Development of High Pressure Hydrogen Regulator for Fuel Cell Vehicles[*1]

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We have developed a high pressure hydrogen regulator for fuel cell vehicles which achieves an improved pressure regulation characteristic, higher reliability, and a lighter weight than the conventional regulator. The pressure regulation characteristic was improved by reducing sliding friction of the seal around the periphery of the piston. Reliability was achieved by decreasing wear through the improvement of surface roughness of the parts which repeatedly open/close and slide during operation. Furthermore, we have achieved weight saving by abolishing stainless steel components of the sliding parts and applying aluminum alloy components with a surface treatment.

Key Words: *regulator, hydrogen, high pressure, fuel cell vehicle*

1. Introduction

In recent years, energy sources have been diversifying in order to reduce the risk of a disruption in energy source supply. Moreover, there has been an increase in the demand to reduce CO_2 emissions of vehicles from the perspective of conserving the global environment and preventing global warming. Against this backdrop, vehicle manufacturers have been working on the development of fuel cell vehicles which use hydrogen as an energy source that can be produced from a variety of ingredients, and do not emit CO_2 during operation. On this occasion, JTEKT has developed a high pressure hydrogen regulator for fuel cell vehicles which adopt the high pressure hydrogen storage method. Compared with the conventional regulator, the newly developed regulator has an improved pressure regulation characteristic and reliability, not to mention reduced weight. This paper introduces the results of this development.

2. An Overview of the High Pressure Hydrogen Regulator

Figure 1 shows the basic structure of the hydrogen gas supply system. The function of the high pressure hydrogen regulator is to reduce the pressure of the high pressure hydrogen stored in the hydrogen tank and supply it to downstream components. Moreover, there is also a built-in relief mechanism to protect components downstream of the high pressure hydrogen regulator when pressure rises. **Figure 2** and **3** show the appearance and structure of the developed high pressure hydrogen regulator.

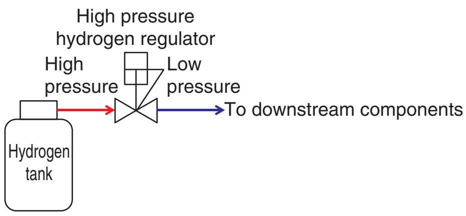

Fig. 1 Basic structure of the hydrogen gas supply system

Fig. 2 Appearance of high pressure hydrogen regulator

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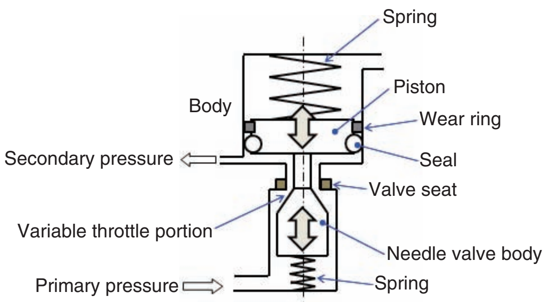

Fig. 3 Structure of high pressure hydrogen regulator

3. Development Content

Table 1 shows the main development items of the high pressure hydrogen regulator developed this time.

Table 1 Main development items of high pressure hydrogen regulator

Aim	Development content	Development item
Improvement of the pressure regulation characteristic	Reduce variation of the pressure regulation value	Reduce sliding friction of the seal around the periphery of the piston
Improvement of durability	Improve durability of the variable throttle portion	Improve surface roughness of the valve seat contact portion on the needle valve body
	Improve durability of the sliding portion around the periphery of the piston	・Improve wear resistance of the wear ring ・Reduce the pressing force of the spring ・Improve the surface roughness of the sliding face
Lightening	Reduce the number of components in the sliding portion of the needle valve body	Apply surface treatment to aluminum alloy components

3. 1 Improvement of the pressure regulation characteristic

The high pressure hydrogen regulator is configured from a variable throttle portion which is formed from the needle valve body and valve seat, a piston, piston peripheral seal, spring and so on. For the purposes of this paper, the pressure downstream from the high pressure hydrogen regulator is considered the pressure regulation value. The transient characteristic of the pressure regulation value when the flow rate of the hydrogen flowing through the high pressure hydrogen regulator changes impacts upon control of the components downstream of the high pressure hydrogen regulator. If the variation of the transient pressure regulation value is large, the variation in the characteristics of the downstream components will also be large and this may reduce fuel efficiency of the vehicle. Moreover, when hydrogen flows, the operation of downstream components is synchronized and the hydrogen flow rate of the high pressure hydrogen regulator also changes. The piston strokes in response to this change in hydrogen flow rate and the needle valve body strokes in conjunction with this, thereby opening and closing the variable throttle portion. If at this time the sliding friction of the seal on the periphery of the piston which slides together with the piston is significantly unstable, it will cause variation in the pressure regulation characteristic. As such, while the conventional seal was made from resin, we adopted rubber which has excellent cost performance and is easy to assemble. In the case of rubber, the change in physical properties due to temperature is a factor causing the change in sliding friction of the piston sliding portion to increase. Sliding friction increases at low temperatures in particular. Therefore, we adopted a shape which could secure seal face pressure while reducing the contact surface area of the seal's sliding portion and added a grease groove to the sliding surface to minimize grease supply interruption. These countermeasures made it possible to minimize the increase in sliding friction and secure seal performance.

