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Study on Hydraulic Vibration System of Roller Based on AMESIM

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Abstract: Aiming at problems for hydraulic vibration system of rollers that the system can't regulate the flow and have large impact when it is started, this paper analysis the principle of the hydraulic system of the roller with opened—vibration, and use the pilot relief valve to control the highest pressure of system and provide protection; use vibration to achieve reversing valve vibration motor, so that the wheel vibration produce different amplitudesk, the system provides commutation function, buffer fill valve to prevent cavitation phenomenon, the original protection system components, the use of simulation software AMEsim modeled hydraulic system, hydraulic system and working process of the dynamic simulation. We come to the hydraulic system when conditions change there will be instability and failure factors, which after large-tonnage roller design instructive; large changes in load caused by the flow of the hydraulic system to rapidly change or stagnation the pressure within the system changed dramatically, causing hydraulic peak occurs, creating a hydraulic impact, split hydraulic system start-up hydraulic shock prevention can improve the performance and reliability of construction machinery.

Keywords: AMEsim; roller; hydraulic vibration system; dynamic simulation

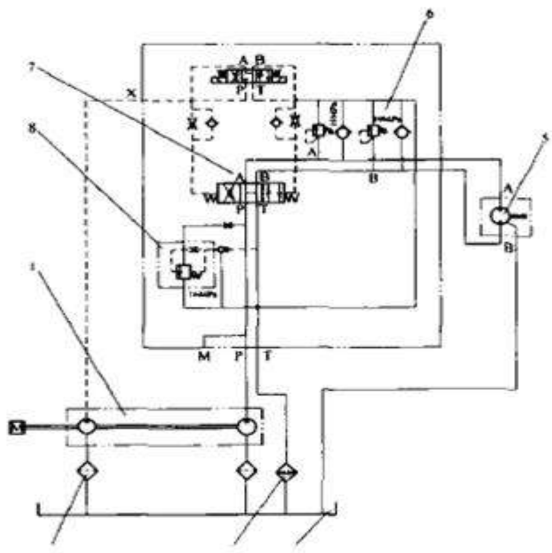
I. INTRODUCTION

The roller is used to compacted roadbed and surface layer, and its transmission system adopts full hydraulic transmission, including hydraulic driving system, hydraulic vibration system and hydraulic steering system[1]. Hydraulic transmission system not only improve the overall performance of the roller, but reduce the intensity of the operators. According to relevant regulations[2], the total length of roadbed that is compacted by the roller should be as short as possible and usually no more than 60 ~ 80 m[3]. Therefore, it must continually work in circle: start → forward compaction → stop → backward start → backward compaction → stop. 20% of the overall cycle time is spent on start and stop[4], and this operating characteristic make the roller have to start up and stop frequently. Owing to the great inertia of the roller's driving system, such frequent start-up and stop vibration will generate a great inertial force[5]. If the parameters do not match the hydraulic system perfectly, the hydraulic impact generated form the inertial force will make the hydraulic components work improperly[6]. So, it is necessary to study on dynamic process of vibration system in order to solve the pressure shocks of the system. This paper uses the AMEsim to simulate and analyze the hydraulic system of rollers, and know that how and why the pressure and flow change when rollers start oscillating, reverse and stop vibrating.

II. STRUCTURE OF HYDRAULIC VIBRATION SYSTEM

According to the requirements on the hydraulic drive system of vibratory roller, Some small rollers make more use of single-frequency vibration which can be obtained from an open-loop quantitative system composed of gear pumps and gear motors. This kind of hydraulic system can achieve constant torque transmission, and easily overcome the large inertia torque at start-up. Reversing valve in system can enable the motor reverse easily, and with the movable eccentric block in the exciter, this roller can achieve double amplitude vibration. For the vibratory roller which requires its frequency can be adjusted , it can use a closed loop system consisting of variable axial piston pumps and fixed displacement motors.

For the open-loop system, its working pressure is low, and its hydraulic components can be easily selected, and the system is also easy to seal and leak-proof and has better reliability. However, its volumetric efficiency and transmission efficiency are low, and it is sensitive to the change of oil temperature. It is necessary to install a cooler in hydraulic circuit for cooling because natural cooling is inefficient. While the cost of hydraulic components and fluid cleanliness in the closed system are much higher than the open system. Thence, the simulation and analysis of the open hydraulic vibration system can help to improve the performance and reliability of the rollers and cut costs.



