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DEVELOPMENT OF TRAVELING EQUIPMENT FOR CONSTRUCTION AND MAINTENANCE OF RAILROAD TRACK BASED ON 14-TON CLASS EXCAVATOR

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Abstract:
The unique traveling mechanism was established and investigated by a coordinated modeling and experimental effort and both results are compared for validation of newly developed traveling equipment based on the conventional excavator system. The various hydraulic characteristics such as flow rate, pressure, revolutions per minute (RPM), and torque was confirmed by numerical and experimental technique with the appropriate test bench. After the above processes, the experimental and analytical results were successfully correlated. As a result, this new traveling equipment can contribute to save the outstanding monetary cost during railway construction and maintenance in that this equipment facilitates the accessibility of the conventional excavator into the work site composed of the railroad track.

Keywords: *Capital Allocation; Generalized Linear Modeling; Regression Modeling; Reserving.*

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1. Introduction

Various social needs related to railroad infrastructure are recently magnified because both rail freight transport and train passenger are consistently increased as well as many people want diversity of route and special transportation faster than conventional train. Therefore, most country has tried to keep pace with these social needs. Federal Railroad Administration (FRA) which is part of the U.S. Department of Transportation announced the national rail plan including issuing the safety regulation and investing the development of new rail network across the country and as a result, FRA has successfully completed the railroad infra structure in the U.S territory [1]. European Rail Research Advisory Council (ERRAC) suggested detail plan for increasing the conveyance of goods and passengers by rail up to 22.2% and 15.3% respectively until 2050 and their catchphrase is that Rail is the Sustainable Backbone of the Single European Transport Area [2]. In addition, China has planned the high-speed railroad construction and expanding the railway route over the 120,000km as national railroad network until 2020 [3], and Korea has also established railroad expanding route plan around 5,000km until 2020 [4].

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These increased demands for urban railway and high-speed railroad induce the global trend for new railroad construction and maintenance of the conventional railroad and this requires the mechanization and automation of railroad construction field to maximize the efficiency of the time and cost. In this reason, railroad excavator has been introduced.

The railroad excavator is special equipment to install the track, replace and renew the ties, align the gravel and so on. This is generally developed by modification of conventional excavator as attaching the special traveling equipment and working attachment. In this paper, we will focus on the traveling equipment rather than working attachment.

In general, traveling equipment can be classified by three different types. The simplest type use only pre-exist wheel in the conventional excavator. Whereas others use newly attached special driving part. The characteristic and representative figure of these types is shown in the Table 1 [5-9].

Table 1: The characteristics of each type

Type	System configuration	Characteristics
1		- Wheel which is equipped in the conventional excavator directly provides the driving power. - Train wheel engages the track guide only.
2		- Wheel which is equipped in the conventional excavator contacts to the supplementary driving system and this system provide the driving power.
3		- Train wheel fully engages the driving power. - Independent driving system and hydraulic control technology are required

Type 1 can be only used in the condition of same track center distance between vehicle and railway. Type 2 needs the modification of driving supplementary system for moving desired direction because contact surface is reversely rotate with rotation of wheel which is equipped in the conventional excavator. Moreover, the driving power of Type 1 and Type 2 is from the excavator wheel directly or indirectly and therefore, acceleration/deceleration and braking system is limited by complicated parameters which is difficult to control. Whereas Type 3 fully lifts the whole excavator and uses the independent driving system rather than the driving system of the conventional excavator and therefore, this system is more efficient compared with other types in the way that the good performance of acceleration/deceleration and breaking stability because of driving system directly contacted to railway. In addition, this type of equipment can easily comply the international railroad regulation such as UIC 505 of International Union of Railway or EN 15746-1 of European Council. Therefore, Type 3 has been broadly used in the railroad construction.

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With increased interest on railroad industry, many studies have extensively carried out the improving the tractive force. Polach evaluated the tractive force control method which can be varied with contact condition between train wheel and track [10, 11]. Heller et al. developed the test bench for characterization of tractive force of driving module, maximum velocity and generating torque for parametric study [12]. Also, Fornarelli et al. analyzed the swash plate pump theoretically and estimated the frictional force of piston and loss of volumetric efficiency with simulation method using AMESim® software.

