Design and development of air powered car using air motor engine

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Abstract. This study aims to design and determine the performance of pressurized air-powered cars. The design results in the form of a three-wheeled air-powered car with a capacity of one person, the engine uses a four vanes-reversible air motor with a maximum rotation of 3000 rpm equipped with an air tube capacity of 6 m³ of pressure 150 bar. Test results with an operating pressure of 80 psi produce 2.74 HP. The car can drive stably and without significant obstacles. An air-powered car with light construction, simple way of working, low manufacturing and maintenance costs, does not produce exhaust emissions. However, it also has a disadvantage that there is still a rather noisy sound from the air outlet; it still needs a large enough and strong tube size to accommodate high-pressure air and large capacity. If these weaknesses can be overcome, pressurized air-powered vehicles will become one of the cars of the future.

Keywords: air-powered car, APC01-ITATS, air motor, zero emission.

1. Introduction
Cars with compressed air drives are not as popular as compared to gasoline cars, diesel cars, or even electric cars. But who would have thought the engine technology by using compressed air has existed since the end of the 19th century. In 1872 the Mekarski air engine was used for street transit, which consisted of a single-stage engine [1,2].

Charles B Hodges will always be remembered as the true father of the pioneering application of the concept of a powered air- car. He not only succeeded in creating a pressurized air drive car but also successfully commercialized a vehicle using a pressurized air drive engine [1,2].

After twelve years of research and development, Guy Negre managed to develop a machine that could become one of the most significant technological leaps of the century. A French mechanical engineer has professionally managed to design engines that are fuel-efficient and without air pollution for city vehicles using compressed air technology [1]. "Air Car" from Motor Development International has significantly stepped up to create a zero-emission car, using a pressurized air drive engine that is safe, quiet, and has a maximum speed of 110 km/hour with a roaming capability of up to 200 km. Guy Negre is the head of research and development at Motor Development International (MDI) Car, which in 1994 successfully created the prototype Zero Emission Vehicle (ZEV) [1].
Vehicles drove off on the highway are still dominated by gasoline and diesel-fueled vehicles. Air pollution in urban areas, approximately 70%, is caused by vehicle emissions [3]. On the other hand, fossil fuel reserves around the world are running out so that oil-fueled vehicles will not be sustainable.

Various attempts have been made to overcome the condition, including developing fuel-efficient cars, electric cars, developing vegetable oil fuels, hybrid vehicles, and many more.

The development of fuel-efficient cars cannot provide a long-term solution because it still uses fossil fuels that will eventually run out. While electric cars have advantages, among others: relatively more economical, zero pollution, noiseless, and energy sources can be obtained from renewable energy. But electric cars also have weaknesses in battery charging technology which still need a time to recharge the power.

In this study, pressurized air drive cars were developed using a machine in the form of a four vanes reversible water motor. The advantage of this machine is that its size is relatively small and can rotate CW and CCW so that it does not require a reverse gear mechanism. Thus, the components and tools of the transmission system are straightforward compared to gasoline and diesel cars.

This compressed-air drive car can later be developed hybrid with electric cars. Similar to an electric car, a pressurized air drive car also has a problem. The problem is the unavailability of infrastructure in the form of high-pressure air filling stations. This is a serious problem because the air compressor used to increase the tire air is only around 15 bars on average. In comparison, a minimum of 100 bars is needed, so the cruising range of the car can be far away. If the air tank is only filled with a pressure of 15 bar, then the range is less than 1 km, this is not feasible. If these problems can be overcome, the car using pressurized air technology will have an excellent prospect because this car is without fuel, without emissions, and has a high economic value.

Utilizing air as fuel is a smart effort because the abundantly available air in nature can be compressed high pressure at a low cost [4].

2. Literature studies
In the past two decades, researchers in various places of the world began to develop this air-powered vehicle enthusiastically. Anirudh Addala et al. from the Visvanda Institute of Technology and Management in 2013 researched pressurized three-wheel drive cars. The driving motor uses pneumatic motor (hand wrench) with 677 Nm of torque, rotation of 300 rpm, 6.2 bar working pressure, 340 l/min air consumption. The results showed the economic value of using this car was Rs 1/km [5].

S.S. Verma (2013) explains that the main weakness of the use of compressed air drive cars is not yet available in high-pressure air filling stations. Still, this car has a bright market share because this car technology can be combined with electric or hybrid car systems between pressurized air cars and electric cars [6]. Research on bicycles using compressed air drive has been done by S.S. Verma (2008) in the form of an air-powered moped is a bicycle with a compressed air drive with two air tanks. From the results of testing, the bike can go with a maximum speed of 18 mph with a distance of 7 miles [7]. Prof. B.S Patel et al. has tried to develop a compressed air power engine by modifying a 4-stroke, single-cylinder engine, SI engine, by replacing spark plugs with compressed air valves. The compressed air works like the fluid on a four-stroke engine. From the results of the cost, analysis shows that the use of compressed air power engines is cheaper when compared to using conventional SI engines [11,12].

Dr. Bharat Raj Sing and Dr. Onkar Sing conducted a study, and they used a novel type of air turbine as the prime mover of a bicycle motorbike. In these experiments, they tried to get an
output of 6.5 to 7.2 HP for torque requirements ranging from 500 to 700 rpm at air pressures of 4 to 6 bar [8]. AA. Keste made prototypes of pressurized air-powered vehicles with the Slider crank mechanism system [9]. At the same time, Bilal Abdullah Baiq uses a Honda CD 100 4 strokes 100 CC engine, which has been modified as a pressurized air-powered car [10].

