

# A Development of Automotive Solenoid Regulator

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## Abstract

Using natural gas as fuel of vehicle is a growing trend in the world, and natural gas vehicle in Korea is mostly manufactured by its revamping. The majority of remodeling technology of NGV is accomplished by small businesses and they have continued to develop its technology. The development of new regulator in this study makes it possible to operate a safe natural gas vehicle with an excellent performance. To be developed the product through this study is a gas pressure regulator which plays roles in making evaporation and decompression from 200 bar to 2 bar by two step process in the high pressure gas cylinder. There are three components such as a regulator assembly, a gas inlet module, and solenoid in an existing regulator. It is redesigned to make one integrated component of three above mentioned components in this study. An existing product which is composed of a regulator, a gas inlet module, and a solenoid is to developed redesigned one integrated component not only to improve the decompression method from an existing 1-stage to 2-stage but also to provide safety function through the prevention of occurrence for gas leakage due to a deformation of O-ring. The 2-stage regulator can maintain constant pressure using the method of two step decompression. This component will be used as a major part for remodeling of CNG vehicle and distributed to remodeling shops for an installation all the country.

**Key Words:**CNG, regulator, decompression, solenoid, bio, relief valve.

## 1. Introduction

A market for modification of natural gas vehicle (NGV) with compressed natural gas (CNG) promotes not only to manufacture NGV but also to build more boosting a construction of the infra for CNG station by an automobile manufacturers. That the supply of modified NGV which is relatively cheaper than the manufacturing cost of NGV makes it possible to form a market of CNG to have enough function of the building infra of CNG station<sup>1</sup>.

The technique of modified NGV that is replacing an existing gasoline or diesel engine with CNG has applied the first generation engine system to save cost cutting rather than its performance. The technique which is an applied third generation technology in the modified NGV has been expanding lately. Railroad cars under development or in service which is used a natural gas or bio-fuel is America, Germany, India, Peru, Russia, and Sweden. They are to be used for a variety of operating purpose such as for passengers, shunting car, and freight train<sup>2</sup>. It will be expected to get the reduction effectiveness of exhaustion of carbon dioxide in case of changing from an existing diesel fuel to clean energy such as LNG, CNG, and bio-fuel in the field of domestic railway. Using natural gas as fuel of vehicle is a growing trend in the world, and most of natural gas vehicle in Korea is manufactured by its revamping. The majority of remodeling technology of NGV is accomplished by small businesses. The development of new regulator in this study makes it possible to operate a safe natural gas vehicle with an excellent performance<sup>3,4</sup>.

## 2. Current Status of Research and Development

### Research Summary

To be developed the product through this study is a gas pressure regulator which plays roles in making evaporation and decompression from 200 bar to 2 bar by two step process in the high pressure gas cylinder. There are three components such as a regulator assembly, a gas inlet module, and solenoid in an existing regulator. It is redesigned to make one integrated component of three above mentioned components in this study. General regulator for CNG vehicle only performs one stage pressure and its components are a supplying fuel part, a diaphragm which can expand and contract according to getting in and draining out of fuel, a pressure adjustment screw capable of adjusting a inflow rate of fuel, and a balance spring pressing a diaphragm<sup>5,6</sup>. In order to depressurize a considerable amount of pressure, 1-stage regulator has to have bigger cross section areas of decompression chamber and to adopt a spring with a high spring constant. This causes problems to increase manufacturing cost due to the overall size of regulator and parts rise in unit cost. There can be no limit to adjust smaller the pressure of outlet in the range of fluctuation in case of too much of the variation due to a decompression through the function of

contractility by a spring and a diaphragm<sup>7</sup>. The typical structure of 1-stage regulator is shown in Fig.1 and 2-stage regulator for only CNG cars to be developed in this study which is to supply a required depressurized gas by two steps in case of injecting from an injector is shown in Fig.2<sup>8</sup>.