1-double pump,2- filter, 3-oil cooler, 4-oil tank, 5-vibration motor,6- vibration fill valve, 7-vibrating valve, 8-pilot relief valve

Figure 1: Hydraulic vibration system of roller SRl2

As the figure shows, this is hydraulic vibration system of the roller SRl2, which is a typical open-valve-controlled hydraulic system.

III. INTRODUCTION OF AMESIM

LMS AMEsim stands for Advanced Modeling Environment for performing Simulations of engineering systems. It is based on an intuitive graphical interface in which the system is displayed throughout the simulation process. The software package provides a 1D simulation suite to model and analyze multi-domain intelligent systems, and to predict their multi-disciplinary performance.

It has many highlights[7]:

- Simulation of physical multi-domain systems
- Broad range of application and physical domains
- Automotive, aerospace, and off-highway-specific solutions
- Steady-state and transient analysis
- Linear and non-linear systems
- Input/output analysis
- Parameter sensibility analyses
- Vibration and order analysis
- Time-domain and frequency-domain analysis
- Test systems with MIL/SIL/HIL and Real-Time
- Integration with CAE software tools (Computer-Aided Engineering)

LMS AMEsim uses symbols to represent individual components within the system which are either: based on the standard symbols used in the engineering field such as ISO symbols for hydraulic components or block diagram symbols for control systems; or when no such standard symbols exist, symbols which give an easily recognizable pictorial representation of the system[8].

LMS AMEsim offers powerful platform features so that any user can easily create an LMS AMEsim model from the standard LMS AMEsim libraries or from his own User libraries, and run it to get interesting analysis results. The LMS AMEsim platform facilities ensure the easy use of the LMS AMEsim models in day-to-day work, and they allow the integration of LMS AMEsim in the design process to be used at most stages of the V-Cycle[9]. The LMS AMEsim Platform facilities go from the "Simulator scripting" and "LMS AMEsim customization" facilities up to the "MIL/SIL/HIL and Real-Time" or "1D/3D CAE". The architecture of LMS

AMESIM is shown below, see Figure 2.

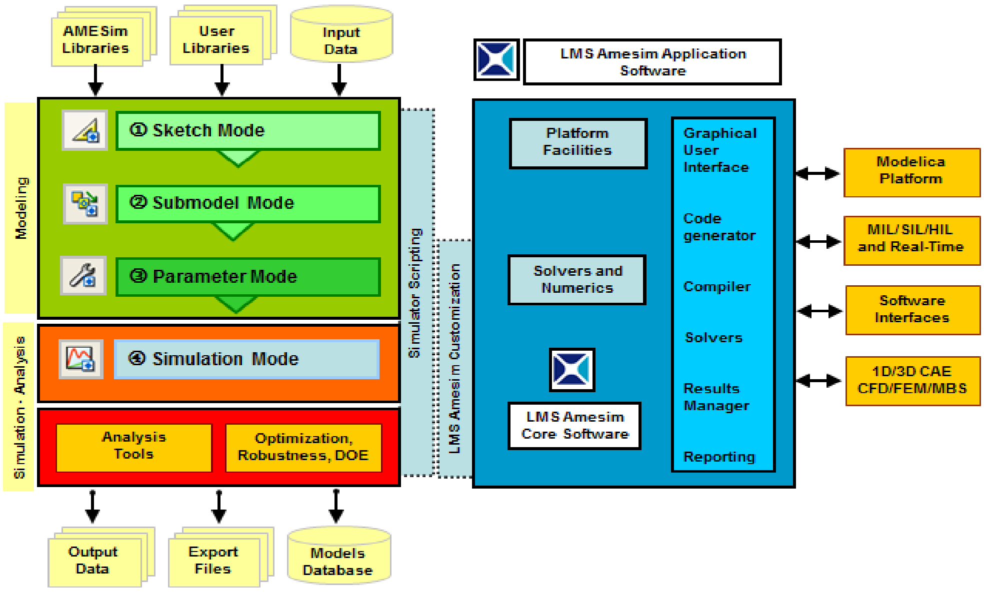


Figure 2: Architecture of LMS AMEsim (simplified view)

Using LMS AMEsim you build sketches of engineering systems by adding symbols or icons to a drawing area. When the sketch is complete, a simulation of the system proceeds in the following stages[10]:

- Mathematical descriptions of components are associated with the icons.
- The features of the components are set.
- A simulation run is initiated.
- Graphs are plotted to interpret the system behavior.

