Approach to building technology for mass production of fuel cell systems for social implementation -

Hiroaki Kawanishi [1] Yusuke Wada [1] Keita Iwaya [1]

1) *HONDA R&D Co., Ltd. Innovative Research Excellence, Power Unit & Energy (4630 Shimotakanezawa, Haga-machi, Hagagun, Tochigi 321-3393, Japan)*
E-mail: hiroaki_kawanishi@jp.honda

ABSTRACT: In this paper, we developed trimming technology, stack load control technology, and segmented electrical shorting inspection technology to achieve the goals of miniaturization, high output, improved durability, and cost reduction in the development of automotive fuel cell systems. This allows for the high utilization of expensive materials without waste, contributing to the establishment of mass production processes for promoting the social implementation of fuel cells.
KEY WORDS: fuel cell, high material utilization, mass production,

1. INTRODUCTION

The development of fuel cell systems for automobiles faces several challenges, including the need for compactness, high power output, improved durability, and cost reduction. Achieving these goals is a significant barrier to the widespread adoption of fuel cells in society. While various materials are being developed to address these challenges, it is crucial to focus on production technology that maximizes the utilization of expensive materials for mass production.

Honda has developed a method for fabricating fuel cell stacks by depositing anode and cathode electrode materials onto a rolled substrate, sandwiching them between electrolyte membranes, and stacking hundreds of Membrane Electrode Assemblies (MEAs) and metal Bipolar Plates (BPPs) in alternating layers at high speed. This paper presents Honda's approach to production technology that ensures the efficient use of materials, using the electrode formation process, stacking process, and inspection process as examples.

2. MANUFACTURING METHOD TO IMPROVE CARBON PAPER UTILIZATION

2.1. Material and structure of membrane electrode assembly

The MEA in a fuel cell stack consists of Anode Electrode Layer (AnEL), Cathode Electrode Layer (CaEL), Polymer Electrolyte Membrane (PEM), and Gas Diffusion Layer (GDL). Carbon paper is used for the GDL. Carbon paper plays a complex role in gas diffusion, electron conductivity, and mechanical support. It also serves as a base material on which the anode and cathode electrode layers are formed in subsequent processes.

2.2. Electrode sheet producing for mass production

Carbon paper used for MEA is made into a sheet from roll, and anode electrode, cathode electrode, and electrolyte membrane are integrated by thermal press. In order to improve the material utilization rate, it is necessary to carry carbon paper with more than a certain tension in order to reduce punching loss generated in sheeting. Although high-speed conveyance is essential for mass production, the development of conveyance technology was necessary because carbon paper tends to break when subjected to high-speed conveyance under high tension.

This development, as shown in Fig. 1, a process to compensate for the insufficient strength of carbon paper as shown in Fig. 2 was established by an approach to simultaneously feeding carbon paper and protective film. As shown in Fig. 3, the fracture of carbon paper is suppressed by this system, and the range of tension control is expanded, and the amount of displacement in the conveying direction of carbon paper is 58% more accurate than before. In addition, as shown in Fig. 4, a camera system which detects the marking of the defective part of the electrode defect detected in the previous process is constructed, and by skip-cutting the defective part, it is possible to prevent the utilization rate lowering due to the discrimination of the defective part of the electrode in the later process. As a result, 2.7% improvement in material utilization was realized compared with the previous fuel cell production process.

