

Design & Analysis of Dynamic Response in Hydraulic Equipment Working with Heavy Loads



Sharanagouda Hadimani, Nilesh Diwakar, G.R. Selokar, B Nageshwar Rao

Abstract: Hydraulic system has benefits over pneumatic or electric systems, especially when heavy loads are involved, or when very smooth and precise position or pressure control is required. Hydraulic actuators have several advantages including the fact that they produce less heat and electrical interference at the machine than do electric actuators. A simulation model of the support was established to determine the dynamic responses of the hydraulic support under dual impacts from its roof and shield beams, and the column and balance jack were replaced using a spring-damper system. Analysis of poses was performed and dynamic support responses were obtained.

Keywords: Hydraulic, Machine, Dynamic Response.

I. INTRODUCTION

Hydraulic system has benefits over pneumatic or electric systems, especially when heavy loads are involved, or when very smooth and precise position or pressure control is required. Hydraulic actuators have several advantages including the fact that they produce less heat and electrical interference at the machine than do electric actuators. But there still some problems encountered in power hydraulics such as the unjustified energy losses at throttles through the entire system. Cylinder actuators are the one of the hydraulic system components that causes a lot of energy losses in power transmission and control. A conventional double acting differential hydraulic cylinder has two ports of small cross sectional areas. When the cylinder is actuated by supplying pressure at either port; the piston starts to move away as a result of the force difference on the two sides of piston; the piston push the oil out of the cylinder through the other port; the oil flow is highly restricted by the small area of the outlet port. The small sized port acts as an orifice and resists the migration of the incompressible oil from the cylinder; consequently the piston motion is slowed down. The energy lost in this process is converted to heat within the oil and add an additional load to the pump. The ports in hydraulic cylinders act as orifices for oil flowing through it. Provided the fluid speed is sufficiently subsonic ($V < \text{Mach } 0.3$), the

incompressible Bernoulli's equation for laminar flows, can be used reasonably well in obtaining the pressure drop through the cylinder ports. Typical hydraulic press consists of a pump which provides the motive power for the fluid, the fluid itself which is the medium of power transmission through hydraulic pipes and connectors, control devices and the hydraulic motor which converts the hydraulic energy into useful work at the point of load resistance. The performance of a hydraulic press depends, largely, upon the behaviour of its structure during operation. However, these welded structures are becoming complicated and their accurate analysis under given loading conditions is quite important to the structural designer. Hence it is found that optimal design of a hydraulic press in terms of its weight is the need of the hour. In this we covered introduction of hydraulic system, flexible working hydraulic system, mathematical modeling of hydraulic components, hydraulic drive and heavy loads. In this chapter we clearly stated that the detailed description of the title relevant contents. Mainly we focused problem statements and objective of the study.

II. PROPOSED WORK

The numerical simulation model of hydraulic support is established as shown in Fig.1, where 1 is the upper beam, 2 is the leg, 3 is the base, 4 is the rear bar, 5 is the front bar, 6 is the shield beam, 7 is the balance jam, and a-c are the panel points. The model height is set to the maximum working height of the hydraulic support. First, material properties of components are determined, including density (7860 kg/m^3), Young's modulus ($2.1 \times 10^{11} \text{ Pa}$) and Poisson's ratio (0.3). The column and balance jack of the hydraulic support are replaced equivalently by the spring-damping system.

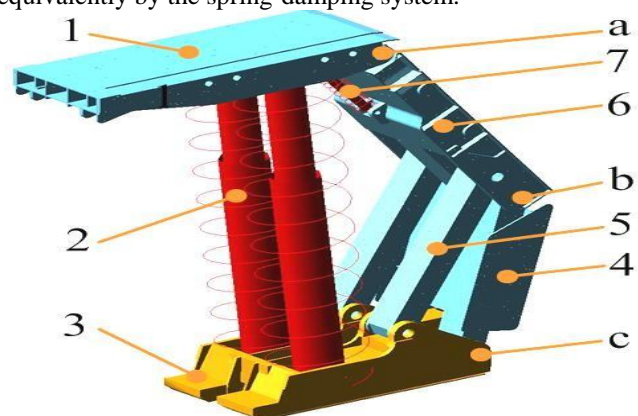


Figure 1: Simulation model of the hydraulic support. Hinge joints between the roof beam and shield beam, between the shield beam and front and back connecting rods, and between the front and back connecting rods and the base are used by

Manuscript received on February 13, 2021.

