

Development of Original Self-Oscillating Washer Nozzle

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ABSTRACT

As an integral element of automotive wiper systems, an automotive washer system is designed to contribute to the security and safety of automobile-based societies by providing drivers with a clear field of vision. Washer fluid is discharged from washer nozzles, typically mounted on the engine hood, to distances of more than 300 mm across the windshield. However, the fluid discharged may fail to reach targeted areas due to the effects of wind pressure when the vehicle is moving at high speed or due to the increased viscosity of methanol in the washer fluid (at concentrations of 30-60 %) at low temperatures, resulting in failure to ensure a clear field of vision. We developed a self-oscillating washer nozzle to remedy these shortcomings of conventional washer systems. Based on CFD and optimization, the flow passage is designed to generate a stable discharge of washer fluid, even under conditions of high-speed air flow or low temperature. Another point of great concern is the size of the washer nozzle. To avoid adverse effects on automobile design, we sought to develop small nozzles based on the world's smallest flow passages. Additionally, our nozzle can be installed at a wide range of mounting angles, ensuring compatibility with a wide range of vehicles, and is capable of discharging large droplets to maximize wiper system performance. It consumes less washer fluid than conventional systems, contributing to the design of smaller, lighter, and more fuel-efficient vehicles. This new nozzle is produced by our proprietary OSI molding method, previously presented by Mr. Umezawa at the SAE 2009 World Congress & Exhibition and patented in Japan.[1]

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INTRODUCTION

Windshield wiper systems use rubber wiper blades to clear rain and dirt from windshields. They are essential to safe driving and relied upon to ensure a constant clear field of vision under various weather and environmental conditions. [Figure 1](#) shows a typical washer system and washer nozzle. Washer fluid stored in a tank installed in the engine compartment is forced by an electric pump incorporated into the tank via thin tubes to washer nozzles mounted on the engine hood and discharged onto the windshield. These washer systems pose the following major issues:

I. Reduced Reach of Discharged Wiper Fluid at High Speeds

Washer fluid may fail to reach the targeted areas of the windshield due to the effects of high-speed air flow when cars move at high speed. Inadequate distribution across the windshield can impair cleaning performance and create significant driving hazards, a serious issue that requires resolution.[2]

II. High Washer Fluid Viscosity at Low Temperatures

The methanol found in washer fluid is more viscous at low temperatures, increasing fluid resistance, reducing discharge pressure, and degrading washer fluid distribution. Since commercial washer fluid products contain varying concentrations of methanol, this aspect requires investigation. [3]

III. Application Area

Washer nozzles are very small relative to windshield dimensions. A clear field of vision cannot be ensured without the appropriate distribution of washer fluid over the areas traversed and cleared by the wiper blades. Washer nozzles need to discharge washer fluid over wider areas in accordance with the movement of wiper blades.

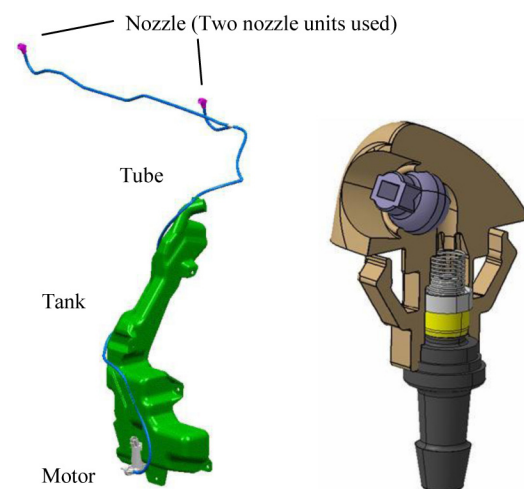
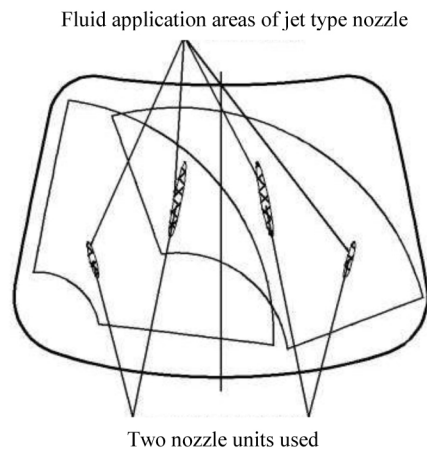
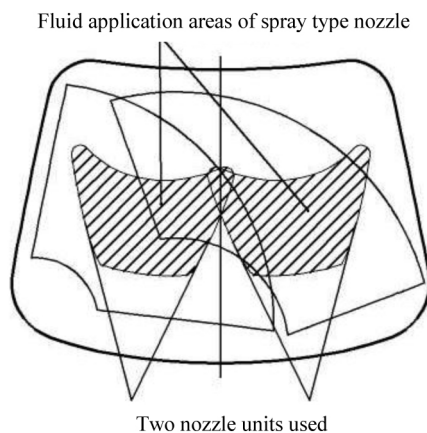