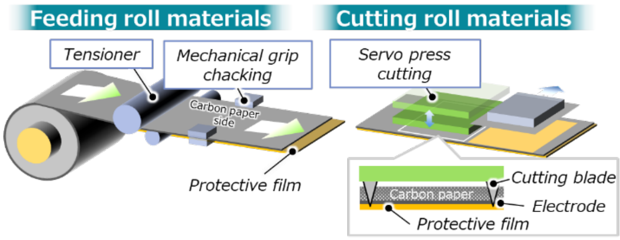

Fig. 1 Configuration of high-speed sheet trimming process

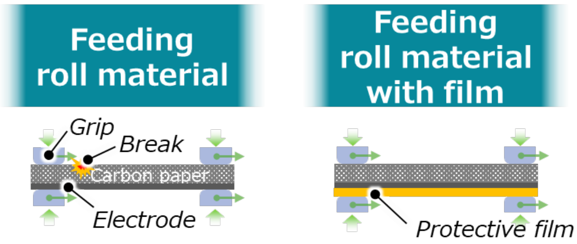

Fig. 2 Feeding structure with and without Protective film

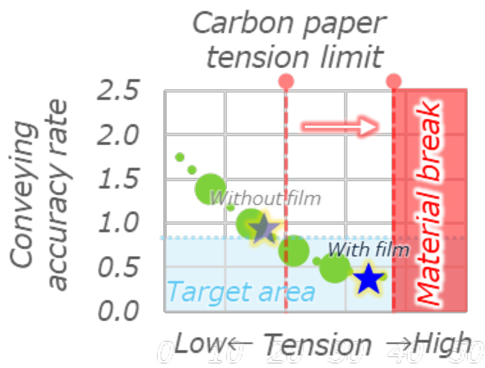

Fig. 3 Limit of conveying tension for carbon paper with and without protective film

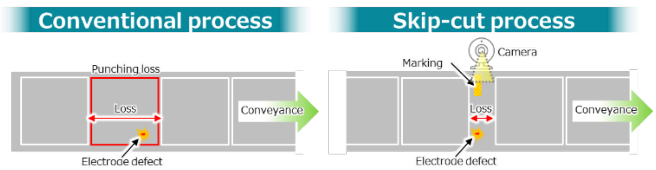

Fig. 4 Skip-cutting process for electrode defect

3. IMPROVEMENT OF CELL UTILIZATION BY STACK LOAD ADJUSTMENT METHOD

3.1. Function and component of fuel cell stack

As shown in Fig. 5, the new fuel cell stack consists of several hundred cell layers, each of which consists of MEA and bipolar plate (BPP) stacked in series. MEA is responsible for power generation, and BPP is responsible for sealing and gas supply. In order for the fuel cell stack to function optimally, it is important that the load of the generator and the seal are in the appropriate load range at the given stack fastening height. The fastening load is affected by the variation in the thickness of MEA and BPP constituting the stack. Since the output performance of the stack cannot be guaranteed when the fastening load is out of the design range, it was necessary to develop the stack assembly technology to fasten the stack with the predetermined load.

3.2. Development of Stack load adjustment method

Although it is possible to reduce the variation of the stack fastening load by controlling the material thickness variation small, it leads to high cost due to the increase of the material cost. Therefore, we developed a method to adjust the stack fastening load in the stack assembly process. Specifically, we developed a method to adjust the thickness of the MEA in the stack fastening process so that the loads of the MEA and seal portions are within the design range when the stack is fastened.

In order to adjust the fastening load of the stack, a technique was devised to reduce the load of the power generating section at the fastening height by plastically deforming carbon paper which constitutes the MEA as a power generating section by applying additional pressure from the stack fastening height. When the load is adjusted, the seal part is also pushed in simultaneously, but only carbon paper can be plastically deformed by applying the load to MEA within the elastic region of the seal. In order to realize the load adjustment technology, a jig capable of measuring separately the load of MEA and seal portions shown in Fig. 6 was produced. Next, to determine the required thickness reduction for the design load range, the plastic deformation characteristics of the thickness of MEA against the applied load were obtained as shown in Fig. 7. It was confirmed by actual measurement that the load adjustment was possible using these. As shown in STEP1 of Fig. 8, when the load is not within the appropriate load range at the given stacking cells height, as shown in STEP2 of Fig. 8, additional pressure is applied in consideration of the decrease in the thickness of the carbon paper. As a result, as shown in STEP3 of Fig. 8, it was realized that the load was adjusted within the design range by the additional compression. It was also confirmed that there was no difference in power generation performance between the stack with load adjustment and the stack without load adjustment. As a result, the process in which the go-through rate of stack was almost 100% was established.