As much automation as possible has been carried out on these steps and at every stage you will see the sketch of the system. Working with LMS AMEsim, you can take advantage of Equations and the Standard library.

IV. DESIGN OF SIMULATION MODEL

4.1 Construction of the model

Building sketch model of hydraulic vibration system by using standard hydraulic, mechanical and control symbols which are provided by AMEsim, based on Figure.1.The sketch model of hydraulic vibration system is shown in Figure 3.

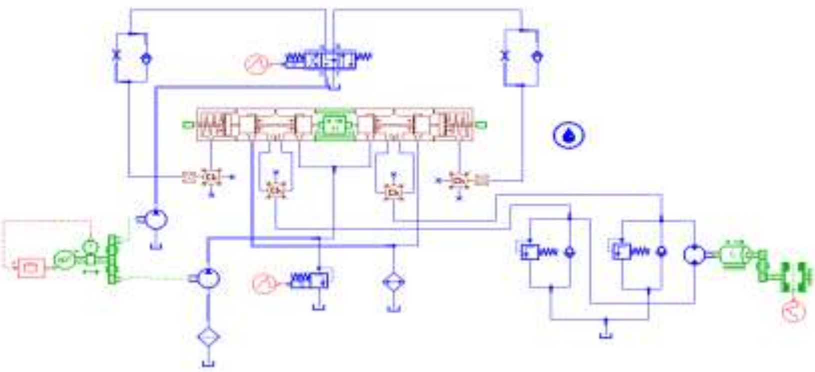


Figure 3: Model of hydraulic vibration system

4.2 Parameter determination

(1).Hydraulic oil

The types of hydraulic oil's properties are simplest, elementary and advanced respectively. Different fluid properties caused different simulation results[11]. In this paper, the property of hydraulic oil is advanced in the process of simulation, because this type of fluid can simulate properly various characteristics of hydraulic oil at a temperature of 40 degrees. Other parameters are default values.

(2).Piece-wise linear signal source

The signal source is set to change the load vibratory roller suffered. In order to simulate operation of the system in different conditions and consider the changes in the torque of vibrating wheel at start-up and commutation time, the load signal of vibrating wheel is shown below, see Figure.4.

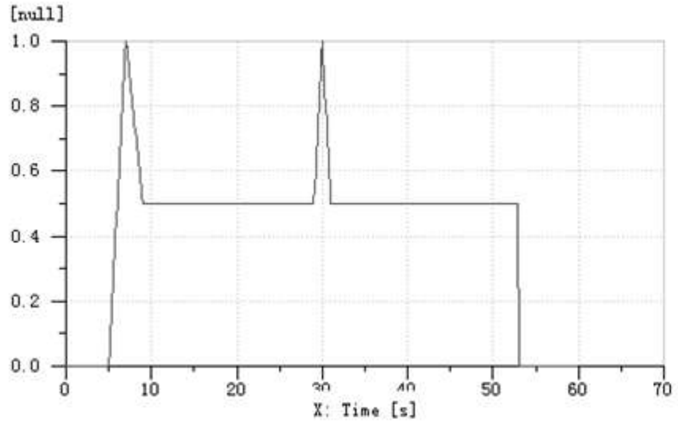


Figure.4: Load signal of vibrating wheel

In order to make the roller start oscillating, change direction and stop vibrating, The signal source for reversing valve is set as Figure.5. The valve starts oscillating when $t=5s$, changes direction when $t=29s$ and stops vibrating when $t=50s$.

