Dynamic Characteristic Analysis of Linear Induction Motor for Magnetic Levitation Vehicle Propulsion System considering Operating Condition

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Abstract —This paper deals with dynamic characteristic of linear induction motor (LIM) considering acceleration time and jerk conditions. For dynamic simulations, dynamic modeling of LIM operated by SVPWM (space vector pulse width modulation) inverter is performed using Matlab Simulink, and the electromagnetic field theory is employed to derive equivalent circuit parameters. The results by electromagnetic field theory are validated by finite element method. The analysis model is applied to magnetic levitation vehicle for electromagnetic propulsion force, and its dynamic characteristics are analyzed to anticipate its operating performance. Besides, experimental results are offered to demonstrate the validity of this paper.

I. INTRODUCTION

Due to its various advantages and high demands, plenty of researches on LIM (Linear Induction Motor) have been actively performed [1]-[3]. Despite of those various studies, however, the researches on dynamic characteristics of LIM to anticipate its operating characteristics have not been sufficiently performed. In other words, the VVVF(Variable Voltage Variable Frequency) characteristics and SVPWM (Space Vector Pulse Width Modulation) inverters of normal LIMs have been studied in previous researches[4]-[5], but the dynamic characteristics of the application to magnetic levitation vehicles considering the operating circumstances have rarely been analyzed. When LIM is applied to transportation system, its dynamic characteristic is most important to guarantee passengers' safety and riding quality. Therefore, this paper deals with dynamic characteristics of LIM applied to a magnetic levitation vehicle to consider operating circumstances. To derive equivalent circuit parameters, the electromagnetic field theory is applied, and then dynamic modeling of LIM using voltage and flux equations is performed by Matlab Simulink. Furthermore, this paper assumes excessively shortened acceleration time and jerk scenario to consider possible outer disturbance of LIM. In addition, the simulation results are compared with experimental results to validate this paper.

II. DYNAMIC CHARACTERISTIC ANALYSIS OF LIM

A. Electromagnetic Field Analysis

Since LIM has the primary structure with tooth and slots, it makes difficulty for analysis. This paper employs

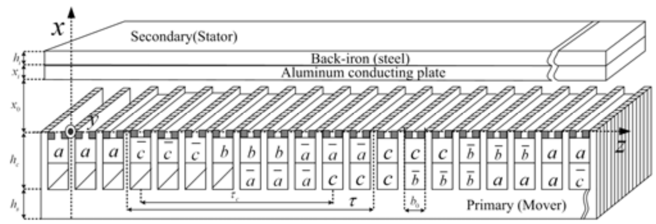

Fig. 1. Analysis model.

the equivalent model which translates the structure of teeth and slots to sheet current. Based on the Maxwell's equations, the governing equations and flux density in each region are derived, and its unknown coefficients are obtained applying boundary conditions. Here, the flux density is applied to derive circuit parameters. To validate this process, the characteristic analysis of analysis model in Fig.1 by finite element Method (FEM) is performed, and the comparison of both results are presented in Fig.2.

B. Dynamic Modeling of Propulsion System

In inverter-fed LIMs the linear velocity can be controlled by varying input frequency and input voltage or both input frequency and voltage, keeping air-gap magnetic flux constant. The majority of LIMs can be operated under such conditions without mechanical and thermal problems. Therefore, the analysis model in this paper is simulated by constant voltage/frequency ratio and with SVWPM inverter. Fig.3 presents the operating condition of the magnetic levitation vehicle. In every range, the LIM of the propulsion system is operated by constant V/F ratio.

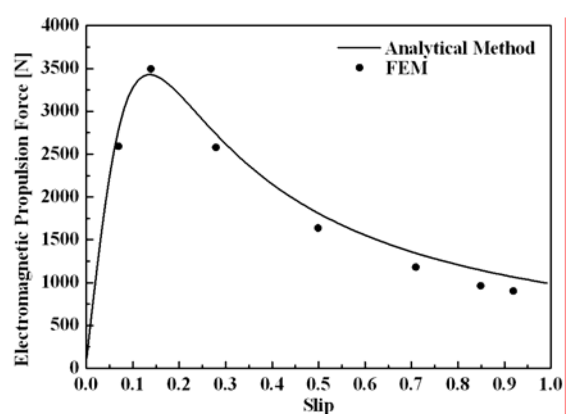

Fig. 2. Comparison of electromagnetic propulsion force.