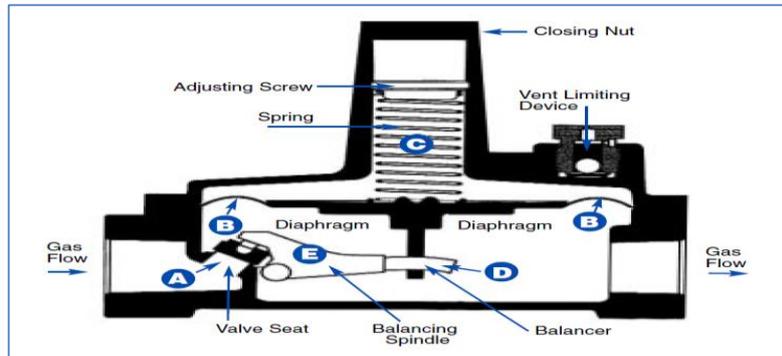


Figure 1: General Structure of 1-stage Regulator for CNG Vehicle

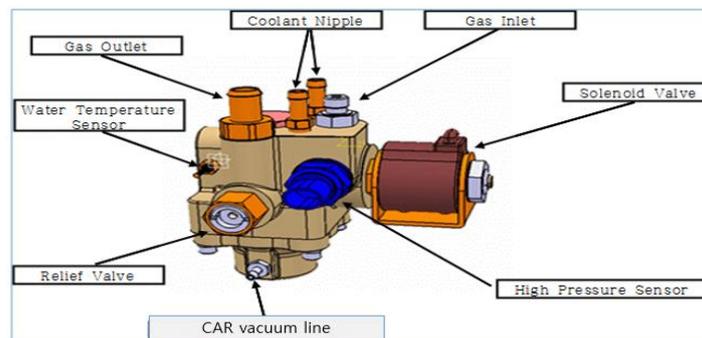


Figure 2: Schematic Diagram of Development Product

### Related Technology Status at Home and Abroad

The number of natural gas fueling station in place and operational all over the world is 19,941 and has been increasing by 8.2 percent during five years while the number of supply per each station is 762 which is increased by 14.2 percent compared that of 667 in 2007. The number of CNG car shows 13.6 million equivalent to 93.3 percent of NGV vehicle running all over the world whereas bus is 440,000 and truck is 250,000. Considering regional distribution status, the number of Asia-Pacific region is 88 million in 57.9 percent of total supply and this is the largest number in one region while Latin America region is 43.4 million(28.6%) and European region is 17.6 million(11.6%). An average annual increasing rate of NGV during ten years recorded the highest in Asia-Pacific region, 38.7 percent while European and African region is 16.2 percent and 16.1 percent respectively and north American region was showed a declined trend by 1.2 percent<sup>9</sup>. Especially in case of developing countries, the cars have made by modifying existing vehicles which have competitive price will be mainly expended its distribution due to relatively legging behind other nation in the manufacturing technology of car, including their poor funding situation.

Registered number of CNG cars in Korea according to Ministry of Land, Transport and Maritime Affairs had been counted to 32,441 which makes up at least 0.2 percent of the overall population of cars. CNG passenger van is recorded the highest number by 27,307 among all other type of vehicle while a CNG sedan is 4,082 and CNG truck is 1,052. The number of registered CNG cars has been on the rise annually. The current technology development of CNG engine all over the world is almost completed. The domestic engine technology which has been developed a lot of them should not behind in the technology development of advanced countries. The remodeling market of CNG in Korea is taken the lead in the development of technology and its product by small business<sup>10</sup>.

### **3. A Development of Automotive Solenoid Regulator**

#### **Mechanism Design**

The first decompression part that is decompress gas firstly and the second decompression part that is decompress gas secondly which passes the first one are designed. The first decompression part is designed like the following as the first housing that is formed the first orifice which is connected the first valve shaft, the piston that works a linear reciprocating motion contacting the first stage of the first valve shaft, the first spring that is assembled between the first cap as well as piston that is connected the first housing to cover the part of piston installation and the first cap. The second decompression part is also designed to connect the first housing vertically and designed like the following as the second housing that forms the second orifice, the second valve shaft that is connected the second orifice, a diaphragm that works a linear reciprocating motion contacting the first stage of the second valve shaft, and the second spring that is assembled between the second cap as well as diaphragm that is connected the first housing to cover the part of diaphragm installation and the second cap.

An input port that supplies high pressure gas is connected up a cooling water part that supplies water together in the first decompression part. A cooling water port is designed to circulate the surroundings of decompression room to prevent an overheated engine due to absorbing heat from the engine for the prevention of rapid changes in temperature that is occurred by the fuel characteristics during an operation of decompression in the first and second part of that. A relief valve which can discharge the fuel inside regulator in case that the head pressure creates high pressure with above required level due to fire and external shock or malfunction of inner workings between the first decompression part and the second decompression part is also designed. For the purpose of assembling each component correctly an availability of assembly is to be improved. 3D tool design and assembly drawing of solenoid regulator for vehicle is shown in Fig.3.