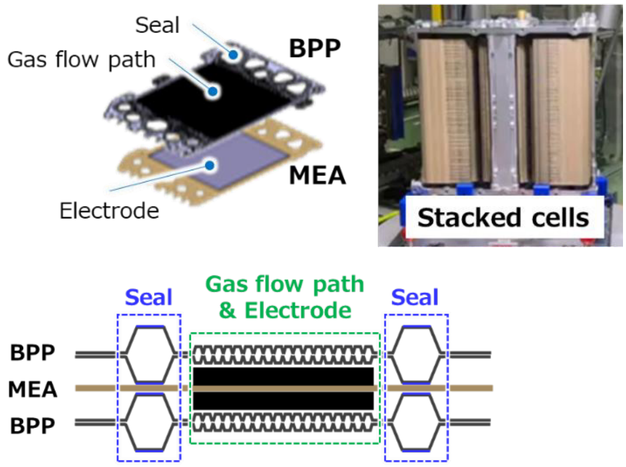

Fig. 5 Image of BPP, MEA and stacked cells

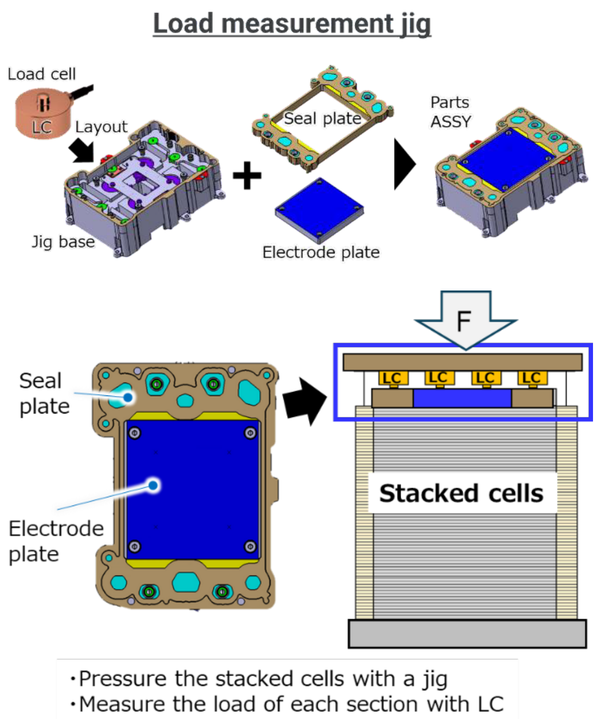

Fig. 6 Split load measuring fixture and usage

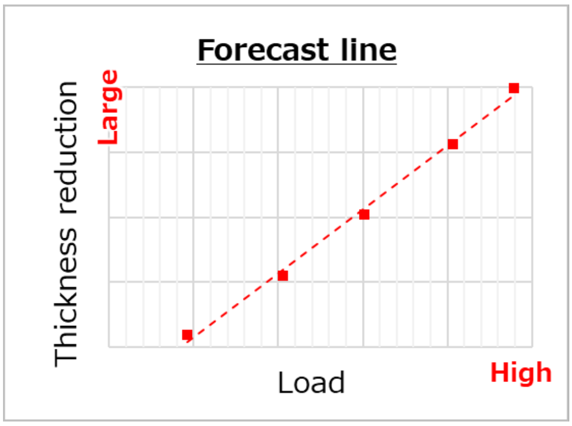

Fig. 7 Prediction of thickness reduction

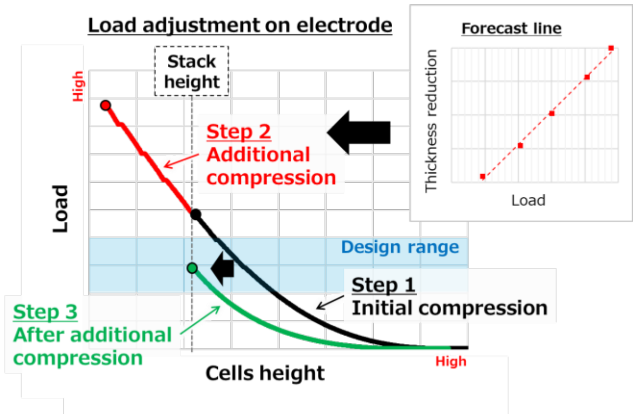

Fig. 8 Load adjustment by additional compression

4. DEVELOPMENT OF SEGMENTED ELECTRICAL SHORTING MEASUREMENT TECHNOLOGY TO IMPROVE INSULATION QUALITY YIELD

4.1. Electrical shorting of fuel cell MEA

To ensure the performance and durability of the fuel cell stack, the insulation of the polymer electrolyte membrane and the gas barrier properties are essential. One issue that hinders the insulation of the electrolyte membrane is the electrical shorting caused by fibers piercing through the membrane, as shown in Fig. 9. This electrical shorting allows electricity to flow between the anode and cathode electrodes, reducing the open circuit voltage and causing pinholes in the membrane when high voltage is applied, leading to cross leakage of hydrogen and oxygen. Therefore, we conduct electrical shorting inspections of the MEA.