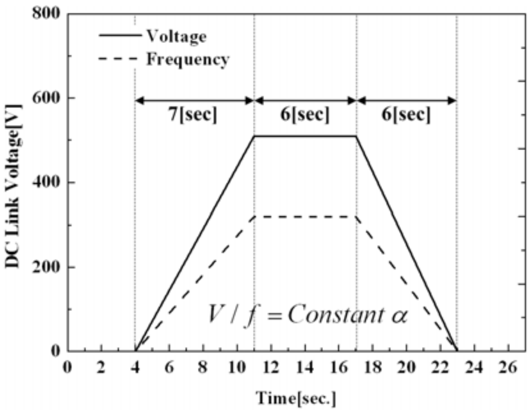

Fig. 3. Operating condition of magnetic levitation vehicle.

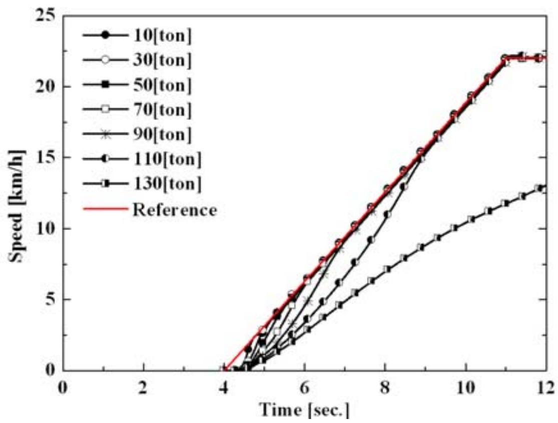

Fig. 4. Speed vs. load conditions.

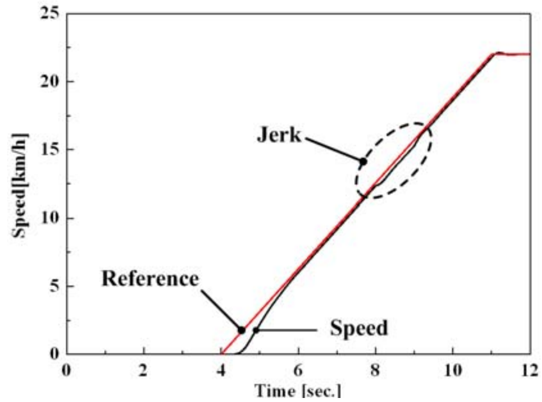

Fig. 5. Speed with jerk by simulation.

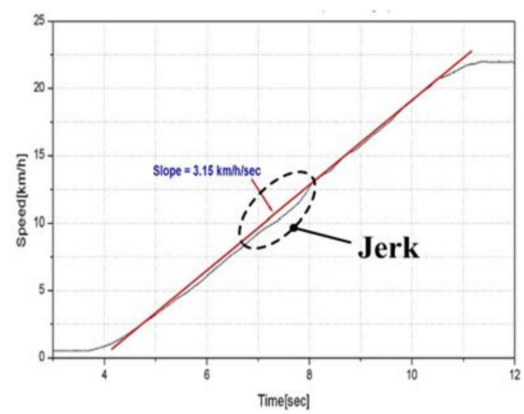

Fig. 6. Experimental Speed with jerk.

C. Dynamic Characteristic Analysis

Fig. 4 shows the speed characteristic according to variation of load condition. In the figure, the load is varied by each 20[ton] step from 10[ton] to 130[ton]. As the load becomes heavier, the time to follow the reference is delayed. In particular, when the load condition is 130[ton], the speed is about 12[km/h] in 7[sec] which cannot follow the speed reference. As a results, it is determined that the maximum load condition is 110[ton] for stable operation. In addition to the speed characteristics according to load conditions, this paper also performed the dynamic simulation according to acceleration time. The acceleration time is varied from 3[sec] to 7[sec], and the speed follows the reference well from 5[sec] to 7[sec] condition. However, when the magnetic levitation train is accelerated in 3[sec], the vibration emerges and the speed characteristic does not follow the reference. As a result, the minimum acceleration time is determined as 5[sec] for stability. The more specific illustration with data will be presented in full paper. During the operation of LIM, its rail condition or outer disturbance can affect to its speed characteristic. In reality, the curve included in the rail makes outer disturbance to train system (300N), so this paper considers those disturbance as a jerk. In Fig. 5, the speed characteristic with jerk is presented. The jerk conditions are simulated by mechanical equation applied to this propulsion system. In comparison with experimental result shown in Fig.7, simulation result is well corresponded.

III. Conclusion

In this paper, for the operating characteristic prediction of magnetic levitation vehicle with LIM, the dynamic modeling was performed, and it is simulated by VVVF control and SVPWM principle. To derive the equivalent circuit parameters, electromagnetic field analysis is performed, and the results are validated by FEM. Besides, considering operating circumstances, the speed characteristics are analyzed. In later full paper, the more specific illustration will have been presented.

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