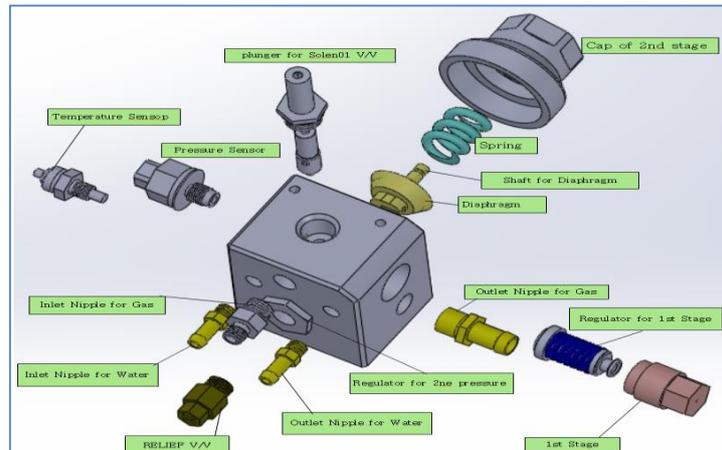


Figure 3: 3D Mechanism Design and Assembly Diagram

**Key Development Points**

An existing product is used by all combinations of three components which is composed of a regulator, a gas inlet module, and a solenoid to make one component and this causes labor costs and product failures when its parts are assembled. The major occurring product failures are a deformation of O-ring and a spiral wear and these cause safety problems due to gas leakage when used for longer periods of time like 30,000km per three months. An existing part which is composed of three components such as a regulator, a gas inlet module, and a solenoid shown in Fig.4 is redesigned to make one integrated component of three components in this study. The improved product changed from an existing decompression method of one stage to two stages that makes it possible not only to reduce labor costs for component assembly but also to prevent gas leakage from the deformation of O-ring shown in Fig.5 for the proper function of safety component. An existing regulator adapted one stage regulator which depressurize gas from 200bar to 2bar is reducing pressure but an engine power degradation which is fall until 1.6bar in outlet pressure especially in case of an acceleration and a mismatch phenomenon are occurring according to nonconstant outlet pressure. In order to keep constant pressure in the outlet, two stage regulator is to depressurize through two steps. The configuration of final product is shown in Fig.6.

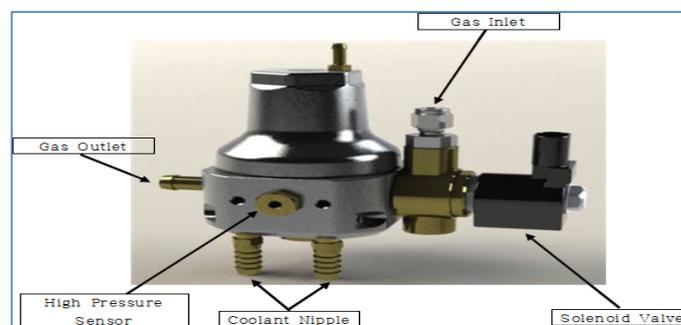


Figure 4: Formation of An Existing Product

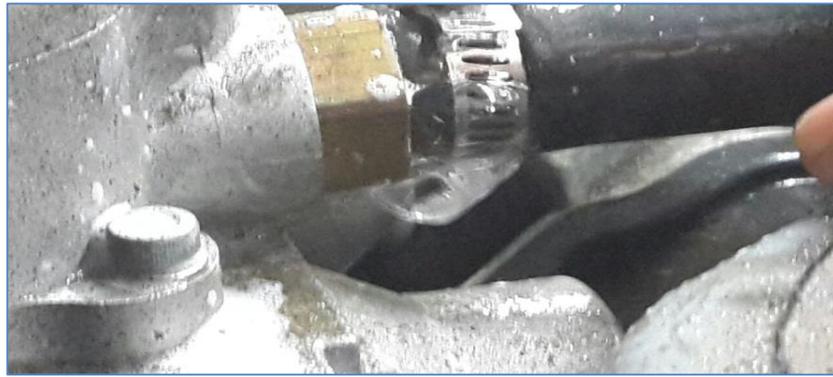


Figure 5: Gas Leakage Due to Deformation of O-ring

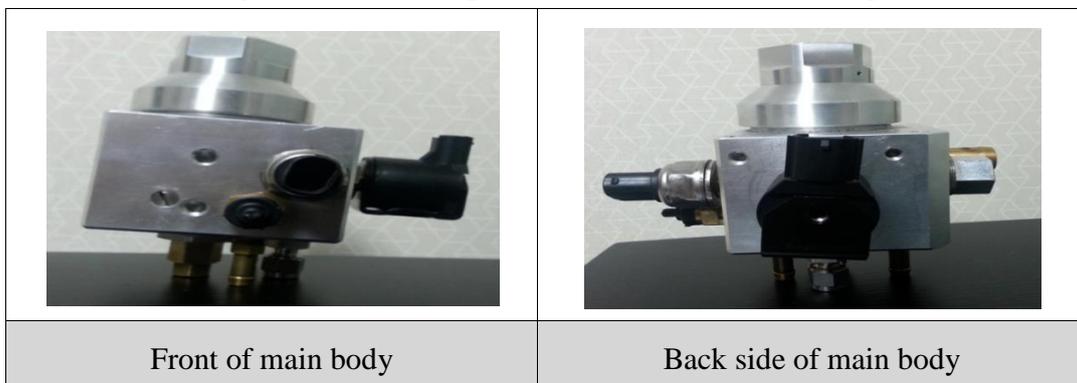


Figure 6: Appearance of Developed Product

#### 4. Conclusion

An existing product is used by all combinations of three components which is composed of a regulator, a gas inlet module, and a solenoid and causes labor costs and product failures when its parts are assembled. In consideration of that the major occurring product failures are a deformation of O-ring and a spiral wear and these cause safety problems due to gas leakage when used for longer periods of time, the improved safety product is developed to redesign making one integrated component of three component by changing from an existing decompression method of one stage to two stages that makes it possible not only to reduce labor costs for component assembly but also to prevent gas leakage from the deformation of O-ring. Also this component will be used as a major part of remodeling of CNG vehicle and distributed to remodeling shops for an installation all the country.

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