Figure 1. Washer system and washer nozzle (cutaway image)

Our existing washer nozzles are one of two types: jet type or spray type. Figure 2 illustrates the corresponding discharge patterns, while Table 1 gives performance descriptions. Based on the idea that the disadvantages of each can be overcome through a combination of advantages, we explored a new washer system. As a means for cleaning windshields, wiper blades with washer functions are already known to the public, but these are associated with high cost. We developed a self-oscillating washer nozzle capable of consistently covering a wider expanse of the windshield with oscillating washer fluid, thereby resolving the issues associated with conventional washer systems. The principle of the self-oscillation of fluid is as follows: The nozzle is designed to generate the Coanda effect (the tendency of fluid to be attracted to a nearby surface) alternately on the side walls of a main channel, using feedback channels as an alternating trigger. Passing through the main channel results in fluid oscillation and discharge, a behavior widely applied for some time now. In this study, we applied this phenomenon to design optimized flow passages.



(a). Jet type nozzle



(b). Spray type nozzle

Figure 2. Discharge images of jet and spray nozzles

Table 1. Performance of washer nozzles

	High speed driving	Low temperature	Application area
Jet type	Good	Moderate	Poor
Spray type	Poor	Moderate	Good
Self-oscillating type	Good	Good	Good

DEVELOPMENT OF THE SELF-OSCILLATING NOZZLE

The design of the inner flow passage of a washer nozzle is important because it is a key factor in the performance of the washer nozzle. We applied CFD analysis to examine the design and performance of flow passages. Washer fluid is discretely discharged with air entrained in the fluid. Due to the high difficulty of reproducing this phenomenon completely through CFD analysis, we used a relatively simple CFD model suitable for qualitative evaluation, with an emphasis on the performance of the inner flow passage alone. This model allowed us to examine various designs, achieve high development speed, and reduce the labor required for prototyping. Table 2 gives the CFD analysis conditions. In addition, we developed a CAE system using Java, linking CAD software, CFD software, and optimization software. We used finite volume method software for CFD analysis and genetic algorithms (GA) for optimization.[4][5] Figure 3 presents a conceptual diagram of the system. Our optimization approach clarifies the parameters that affect vibration in a flow passage and allows efficient determination of design and performance.

Table 2. CFD analysis conditions

Calculation method	Non-stationary Analysis
Time step	1e-5 seconds
Mesh type	Polyhedral
Number of meshes	Approx. 1 million meshes
Turbulence model	k-ε model

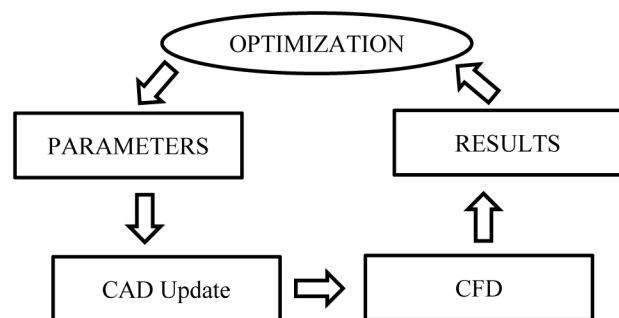


Figure 3. Optimization approach

Figure 4 presents a conceptual diagram of the CFD model used. As boundary conditions, the discharge pressure of the electric washer fluid pump was set as the inlet pressure of a flow passage and atmospheric pressure as the outlet pressure. Since the distribution pressure from a pump varies with temperature, we set two