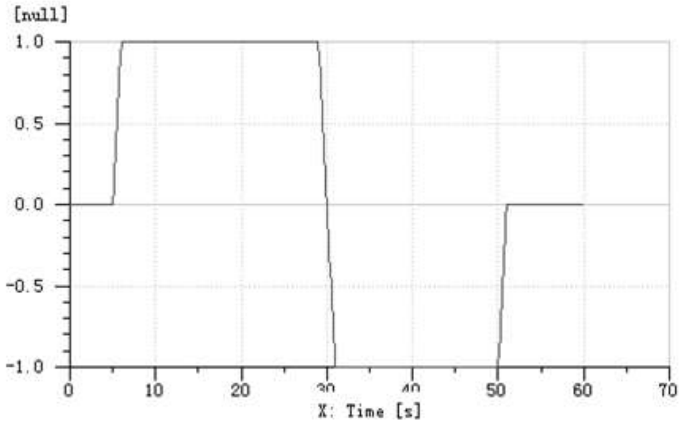


Figure.5: Load signal of reversing valve

Piece-wise linear signal source are used to determine engine speed, control reversing valve opening and closing, change the displacement of variable displacement pump and set dummy roller load . The parameters of signal source for reversing valve are shown in Figure.6.

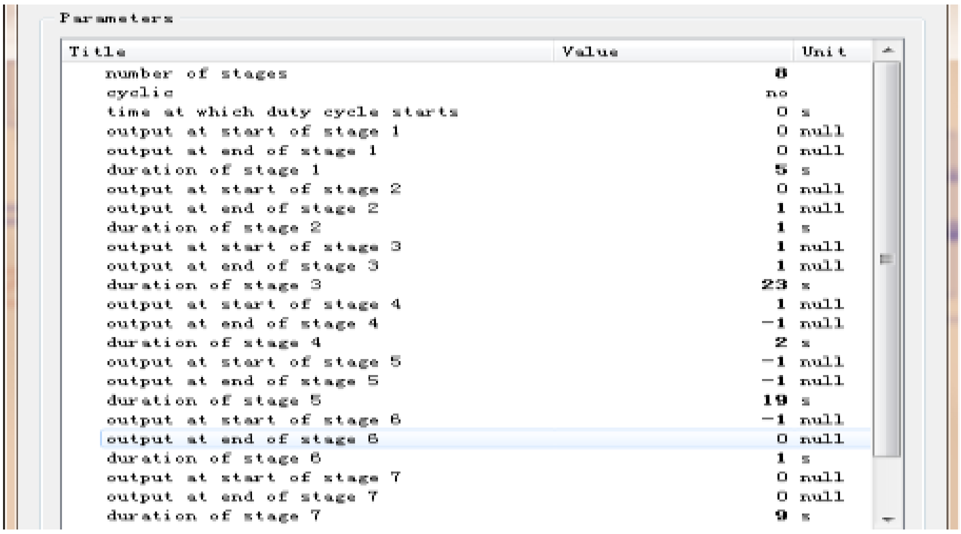


Figure.6: Parameters of signal source for reversing valve

(3).Engine parameter setting

Based on engine external characteristic curve, pre-establishing a ASC II data file which indicates the monotonic relationship between engine torque and the speed[12]. In this way, AMEsim can achieve the simulation of engine speed with the torque variation(the input signal is torque ,output signal is speed, input and output signals are dimensionless). The engine torque-rev curve can be seen in Figure.7.

