure unless they notice unusual vehicle performance. Visual checks are often insufficient to determine under inflation.

In 2000, the U.S. Transportation Recall Enhancement, Accountability and Documentation Act (TREAD) requested that the National Highway Transport Safety Authority (NHTSA) to investigate the implementation of pressure-reduction warning system in vehicles. Beginning with 2006 models, all passenger cars and trucks in the United States are required to have tyre-pressure monitoring systems (TPMSs). A TPMS is a driver-assist system that warns the driver when the tyre pressure is below or above the prescribed limits. Tyres are built with great care in order to provide excellent service for over thousands of miles. Nevertheless, for maximum benefit, proper maintenance must be ensured.

Indrajeet (2016), proved that a drop in tyre pressure by just a few PSI could result in the reduction of mileage, tyre life, safety and vehicle performance. Tawanda (2016), has stressed the optimization of the automobile tyres, and the fact that the underinflated tyres result in increased fuel consumption and overall cost, while properly inflated and maintained tyres ensure safety and are cost effective big time. Petchinathan (2014), proved that accurate pressure maintenance in tyres resulted in enhanced handling and control of the entire automotive system and this concept was supported by developing an automatic tyre inflator that would inflate the tyres during vehicle motion. Sagar (2016), showed that tyres lose air through normal driving-especially when run through potholes & permeation and also due to temperature changes (seasonal). Hemant (2016), proved that the development of an integrated tyre inflation system is the ultimate solution for avoiding under-inflation and corresponding wear of the tyres.

Piston Actuated Valve: The Piston Actuated Valve (PAV) uses a double acting cylinder of diameter 20mm, made up of aluminium. A rubber O-Ring is placed at the bottom end of the piston to let the atmospheric air into the cylinder (figure 1-b). Acirclip of 20mm diameter is placed above cylinder head to hold it in place. The spring placed inside the cylinder has 12mm diameter, open-coil type and has five coils. A T-Junction, which is made of phosphor bronze, controls airflow from the cylinder to the tyre tube airflows through 0.8mm diameter micro machined holes. Air flows in and out of the T-Junction through a drilled hole in the cylinder made of cast aluminium. The cylinder consists of a non-return valve, which controls the airflow. A hole is drilled on the circumference of the rim. The base part of the piston of PAV is kept inside the hole and the valve is bolted to the rim (figure 1-b& c). The tubeless tyre encloses the rim and the PAV. The dimensions of PAV and its different views are shown below (figure.1-a).

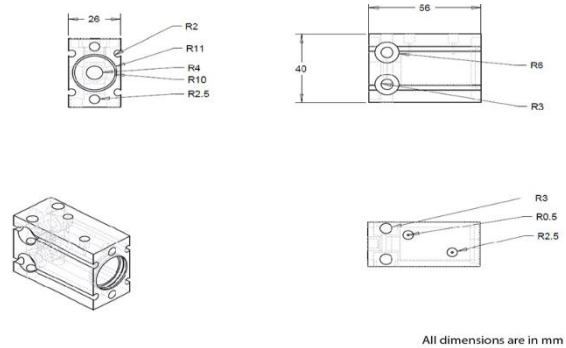

Figure.1-a.Creo model of Piston Actuated Valve (PAV)

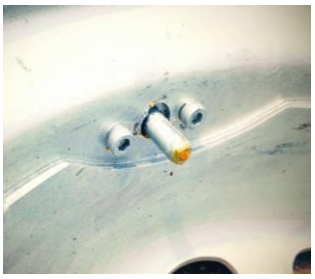

Figure.1-b. Bottom view of Piston Actuated Valve (PAV)

Figure.1-c. Top view Piston Actuated Valve (PAV)

2. MATERIALS AND METHODS

Construction: The model consists of various parts which are seen in a general automobile to form the inflation system which has Rim, Wheel hub, Brake disc, Brake caliper, Spindle, Piston Actuated Valve (PAV), Metallic strip shaped in the form of cam profile and a frame to mount the system. The Spindle is welded to the frame and then the wheel hub is mounted on the Spindle. Near the wheel hub is the brake disc, which mounts the brake caliper upon which the metallic strip is welded to form the cam profile. The wheel rim houses the cam profile strip and then the piston-actuated valve (PAV) is designed and bolted to the wheel rim. A hole is drilled on the wheel rim so that the piston of the PAV is inserted inside to provide actuation.

Figure.2-a. Front view Integrated Tyre Inflation System

Figure.2-b. Rear view Integrated Tyre Inflation System

Rim: The rim is the outer edge of the wheel and is made of forged aluminium alloy (figure 3). It holds the tyre and is used to cover the wheel hub. It is bolted to the wheel hub. The standard size of the rim used is 5.5Jx15 ET45.