Despite these efforts, most study was focused on the transporting train thus study of railroad construction equipment is not easily found out. It is a matter of common that quality of railroad construction is directly affected to efficiency of transportation.

In this manuscript, therefore, we introduce a novel modeling and experimental investigation on the hydraulic performance for traveling equipment for construction and maintenance of railroad track based on 14-ton class excavator which is newly developed by us. The driving module was only used in this study and we observed the hydraulic characteristics under given flow rate. As the relevance of the analytical model is proved by correlation with bench test result, we can successfully predict the hydraulic behavior of the driving system under given condition. We believe this study can contribute several parametric studies related to hydraulic performance using developing the simulation platform based on the AMESim® software.

2. Configuration of Traveling Equipment System

The driving module of the traveling equipment firstly moves to downward and then the train wheel is touch the railway and finally lifts the whole excavator. In fact, the lifting system is also operated by hydraulic power, but this study was focused on the driving performance only. After the lifting the excavator, this module moves along the railway track to the working space. The driving module is composed of four wheels and each pair is installed at the front and rear part. The module is designed as the maximum velocity is 25km/h or more and breaking distance is within 20m. The schematic of the traveling equipment system is shown in Figure 1.

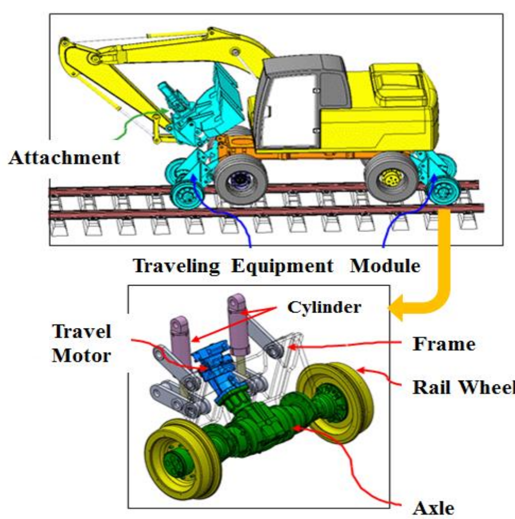

Figure 1: Schematics of the traveling equipment system

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The driving power is provided by diesel engine and the power from engine is transmitted to the hydraulic pump and Main Control Valve (MCV). MCV distributes the hydraulic power to the axle trough the center joint and the train wheel is operated by this transmitted power. Most of the hydraulic control system is kept as original excavator system and the supplementary hydraulic control system for the driving module is additionally designed and installed into excavator system.

The select valve is added for set up the both excavator wheel operating mode and train wheel operating mode. In accordance with each mode, new hydraulic circuit is laid out and this is shown in Figure 2.

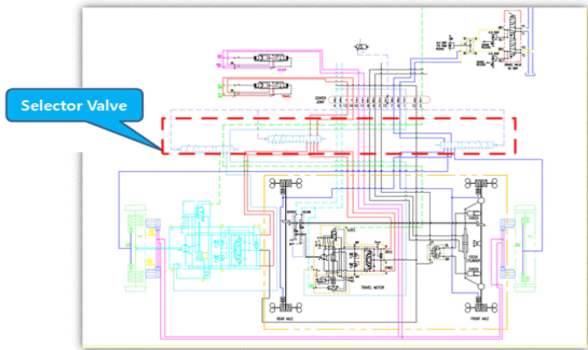

Figure 2: Hydraulic circuit for traveling equipment system

3. Development of Simulation Model

The purpose of this study is developing the simulation platform for parametric study. Therefore, novel simulation model was established using AMESim® software and several hydraulic performances of driving module were observed based on the newly developed simulation platform with given flow rate.

Figure 3 shows the AMESim® model composed of pump, track driving hydraulic motor, axle and external loading device. This hydraulic circuit is basically controlled by constant power control circuit and the appropriate moment of inertia is applied to the axle. Also, additional pump for external loading is connected to the rotating part.