Revised Manuscript received on February 20, 2021.

Manuscript published on February 28, 2021.

* Correspondence Author

Sharanagouda Hadimani*, Dept. of Mechanical Engineering, Sri Satya Sai University of Technology & Medical Sciences, Sehore, MP, India

Dr. Nilesh Diwakar, Dept. of Mechanical Engineering, Sri Satya Sai University of Technology & Medical Sciences, Sehore, MP, India

Dr. G.R. Selokar, Dept. of Mechanical Engineering, Sri Satya Sai University of Technology & Medical Sciences, Sehore, MP, India

Dr. B Nageshwar Rao, Dept. of Mechanical Engineering, Mahaveer Institute of Science & Technology, Hyderabad, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

“revolution joints”. Friction coefficients in “revolution joints” are set to 0.1. The support base serves as the rack and is locked on the ground by the rigid body and “fixed joints”. Finally, the gravitational field is applied perpendicular to the support base. Owing to changes in impact load positions and the effects of small deformation of the support structure on force transmission and force equilibrium, the meshing of roof beam, shield beam, and front and back connecting rods and the related flexibility process are facilitated by Hypermesh software in this study. The rigid body model in Adams software is replaced to form a rigid-flexible coupling model with the rigid base. The flexible meshing of components is shown in Fig 2. Circles are rigid-connected regions of hinge joints of components, and the corresponding constraints are defined at principal nodes in this region for the convenience of force transmission.

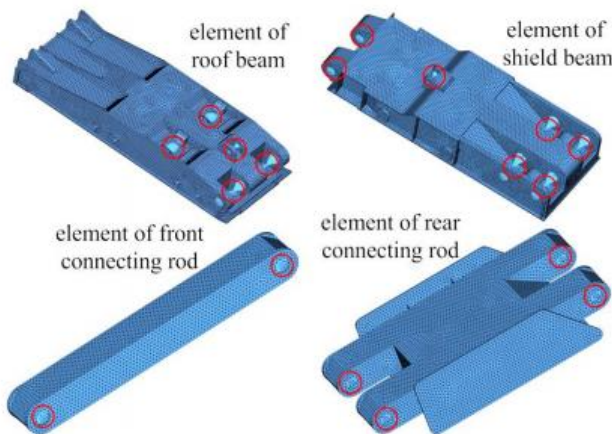


Figure 2: Finite element models of the shield beam.

A comparison of the improved nonlinear, linear and simplified linear models is conducted in this section. The enhanced models, in other words, include compensation parameters & nonlinearities for valve hysteresis and valve flow. In addition, at each time step, the parameter feedback also updates the state variables. Measured data is also included for the given valve input signal. Due to the nonlinear behaviour of the hydraulic system, the comparison is carried out for different step input signals should be noted, however, that the precision of the improved models is better than that of regular models. The nonlinear model displays the highest precision for displacement

In Table 1, the steady state displacement errors of all models are compared in this chapter to provide the reader with a complete overview. Relative errors below 7.5 percent are considered to be highly accurate, between 7.5 and 20 percent are considered to be moderately accurate, while relative errors greater than 20 percent are assumed to be inaccurate.

Valve Signal	Nonlinear	Improved Nonlinear	Linear	Improved Linear	Simple Linear	Simple Imp. Linear
20.3%	Inaccurate	Accurate	Inaccurate	Inaccurate	Inaccurate	Inaccurate
25.8%	Inaccurate	Accurate	Moderate	Inaccurate	Inaccurate	Moderate
36.8%	Inaccurate	Accurate	Accurate	Accurate	Inaccurate	Accurate
50.5%	Inaccurate	Accurate	Accurate	Accurate	Inaccurate	Moderate
71.3%	N/A	Accurate	N/A	Accurate	N/A	Moderate
91.6%	Inaccurate	Accurate	Inaccurate	Moderate	Inaccurate	Moderate