Figure.3. Rim

Wheel hub: The wheel hub is the central part of the wheel unit. It is made of aluminium and consists of wheel bearing where the Spindle is connected. The standard size used is 4/100 mm.

Brake disc and Brake caliper: One of the commonly used brakes in automobile. The brake disc, also known as rotor is made of cast iron and is mounted on the wheel hub. The brake caliper used is a fixed type and it does not move with respect to brake disc. The material used in brake caliper is chrome plated steel.

Spindle: The spindle, also known as upright holds the wheel hub. It is one of the main components of steering and suspension systems.

Figure.4.Various parts of Integrated Tyre Inflation System

Working: The proposed integrated tyre inflation system would comprise of a **"Piston actuated valve (PAV)"** which would supply the necessary air to the tyres as and when required. A cam profile is mounted along the inner circumference of the wheel hub. The PAV is attached to the wheel hub through a suitable manifold. A portion of the valve (a stem like portion) beneath the wheel hub will always remain in contact with the cam profile. The cam profile

is designed in such a way that for a certain length of the circumference it broads out and for a remaining small length of the circumference, it narrows down and set tight.

When the tyre of an automobile rotates, the rim also rotates which makes the PAV to move along with it. The metallic strip shaped in the form of cam profile is stationary so that the piston of the PAV acts as the follower. One revolution of the rim makes the piston to perform reciprocatory motion thanks to the cam profile. The PAV (Piston Actuated Valve) is provided with two specialized micro ducts. Both ducts are used to store air temporarily before letting them move on to next stage. Bottom cylinder sucks the atmospheric air in when piston reaches TDC during compression the air passes through the non-return valve through the T-Junction and finally into the top cylinder. When the piston again reaches the TDC, the air stored in the top cylinder is compressed and opens the non-return valve pushing its way through the T-Junction and into the tyre tube.

This compressed air would act as the source for providing the necessary inflation for the tyres. The return motion (downward motion of piston) and the compression motion (upward motion) of the piston (stem of the piston) together contribute one cycle. Thus, one cycle is completed in one complete revolution of the rim. The cycles are repeated continuously for successive revolutions of the rim. The amount of compressed air can be effectively controlled by loosening the screw (increasing the available volume) using the groove provided at the end of non-return valve.

It has to be noted that suitable sized non-return valve and spring arrangements are used at the micro level, within the PAVin the T-Junction, to ensure theproper compression and airflow. The movement of the compressed air into the tyres is ensured to be unidirectional with the help of the non-return valve.Non-return valve houses a stopcockarrangement, which eliminates the return flow of compressed air. All the minute components are designed and machined in such a way that they all function together to ensure the proper working and structural stability of the PAV.

When the PAV and the cam profile arrangement is used in large scale or in a more commercial manner in all the vehicles, a highly capable Electronic Control Unit (ECU) and a supporting electric circuit can be used so as to monitor the pressure drop in the tyres and control the amount of compressed air supplied to the tyres. This would furthermore exploit the potential strengths of the entire system and thus offer more convenience and advantages.

3. RESULTS AND DISCUSSIONS

For a tyre travelling a distance of 1km, about $1cm^3$ of air is filled automatically during the continuous rotation of the rim. The amount of compressed air filled can be increased by loosening the non-return valve to our requirements. The non-return valve does not allow the atmospheric air to enter back into the cylinder as it is provided with a stopcock. It is also observed that a car driven with 15% reduction in nominal tyre pressure guzzled up 1.2% more fuel. In other words, our project, which maintains a constant tyre pressure at all times, gives a better fuel economy. Keeping the perfect tyre pressure will decrease the issue of “bad wear patterns” and thus tyre won’t wear out as quickly. It also improves vehicle handling. If the vehicle is not able to maintain traction on the road, driving gets really dangerous and could also be fatal. Hence, by implementing our project in automobiles, we could not only improve the mileage and tyre life but can also reduce accidents.

4. CONCLUSION

The integrated tyre inflation system would be capable of succeeding as a new product in the automotive supplier industry. It specifically addresses the needs of the consumers by maintaining appropriate tyre pressure conditions for reduced tyre wear, increases fuel efficiency, increases overall safety of vehicles. It helps in the monitoring of tyre pressure constantly, provides inflation of the tyre, and helps in attaining better mileage also offers comfortable and secure driving. The vehicle usage is growing day by day and the ultimate goal of the engineering discipline would be to ensure satisfactory service provision. Proper and efficient tyre pressure maintenance is one of the answers to many rising problems related to vehicles. Hence, by the development of the integrated tyre inflation system, the performance andsafety of the automobile and its useris improved to greater horizons.

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