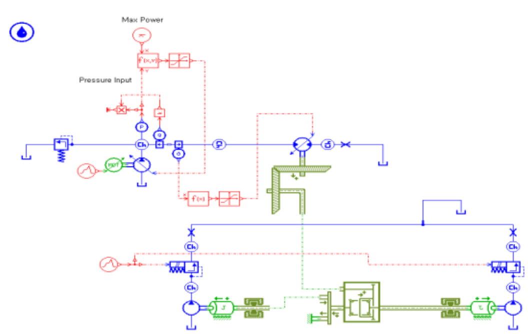

Figure 3: AMESim® model of the driving module

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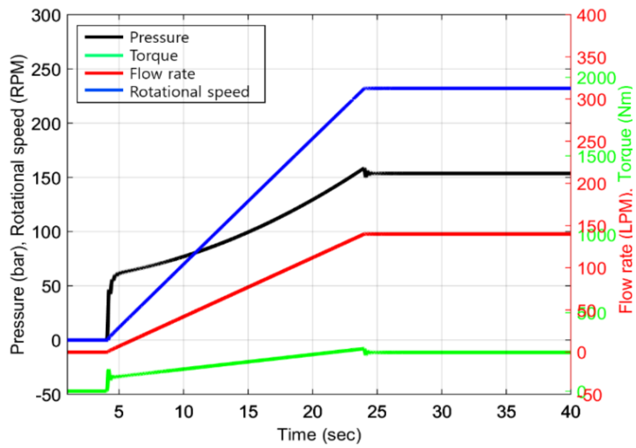
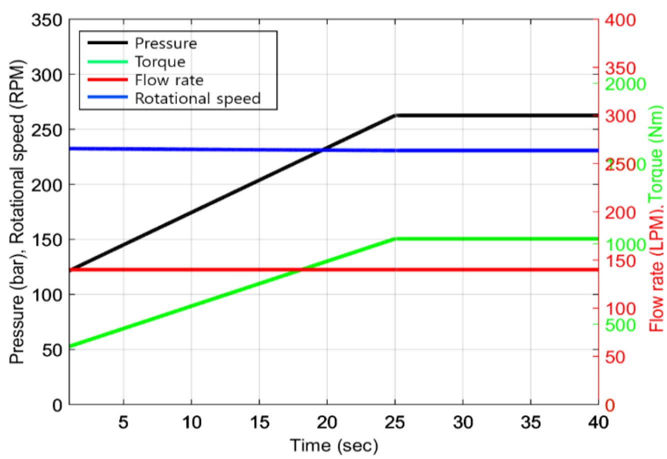
4. Execution and Results of Simulation Model

In order to confirm the hydraulic performance such as pressure, torque and rotational speed under given flow rate, the simulation was performed for two different loading conditions. Figure 4 (a) shows the simulation results without loading and Figure 4 (b) shows the results with the external loading. In this simulation, flow rate of 140LPM was provided to the driving module.



(a) Simulation results without loading



(b) Simulation results with external loading

Figure 4: Simulation results

As shown in Figure 4 (a) the rotational speed of axle and pump pressure were observed as 240RPM and 135bar respectively. At this time, also, torque of axle was measured as 260Nm due to small angle of swash plate. Whereas pump pressure was increased up to 265bar despite the rotational speed was kept as 240RPM when the external loading was applied by 1kNm shown as Figure 4 (b).

To confirm the usability of this simulation platform, additional simulation was also carried out. We can find out how gear ratio affects the rotational speed of axle. Even though hydraulic motor

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speed was kept as 3,350RPM, the rotational speed of axle was decreased by raising the external torque. The torque was linearly raised up to 700Nm and then kept as this value. It is indicated that a smaller reduction gear ratio was more sensitive to the external torque. This phenomenon can be observed in Figure 5.