Table 1 Relative displacement errors of each model

III. RESULTS

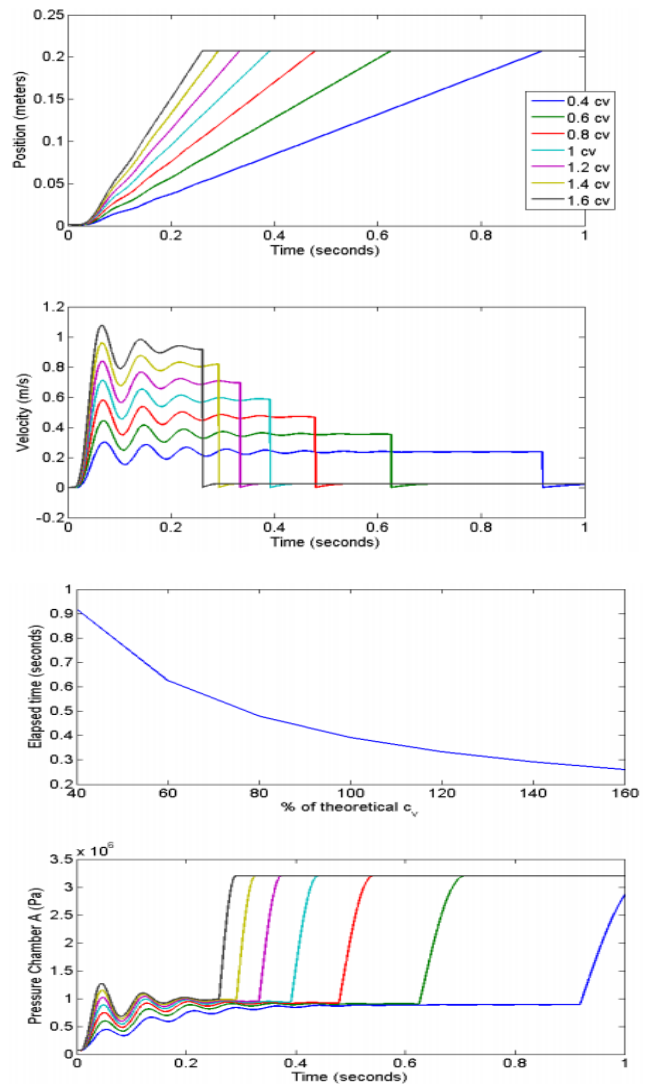
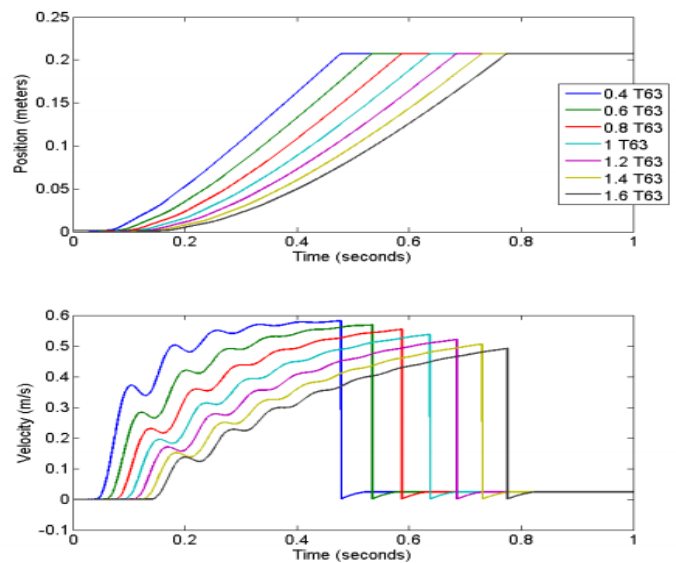


