

Development of Third-Generation Electronically Controlled AWD Coupling with New High-Performance Electromagnetic Clutch

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ABSTRACT

This paper describes the development of the new third-generation electronically controlled all-wheel drive (AWD) coupling that achieves drastically improved drag torque performance and torque accuracy at low temperatures, and contributes to higher fuel efficiency through weight reduction in the driveline. One issue for electronically controlled AWD couplings is an increase in torque due to higher lubricant viscosity at low temperatures, especially below 0°C, because of clutch slide with the lubricant sealed inside the couplings. The developed third-generation electronically controlled AWD coupling addresses this issue by focusing on the surface texture of the electromagnetic clutch. The third-generation coupling also restricts the torque increase by actively utilizing the dynamic pressure between the clutch plates and increasing the clearance of the clutch plates at low temperatures where viscosity increases. This enables further weight reduction in the driveline. In order to reduce drag torque at low temperatures, a macroscopic sliding surface profile in the order of tens of micrometers is provided on the electromagnetic clutch under fluid lubrication. In addition, to reduce control torque at low temperatures when current is applied, the microscopic sliding surface profile on the electromagnetic clutch, which is in the order of several micrometers, is optimized under boundary lubrication. This results in stable torque accuracy at both low and high temperatures.

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INTRODUCTION

In the field of vehicle driveline components, the development of new products that contribute to improved fuel efficiency while maintaining driving stability and safety has become an urgent need from the standpoint of helping to protect the global environment. Improving fuel efficiency through weight reduction and higher driveline efficiency is particularly important for vehicles installed with an all-wheel drive (AWD) system such as that shown in Figure 1.

Minivans and sports utility vehicles (SUVs) based on the chassis of passenger cars have become popular all over the world, especially in North America and Japan. Furthermore, AWD systems are increasingly adopting couplings capable of

electronically controlling the transmission torque as shown in Figure 2.