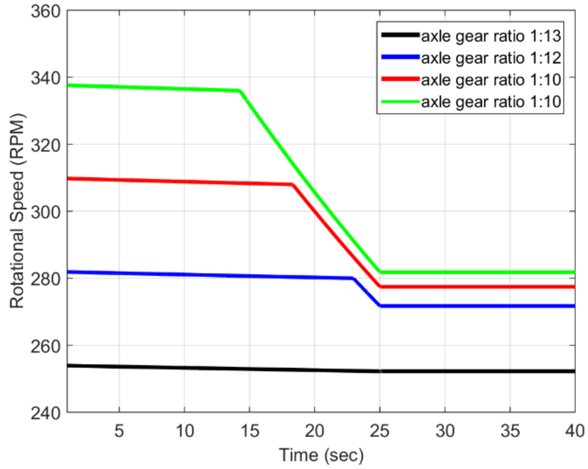


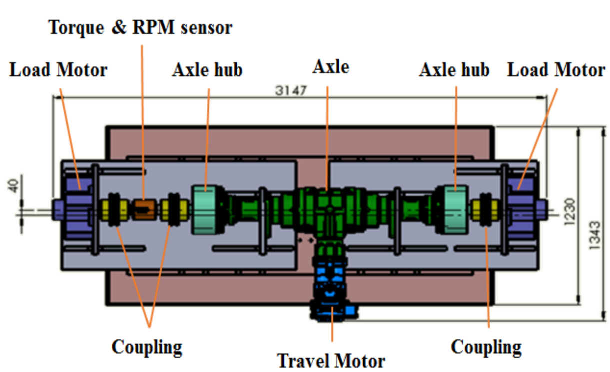
Figure 5: Variation of rotational speed in accordance with gear ratio under external loading condition

5. Configuration of Test Bench and Results

To perform the bench test and validate the newly developed simulation platform, the special test bench was manufactured. The specification of Hydraulic Power Unit (HPU) is as following.

a. Maximum pressure: 420bar
b. Maximum flow rate: 800LPM

The pressure sensor and flow meter were installed in the HPU for measuring the inlet pressure and flow rate into the hydraulic motor. In addition, torque meter and RPM sensor was attached at the end of the axle shaft for torque and rotational speed measurement. Figure 6 shows the schematics and actual test setup of the test bench.



(a) Schematic of the test bench

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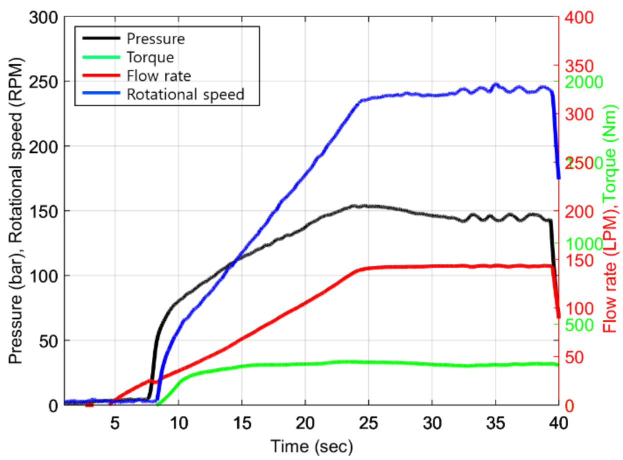
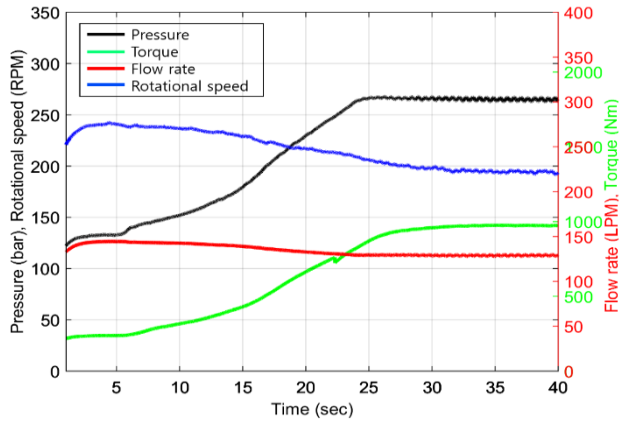
(b) Actual image of the test bench

Figure 6: Experimental test bench

In order to compare the simulation results, the experimental condition was set up with corresponding the simulation condition. Therefore, the providing flow rate was 140±10LPM. The margin of 10LPM is caused by actual hydraulic motor instability. Using each sensor, we can measure the pressure, torque and rotational speed of the actual parts of the test bench.