4.2. Problems of previous electrical shorting inspection techniques

In the previous electrical shorting inspection process, the electrical resistance of the whole MEA is detected by the electrical shorting inspection on the flat plate substrate as shown in Fig. 10. However, as shown in Fig. 11, the electrical resistance of the new structure MEA is greatly reduced compared to the previous MEA, which results in it being judged as defective under the judgement standard of the previous MEA. Since there is a large deviation between the electric resistance measured and predicted from the resistance of the fiber, contribution from other factors like the residual solvent in the MEA was assumed. Due to the significant variation in resistance values caused by the factors like residual solvents , it was considered difficult to discuss the presence of fiber shorting using the previous method of measuring the resistance of the entire MEA. Therefore, a method was developed to measure the resistance specifically at the shorting locations.

4.3. Development of segmented electrical shorting inspection technology

In this development, the segmented electrical shorting inspection equipment was developed aiming at detecting the electrical shorting resistance component without being influenced by the characteristics discussed above. Fig. 12 shows the basic concept of the equipment in which a multi-channel tester is connected to the inspection equipment circuit and the voltage measuring device on the segmented prove board. High-precision shunt resistors with known resistance values are connected under the segmented proves. The voltage applied to each shunt resistor is measured, and the resistance of the MEA is calculated. As a result, as shown in Fig. 13 and Fig. 14, it became possible to separate and detect the electrical shorting and the non- electrical shorting from MEA with high sensitivity, and the existence of the electrical shorting was confirmed from the cross-sectional observation of the MEA at the location where the shorting detected. By this, the yield of MEA electrical shorting quality was improved by 60% compared with the yield assumed in the previous inspection method, and the inspection process which enabled the compatibility of high utilization rate of material and electric insulation was established.

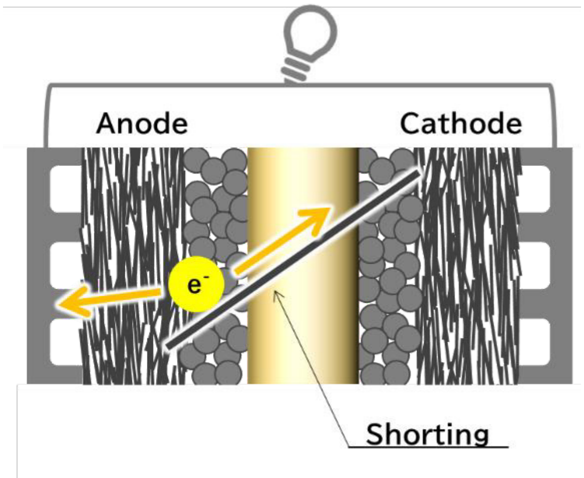

Fig. 9 Illustration of MEA shorting

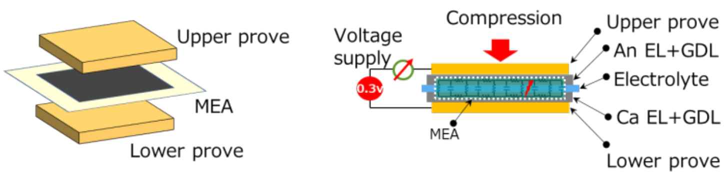

Fig. 10 Shorting inspection system of Honda previous fuel cell

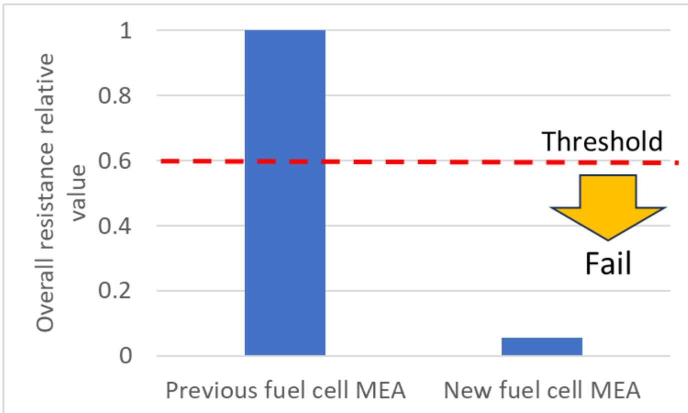

Fig. 11 Comparison of electrical characteristics between previous and new fuel cell MEA