Pressurized air-powered engine technology is cheaper in cost and maintenance, can be easily adapted by the masses, and does not cause any type of environmental hazard [11].

3. Method
This research method is manufacture, assembly and performance testing of pressure air drive car arranged with the following research stages:

- Air drive car assembly
- Performance testing:
  - Rotation, speed, power generated
  - Air pressure, initial speed, braking
  - Minimum turning radius testing

3.1 Machine construction and work system
The pressurized air-powered car that was developed had three wheels. The engine used is a four vanes reversible water motor.

a. Frame
The frame is the most critical part because it supports the entire vehicle component. The material of the light steel frame shaped hollow pipe. Design and frame size results from computational simulation results. Frame length 2350 mm, width 1100 mm (figure 1).

b. Engine
The engine used is the air motor (pneumatic motor) type 4 AM-NRV-22F, four vanes-reversible—maximum rotation of 3000 rpm (figure 2).

c. Steering System
The car has three wheels, namely two in front and one behind. The steering system consists of a steering wheel, steering chassis, wheel support, knuckle arm, and drag link (figure 3).

d. Transmission System
Rotation from the engine is transmitted through the chain to the successor gear. Then from the successor gear, the rotation is reduced to move the central axle of the rear wheel (figure 4).
e. Breaking System
   Car braking uses a disc braking system for all front and rear wheels (figure 5). The braking system component consists of a caliper and brake discs mounted on the axle of each wheel (figure 5).

f. Air Tubes
   The air cylinder uses an oxygen cylinder (O₂) pressure of 150 bar cylinder capacity equivalent to 6 m³ (figure 6).

g. Overall design
   Overall, the design of the car looks like in the picture below. This car is called the Air-Powered Car (APC) 01– ITATS. Rear-wheel drive using air motor. Rear wheel drive has the advantages of simple design and better balance of the car. The vehicle is equipped with a shock absorber to support comfort when driving.
   This car is designed only for one passenger with a maximum weight of 90 kg. The empty weight of a 160 kg passenger car, the weight includes air cylinders when fully loaded and all major components and accessories.
h. Car Dimension
   Following are the technical specifications of APC 01-ITATS car dimensions (figure 8):

   - Wheel base length = 2,263 m
   - Overall length = 2.67 m
   - Car height = 1.30 m
   - Vehicle width = 0.80 m
   - Distance between the front wheels = 1.55 m
   - Clearance ground = 0.28 m

4. Test and calculation
   The car performance test is done in two ways, namely in the laboratory using the dyno test to find out the speed, the power produced (figure 9), and the braking time, in contrast, testing on the road to determine the feasibility of the road and the minimum turning radius.
4.1 Breaking test
This test aims to determine the length of time needed when starting braking on the condition of the road car at a certain speed until the car stops completely. Tests carried out in the laboratory using dyno test equipment.
| Operational Air Pressure (psia) | Motor rotation (rpm) | Speed (km/jam) | Power (HP) |
|--------------------------------|----------------------|---------------|------------|
| 70                             | 1483                 | 29.76         | 2.53       |
| 75                             | 1534                 | 31.26         | 2.66       |
| 80                             | 1599                 | 32.21         | 2.74       |

**Table 2. Breaking Test Result**

| Operational Air Pressure (Psia) | Initial speed (km/hour) | Time of breaking (second) |
|--------------------------------|-------------------------|---------------------------|
| 70                             | 29.76                   | 1.13                      |
| 75                             | 31.26                   | 2.32                      |
| 80                             | 32.21                   | 2.67                      |

### 4.2 Road testing

From testing on the road, APC 01-ITATS car runs in a stable. When the operating air pressure is 80 psi, the speed of the car is 30 km/h lower than when tested in the laboratory (figure 13).

#### 4.2.1 Minimum turning radius test

One of the car maneuver tests is the minimum turning radius test. Turning radius is account of how big circle the car can make when turning. The measurement method is the car runs with a maximum circular turn. Car wheele trajectories that form a circle are marked so that size of the circle can be measured (figure 14). This test aims to determine the minimum radius of the car can turn to form a full circle. The experiment was conducted on the campus of the Surabaya Adhi Tama Institute of Technology.

![Figure 13. APC testing on the road](image1)

![Figure 14. Minimum turn radius test](image2)

### Table 3. Minimum turning radius test results

| Test | Minimum Turning Diameter (m) | Minimum Turning Radius (m) |
|------|------------------------------|-----------------------------|
| 1    | 10.97                        | 5.485                       |
| 2    | 10.83                        | 5.415                       |
| 3    | 10.92                        | 5.46                        |
5. Conclusion
The working principles of an air-powered car are very simple, lightweight and minimalist construction, lower manufacturing and maintenance costs, do not produce exhaust emissions because without burning fuel. However, this air-powered car also has a disadvantage that is still quite noisy from the air outlet. Tubes that are large enough and strong enough to hold high-pressure air and large capacity are also needed. For mass development, adequate infrastructure must be available in the form of a high-pressure air filling station of at least 100 bar. If these weaknesses can be overcome, pressurized air-powered vehicles will become an attractive choice for future use.

6. Acknowledgments
The author acknowledge the support from Rector, Head of Mechnical Engineering, Head of Internternal Combustion Engine Laboratory, and Head of CNC Laboratory ITATS.

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