(a) Experimental results without loading



(b) Experimental results with external loading

Figure 7: Experimental results

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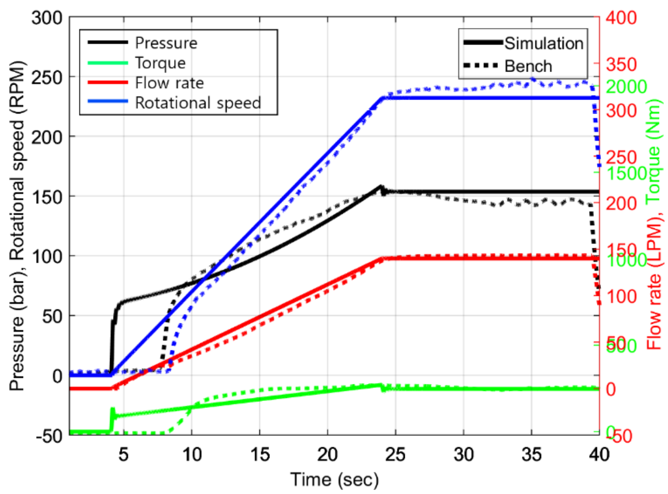
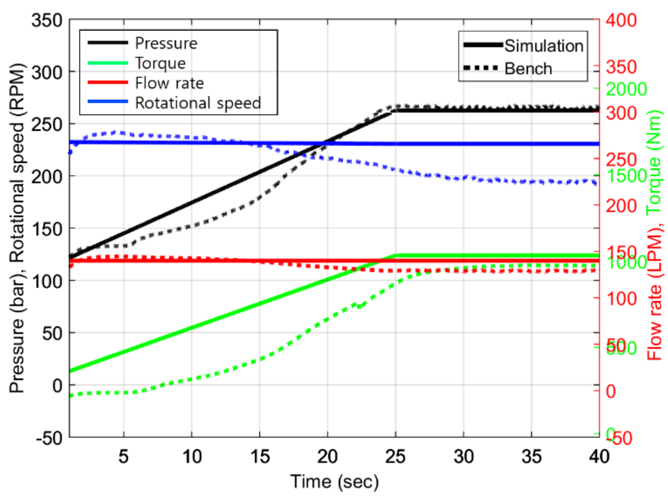
Figure 7 (a) shows the rotational speed of axle and pump pressure and these values were measured as around 240RPM and around 145bar respectively. Also, torque of axle was measured as around 250Nm. As shown in Figure 7 (b), on the other hand, when the external loading was applied by around 1kNm, pump pressure was measured as around 265bar, but the rotational speed was slightly decreased to around 200RPM. This is because of the fluctuation of supplying flow.

6. Validation of Simulation Platform

Figure 8 shows the correspondence between simulation and experimental results and both results are well matched except small fluctuation caused by instability of hydraulic motor. Therefore, it is concluded that the developed simulation platform is very appropriate to the parametric study for hydraulic driving module of traveling equipment based on conventional excavator.



(a) Comparison without loading



(b) Comparison with external loading

Figure 8: Comparison between simulation and experimental results

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7. Conclusions and Recommendations

A new simulation platform is developed to investigate the hydraulic behavior of the traveling equipment based on the conventional excavator using a combined experimental and modeling approach. This novel platform can predict the several hydraulic parameters under certain condition and this numerical technique was verified by comparison with experimental results. For the analysis, novel simulation model was developed using AMESim® software and several parametric studies were carried out for developed driving module. Also, a series of experimental study were performed in accordance with same condition of simulation. As a result, we can confirm the simulation corresponds to experimental results and therefore, it is concluded that the simulation platform can be successfully used in the parametric study of the traveling equipment.
Eventually, this research will be used extensively in actual machine as well as driving module if the hydraulic system of the conventional excavator will be combined. Moreover, several parametric studies can be performed and optimized the hydraulic parameters without actual machine test. It is noted that this platform can contribute to save the outstanding monetary cost during railway construction and maintenance

Acknowledgements

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