Figure 3: Influence of the flow coefficient on the outputs



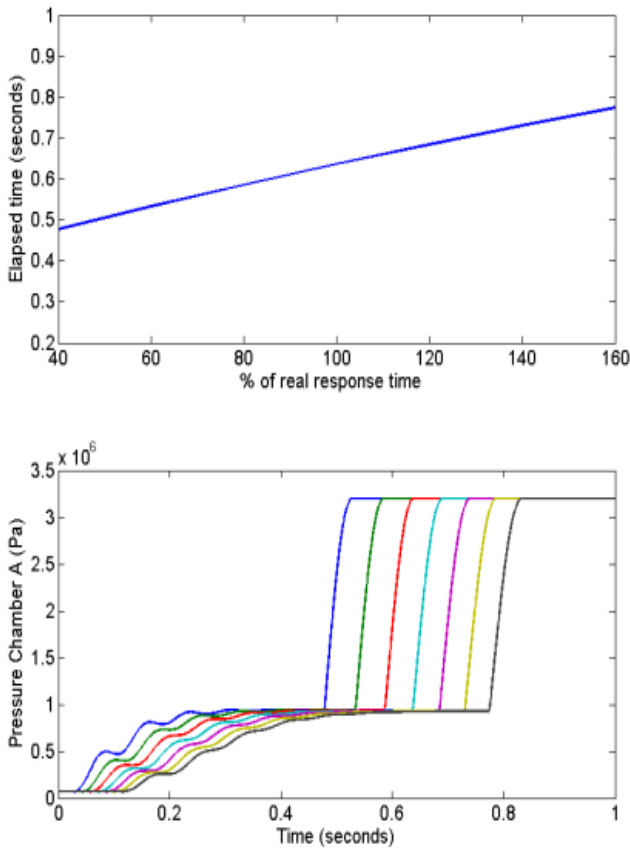


Figure 4: Influence of the valve response time on the outputs

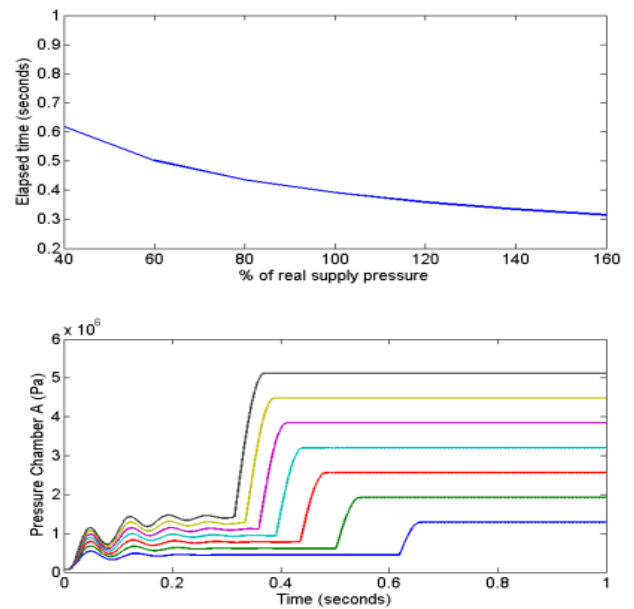
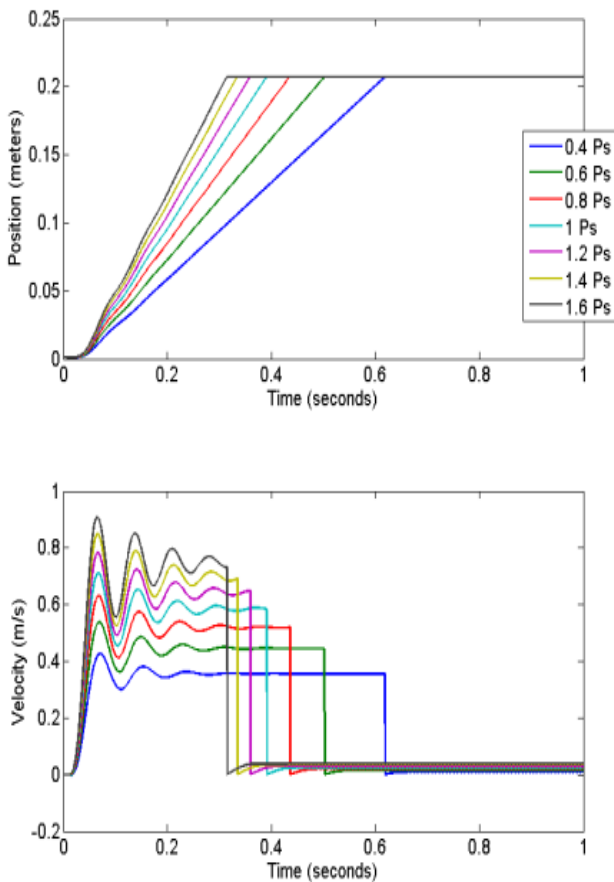