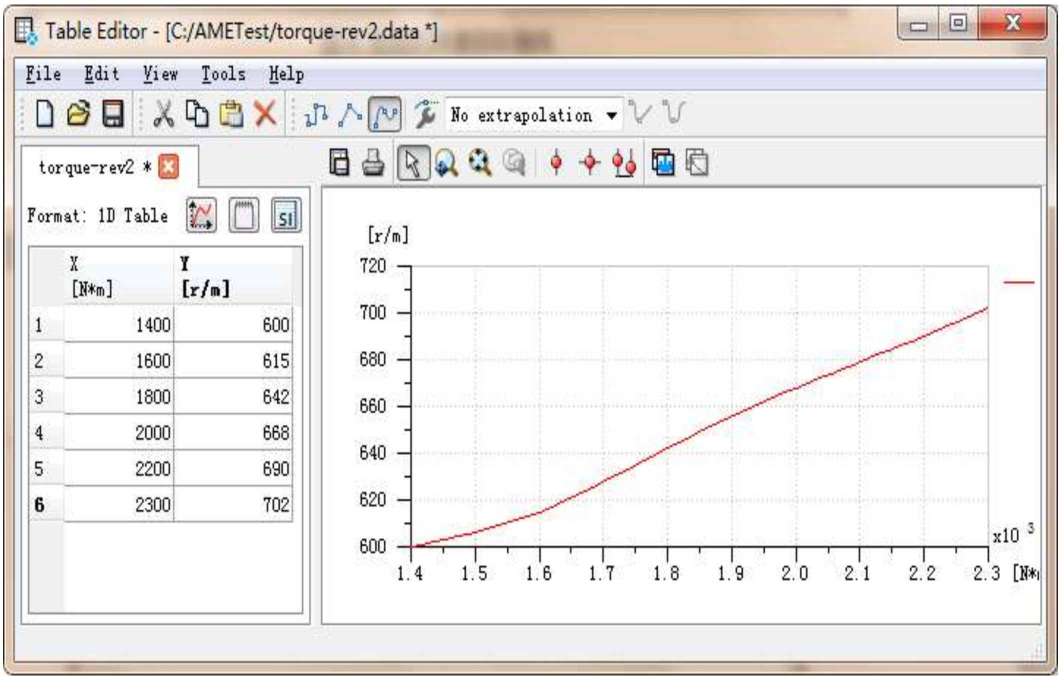


Figure.7: Engine torque-rev curve

（4）Hydraulic vibration system components model

The spool generates inertia when it reverses which have certain impact on the commutation of reversing valve and the fluidity of hydraulic oil in the valve. Therefore:

To the mass model MAS005, mass is set to $0.78kg$, lower and higher displacement limit are $-12mm$ and $12mm$ respectively.

To the valve port model BAO012, spool diameter is $32mm$, rod diameter is $20mm$, underlap corresponding to zero displacement is $3.5mm$.

To the spring piston model BAP016, spool diameter is $32mm$, rod diameter is $20mm$, chamber length at zero displacement is $36mm$, spring force at zero compression is $110N$, spring stiffness is $15.5N/mm$.

To the pilot relief valve model RV001, maximum cracking pressure is $180bar$.
To the relief valve model RV000 in buffer fill valve, cracking pressure is $190bar$.
To the pump model PU001, pump displacement is $65cc/r$, typical speed of pump is $1000r/\min$.
To the motor model MO001, motor displacement is $83.3cc/r$, typical speed of motor is $1500r/\min$.
To other hydraulic component models, we choose the default parameter values in AMEsim.

The features of vibratory roller throughout the start-up process:

(1) Load torque is continually changing during the start-up process.

(2) At the beginning of start-up process, driving torque is determined mainly by the inertia moment of vibration shaft and eccentric block in accelerated motion, and the gravitational moment of eccentric block. During the middle of start-up process, in addition to the factors above, driving torque required is also determined by the vibrating moment of eccentric block. At the end of start-up process, driving torque required is determined by the gravitational moment and vibrating moment of eccentric block, and the load torque tends to be stable.

(3) Start-up high voltage peak occurs at the beginning of start-up process, because the angular acceleration of eccentric block and the driving torque of motor are the maximum at this time.

V. ANALYSIS OF SIMULATION RESULTS

The spool displacement curve is shown in Figure.8. As the figure shows, operation of the spool is consistent with the commutation signals set for reversing valve, this indicates that simulation run normally.

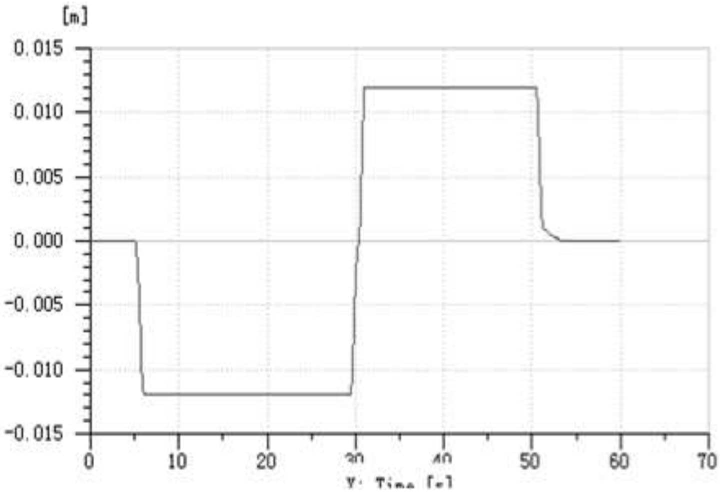


Figure.8: Spool displacement curve

The pilot relief valve flow curve and pressure curve are shown in Figure.9 and Figure.10. As the figure shows, pressure peaks occur when the vibratory roller starts oscillating or reverses, at this point the pilot relief valve open to begin flooding. Only after the hydraulic oil flows through the damping hole in main valve and then to the pilot relief valve, the valve's operating pressure will change significantly. Afterwards, the oil pressure difference between upper and lower chambers in main valve will change to control the operation of main spool. The system needs some time to create pressure difference and this leads to the response lag in pilot relief valve, then the pressure peaks generated by system will do great harm to motor.