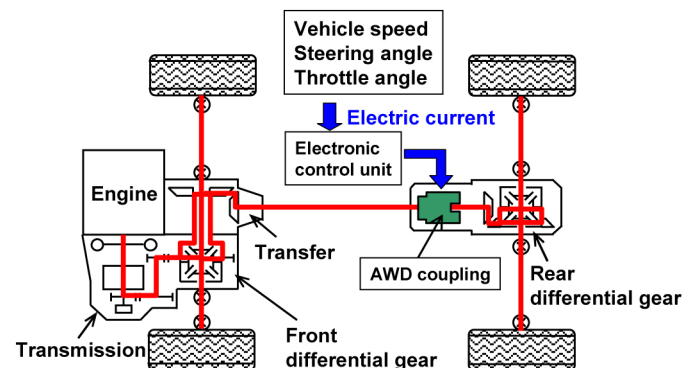


Figure 1. Example of ITCC application

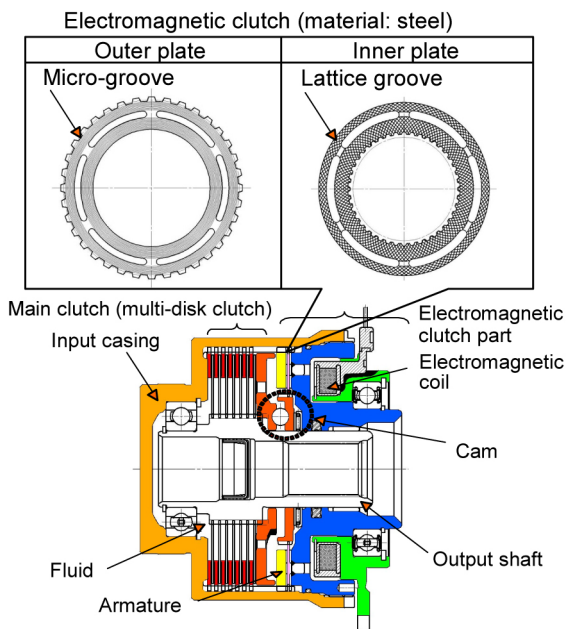


Figure 2. Structure of ITCC

The Intelligent Torque Controlled Coupling (ITCC®) is an electronically controlled AWD coupling that distributes optimum torque as needed. This coupling enables excellent AWD performance and high fuel efficiency, and also allows for a high degree of matching with other control systems, such as brake and electronic stability control systems. In addition, ITCC is being further developed to achieve both higher AWD performance and fuel efficiency. It is important to stabilize torque especially under low temperature environments, and improving this performance may help to reduce the weight of the driveline. The torque derived from clutch drag when the ITCC control current is not applied (i.e., when the clutch is not pressed) and the control torque when the control current is applied (i.e., when the clutch is pressed) increases in low temperature environments due to higher lubricant viscosity. Improving this torque may enable further weight reduction in the entire driveline through reviewing the driveline from the aspect of strength design.

The third-generation ITCC has been developed to achieve this aim by focusing on the surface texture of the electromagnetic clutch. It expands the clearance between the clutch plates to restrict excess increases in torque by actively utilizing the dynamic pressure between the clutch plates at low temperatures where the viscosity of lubricant increases. This enables weight reduction of the driveline and contributes to an improvement in fuel efficiency. This paper describes the high-performance technology of the electromagnetic clutch used in the third-generation ITCC.

HISTORY OF ITCC DEVELOPMENT

Figure 3 shows the history of ITCC development. The first-generation ITCC, an electronically controlled AWD coupling,

was developed in 1997 (Gen1) [1], featuring the first use of its distinct structure with an electromagnetic clutch in the world. The second-generation ITCC was released in 2004 (Gen2). Durability was significantly improved by the use of diamond-like carbon (DLC) coating [2,3,4] on the electromagnetic clutch and a special lubricant [5]. These measures expanded the usable boundary area of the AWD coupling and greatly enhanced the reliability and competitiveness of the product. In addition, improving the durability increased the clutch capacity, thereby reducing the number of clutch plates and helping to reduce size and cost.

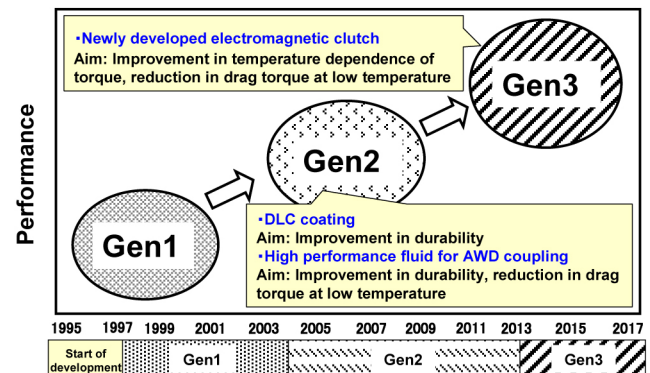


Figure 3. History of ITCC

This paper describes the third-generation ITCC (Gen3), in which the drag torque performance and torque accuracy at low temperatures were drastically improved by modifying the surface texture of the electromagnetic clutch. The third-generation ITCC is now in production.

HIGH PERFORMANCE TECHNOLOGY

Reduction in Drag Torque at Low Temperatures

As shown in Figure 4, the drag torque of the ITCC increases under low temperature environments. This is caused by increased lubricant viscosity. The second-generation ITCC uses a special lubricant with a synthetic base oil. This reduces the increase in viscosity under low temperature environments compared with a general mineral series lubricant. However, it was necessary to modify the sliding surface to further reduce the drag torque.

Figure 5 shows the Stribeck curve. The range of lubrication examined in this study is in the hydrodynamic lubrication region as shown in Figure 5. Figure 6 indicates the influence of each component on the drag torque of the ITCC. The electromagnetic clutch alone contributes five percent of the ITCC drag torque. However, considering torque amplification by cam mechanism, this is equivalent to 88 percent of the overall total drag torque. Therefore, reducing the drag torque depends largely on improving the electromagnetic clutch.