3. 2 Improvement of reliability

The variable throttle portion of the high pressure hydrogen regulator opens and closes in conjunction to the change in hydrogen flow rate due to the operation of downstream components. Therefore, the seal portion with the needle valve body and valve seat which form the variable throttle portion and the sliding portion which operates in conjunction with the opening/closing of the variable throttle portion must have high durability.

3. 2. 1 Improvement of variable throttle portion reliability

The needle valve body makes contact with the valve seat by the opening and closing of the variable throttle portion. The needle valve body is made of metal, while the valve seat is made of resin. Through the repetition of this contact, the resin valve seat wears to match the shape of the needle valve body. As this wear progresses, the contact surface area between the needle valve body and valve seat widens and the seal face pressure of the variable throttle portion drops. In order to prevent this, we improved surface roughness of the portion of the needle valve body which contacted the valve seat through grinding and reduced valve seat wear. **Figure 4** shows a comparison of wear amount of the valve seat with and without grinding. This activity resulted in improving the durability of the variable throttle portion's seal area.

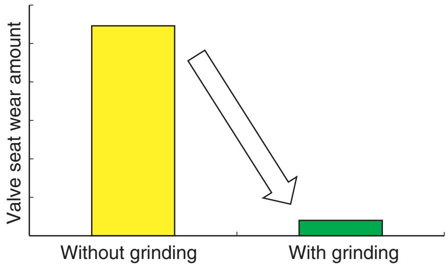

Fig. 4 Comparison of wear amount of valve seat due to existence of grinding

3. 2. 2 Improvement of sliding portion reliability

Next, as an activity to improve the reliability of the sliding portion, we adopted a wear ring made from resin on the sliding portion around the periphery of the piston on the developed regulator in order to prevent direct contact between the piston and sliding contacting face. The piston and contacting face slide together via this wear ring however if the wear of the wear ring progresses, the piston will directly come in contact with the contacting face, changing sliding friction and potentially causing the pressure regulation characteristic to become unstable. As such, we conducted activities to reduce the wear amount of the wear ring. We changed the material of the wear ring to resin which has resistance against wear. This improved the wear ring's wear resistance. Moreover, regarding the spring making contact with the piston, we revised the shape and reduced the load in the vertical direction in relation to the axis, thereby reducing the force at which the spring presses against the wear ring and reducing wear ring wear. At the same time, we also improved the surface roughness of the wear ring's sliding contacting face.

3. 3 Lightening

In order to secure reliability of the sliding portion of the needle valve body's periphery on the conventional regulator, a stainless steel sleeve was embedded inside the high pressure hydrogen regulator so that the face which the needle valve body slides together with would be stainless steel. In order to lighten the weight of the regulator developed this time, we conducted activities to omit this stainless steel sleeve. If the stainless steel sleeve is omitted, the aluminum alloy body and needle valve body will slide together. However, generally speaking, aluminum alloy has low hardness and, if it forms a sliding face, it may cause sliding problems due to wear or the powder created when the material wears may infiltrate the seal portion of the reduction valve, causing seal performance to deteriorate. We investigated the possibility of surface treatment on the aluminum alloy as a countermeasure to this problem. As an investigation method, we conducted a wear test using the ball-on-disk method within the hydrogen and carried out a basic evaluation. **Figure 5** shows the overview of the test we have conducted. Assuming that the ball side was the needle valve body and the disk side was the body, we made the ball side the same metal material as the needle valve body and the body side aluminum alloy, then conducted an evaluation for various types of surface treatment. We determined the applied load by calculating the load applied to the body by the needle valve body and set the sliding distance by calculating from the life of the high pressure hydrogen regulator. Through the wear test, we learnt that sufficient wear resistance could be secured even in hydrogen by performing alumite surface treatment on aluminum alloy. **Figure 6** shows a photograph of the disk surface after the wear test was conducted on a disk which has had alumite treatment carried out on aluminum alloy. In this way, we succeeded in lightening the reduction valve by adopting alumite treatment and abolishing the stainless steel sleeve.

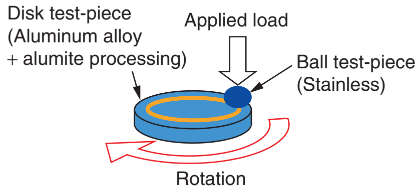

Fig. 5 Overview of ball-on-disk wear test

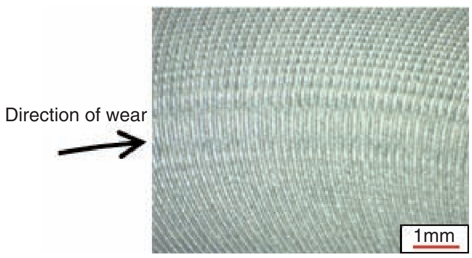

Fig. 6 Photograph of surface of alumite-treated components after wear test

4. Conclusion

Compared with the conventional regulator, the newly developed high pressure hydrogen regulator had improved reliability of the variable throttle portion and sliding portion, an improved pressure regulation characteristic and reduced weight. JTEKT will continue pursuing activities to lower cost and further reduce the weight of the next regulator model so that our products for fuel cell vehicles may be adopted by many customers in the hydrogen energy society predicted to emerge in the future.

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