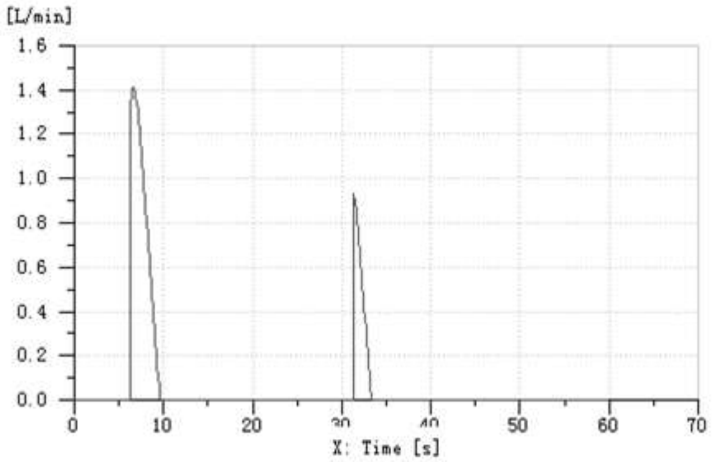


Figure.9: pilot relief valve flow curve

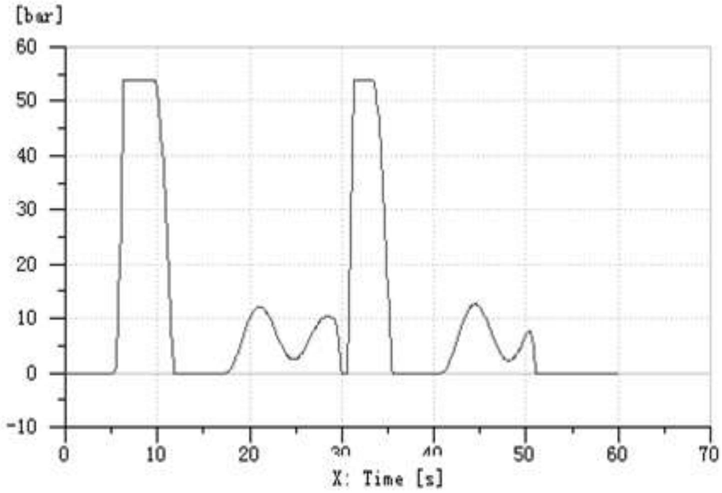


Figure.10: pilot relief valve pressure curve

The flow curves of relief valve and fill valve in buffer fill valve can be seen in Figure.11 and Figure.12. When the vibratory roller starts oscillating or reverses, buffer fill valve plays the role of a buffer overflow. When the roller reverses or stops vibrating , buffer fill valve plays the role of filling oil. But the buffer fill valve also exists response lag and the process of filling oil is inefficient due to simulation error.