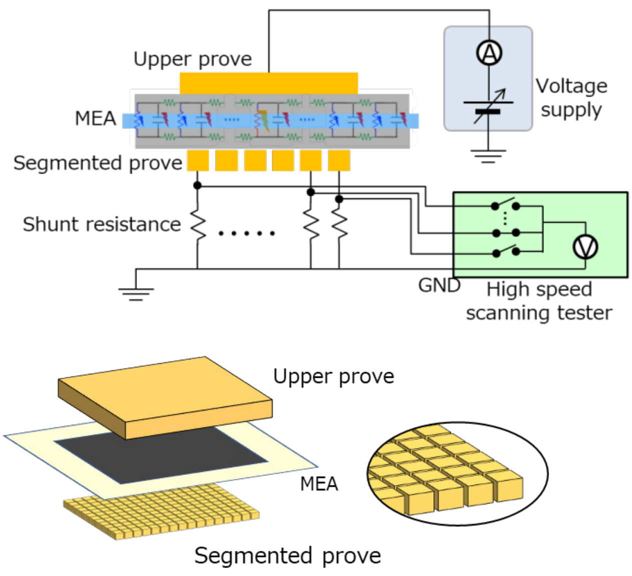

Fig. 12 Shorting inspection system

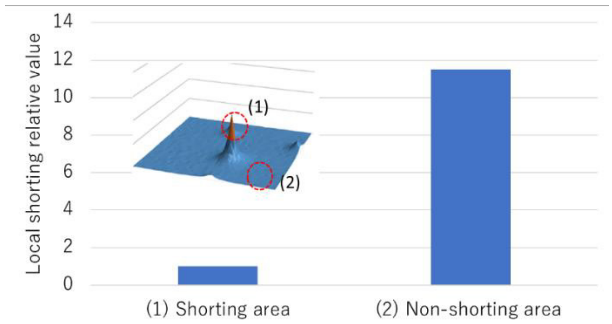

Fig. 13 Relative value of detected voltage between shorting and non-shorting areas

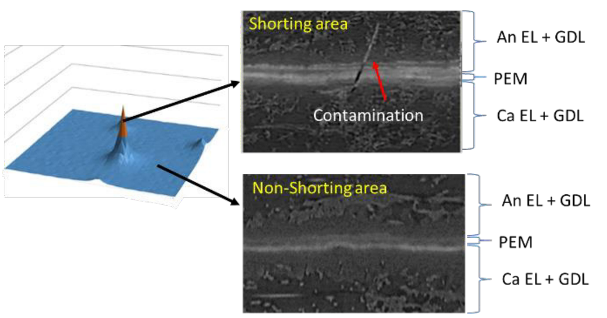

Fig. 14 Detected shorting by new shorting inspection system and X-ray CT image of the shorting section

5. CONCLUSIONS

To promote the social implementation of automotive fuel cell systems, we have been developing mass production processes to improve the utilization rate of expensive fuel cell materials. In this report, we introduced the following approaches to reduce material loss in stacks composed of hundreds of cells:

- Low material loss through selective elimination of electrode defects and the development of tension control range expansion technology.
- Improving stack yield through the development of load adjustment processes.
- Enhancing insulation quality yield through the development of segmented resistance measurement technology.

We will continue to develop production technologies that achieve higher material utilization rates.

ACKNOWLEDGMENT

We would like to thank the many people who have supported us from various perspectives in the development of this mass production process.

References

(1) https://global.honda/en/newsroom/news/2023/c230202eng.html, (accessed 2024/06/07)

(2) Kikuchi, H., Kaji, H., Nishiyama, T., Okonogi, D., Harata, H.: Development of New FC Stack for CLARITY FUEL CELL, Honda R&D Technical Review, Vol. 28, No. 2, p. 45-52

(3) JP,2018-160371,A