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PERFORMANCE PREDICTION AND FLOW CHARACTERISTICS OF A HYDRAULIC PUMP FOR ABS AND ESC SYSTEMS USING FSI SIMULATION

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ABSTRACT- The electronic stability control (ESC) system is a computerized technology that improves vehicle stability by detecting and reducing the loss of traction. The hydraulic control unit for an anti-lock braking system (ABS) or an ESC system in a car includes a hydraulic pump located between the wheel and master cylinder. The function of the hydraulic pump is to allow the brake fluid to return from the wheel to the master cylinder when the ABS or ESC is actuating. This study performs numerical investigations with the aim of predicting the performance of the hydraulic pump by better understanding the dynamic behavior characteristics of the inlet ball under instantaneous fluid forces during the suction cycle and the corresponding flow characteristics under various motor speeds. A fluid-structure interaction (FSI) simulation of the hydraulic pump is conducted under various motor speeds with an unsteady three-dimensional approach considering laminar flow and the user-defined function (UDF). Experimental verification of the simulation results at the standard pump pumping test system of the Mando Corporation in Korea indicates considerable reliability. The findings of this research can provide valuable insights into designing high-efficiency pumps.

KEY WORDS : Anti-lock braking system (ABS), Electronic stability control (ESC), Hydraulic pump, Fluid-structure interaction (FSI) Simulation, User-defined function (UDF)

NOMENCLATURE

F_{fluid} : sum of pressure and viscous forces, N
$F_{pressure}$: pressure force, N
F_{spring} : spring force, N
F_{total} : total force, N
$F_{viscous}$: viscous force, N
k : spring constant, N/mm
L_{init_disp} : initial length of spring, mm
L_{ref} : piston displacement, mm
L_{valve} : valve displacement, mm
m : ball mass, kg
T* : time, dimensionless
$\ddot{x}$: acceleration in x-direction, mm/s^2
V_t : velocity at current step time, mm/s
$V_{t-\Delta t}$: velocity at previous step time, mm/s
x_t : displacement at current step time, mm
$x_{t-\Delta t}$: displacement at previous step time, mm
Δt : time step size, s

1. INTRODUCTION

Electronic stability control (ESC) systems are a form of computerized technology that improves vehicle stability by detecting and reducing loss of traction (National Highway Traffic Safety Administration, 2007). The system controls the braking force and driving force with an anti-lock braking system (ABS) and traction control system (TCS) that prevent the vehicle from slipping to the left and right by analyzing the road and driving environment through data obtained from various vehicle sensors (Jeong *et al*., 2015). Intelligent safety vehicles have been the focus of many studies aimed at developing the next generation of smart vehicles based on active control technology and employing cutting-edge electronic and IT technologies (Jeong *et al*., 2015; Kim *et al*., 2015).

An ESC system has two main components: an electronic control unit (ECU) to determine optimal driving conditions and a hydraulic control unit (HCU) to offer hydraulic power for wheel pressure generation. The HCU plays a particularly important role in achieving a stable attitude control of a vehicle by adjusting each individual wheel force. For this reason, many researchers prioritize improving the performance of ABS or ESC systems when developing braking systems which involve a hydraulic pump (Choi *et al*., 2004; Yang *et al*., 2003). For decades, studies have revealed good results in model-based design analysis and vehicle system control (Bharadwaj, 1997;

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