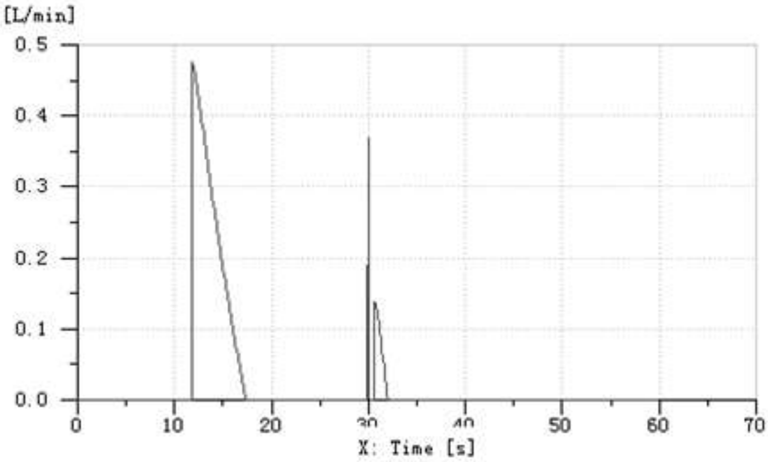


Figure.11: Relief valve flow curve

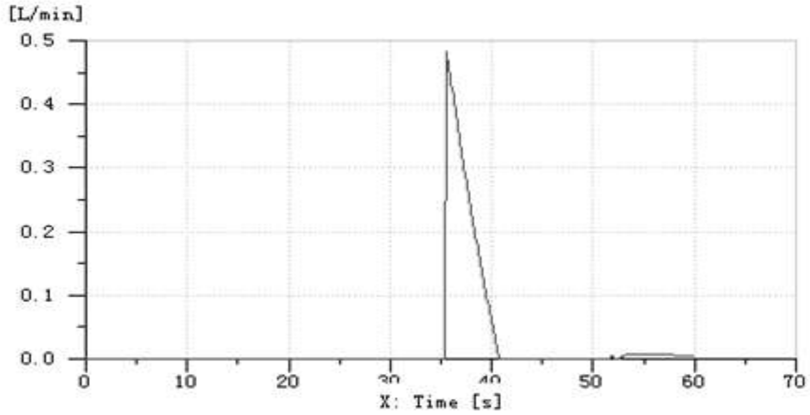


Figure.12: Fill valve flow curve

In the start-up process of vibratory roller, fluid is obstructed to flow in pipelines and then the hydraulic vibration system will have an impact. Due to the load, motor generates resistance to the flow of hydraulic oil which result in its speed dropping. According to the theory of fluid dynamics, flow rate of fluid dropping will inevitably lead to pressure increasing. Furthermore, the greater the flow rate drops, the larger the system pressure rises. Because of the total energy of the fluid transforming into pressure energy, the pressure of the hydraulic system rapidly changes and instantaneous high pressure appears which lead to a hydraulic shock. The motor flow curve, speed curve and pressure curve are shown in Figure.13, Figure.14 and Figure.15.

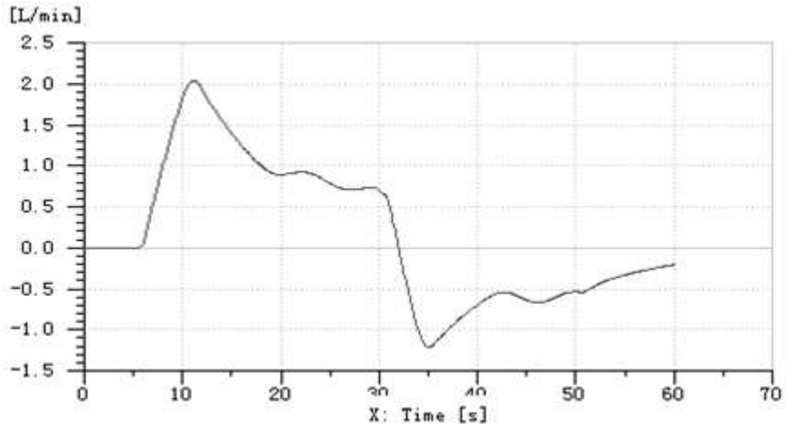


Figure.13: Motor flow curve

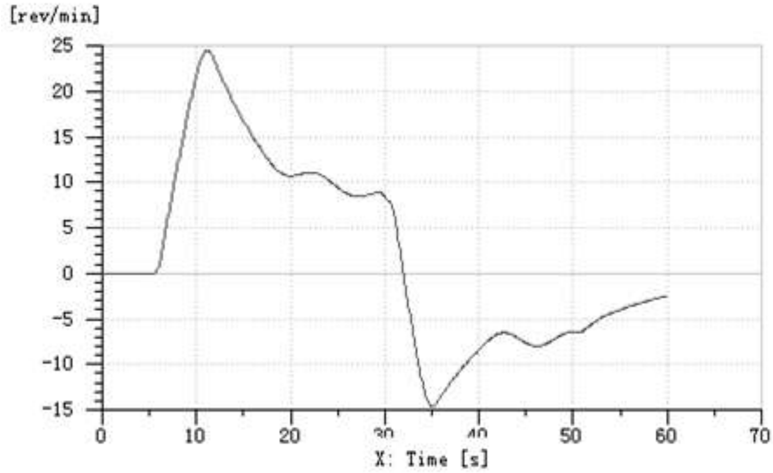


Figure.14: Motor speed curve

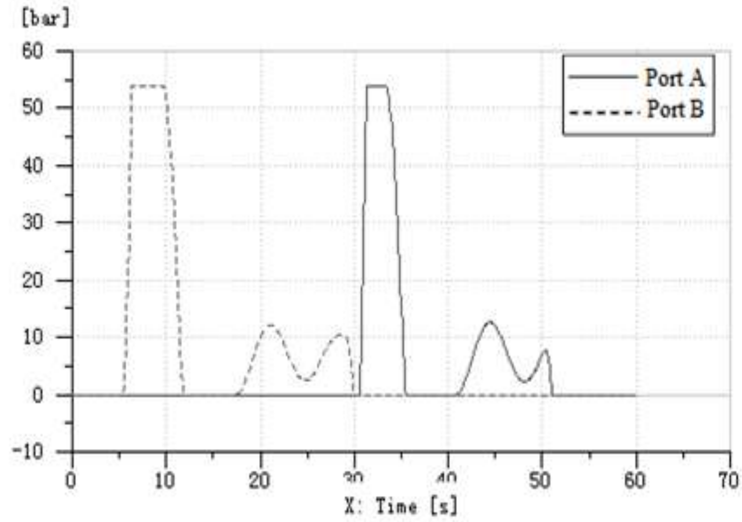


Figure.15: Motor pressure curve

As the figure shows, the first pressure peak occurs in the motor port. Then, from the beginning of reversing to the end, in other words, from $t = 29s$ to $t = 31s$, the second pressure peak appears around the motor port when it is $t = 31s$.

Figure.16 shows the motor torque curve, when the conditions change, the system would generate a larger impact with greater volatility.

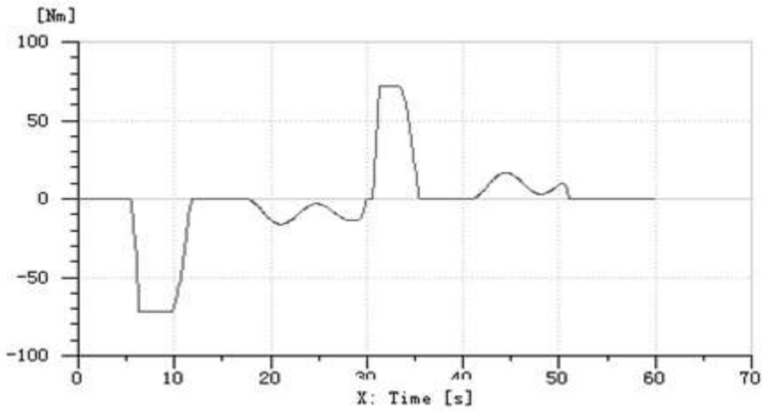


Figure.16: Motor torque curve

VI. CONCLUSION

In order to make the roller achieve good compaction effect at different conditions, this paper analyzes the hydraulic vibration system on roller, establishes simulation model by AMESim based on its working principle, and selects the appropriate parameters in the light of its work performance and overall performance. On the basis of the above analysis of the hydraulic system, we can get the following conclusions:

(1) With the roller changes its working conditions, the impact of the system will also change significantly, which make the system relay more on the hydraulic components with impact resistance and high pressure resistance. In order to resist the torque shock when changing direction, these components are required to both satisfy the operational requirements and leave some torque margin on stable conditions. In the later design procedure, it is very essential to pay great attention on the factors of instability and insecurity which appear when the hydraulic system change its working conditions.

(2) From the analysis of simulation results, we can conclude that the changes in the hydraulic system load tend to cause the reversal or stagnation of fluid, which make the system pressure change dramatically, and form the momentary pressure spikes, and generate an impact. The peak pressure is usually several times as it is under normal condition. The huge shock consequent often lead to some malfunction of hydraulic components and even make them broken, so that the system cannot woke normally. In fact, the load of engineering machinery is frequently changing when working. For the purpose of improving the engineering machinery's performance and reliability and getting lower costs, it is particularly important to carry out the hydraulic shock prevention when the hydraulic system starts up.

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