Figure 5: Influence of the mass variation on the outputs

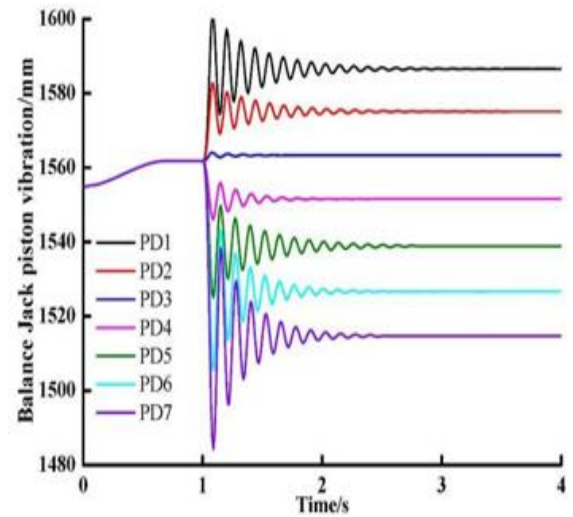


Figure 6: Vibrations of balance jack piston.

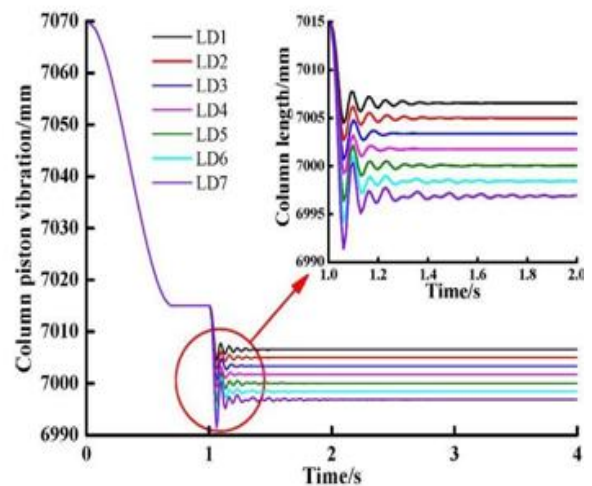


Figure 7: Vibrations of column piston.

IV. CONCLUSION

A simulation model of the support was established to determine the dynamic responses of the hydraulic support under dual impacts from its roof and shield beams, and the column and balance jack were replaced using a spring-damper system. Analysis of poses was performed and dynamic support responses were obtained. As follows, conclusions are drawn. (1) When the impact load is applied only to the roof beam, the force at the hinge point between the roof beam and the shield beam and the force at the column constitute the strongest response to the single impact force. However, when the impact load is applied to the roof beam and shield beam, the force at the hinge joint between the connecting rods between the front and back mainly responds to the dual impact force.

(2) Due to the impact load at the rear end of the roof beam, if the impact load is only applied to the roof beam, the angle of the column increases (0.67) and the roof beam points upwards (6.50). However, the angle of the column decreases and the column points downward when the impact load is applied to the front end of the roof beam. In order to achieve stability control and structural design of hydraulic support, this study is helpful. However, given that the hydraulic support working conditions in mines are extremely complex, only two typical impact loads are used to perform a pose and a dynamic analysis. The dynamic response of the hydraulic support under three or more resultant impact loads will be considered in future research.

REFERENCES

1. Chen, X., J. Zhou, L. Li, and Y. Zhang. "Cushioning structure optimization of excavator arm cylinder." *Automation in Construction* 53 (2015): 120-30.
2. Chengbin, W., and Q. Long. "Study on simulation and experiment of hydraulic excavator's work device based on Simulation X." *International Conference on Electric Information and Control Engineering*, 15-17 April 2011.
3. Esposito, A. *Fluid Power with Applications* (6th ed.). Upper Saddle River, N.J.: Prentice Hall, (2003).
4. Green, W. L. "Cushioning for hydraulic cylinders." *Hydraulics & Pneumatics* (1968): 100-04.
5. Kratz, A., H. Macintire, and R. Gould. "Flow of liquids in pipes of circular and annular cross-sections." *University of Illinois Engineering Experiment Station* (1931).
6. Merritt, H. *Hydraulic control systems*. New York: Wiley, (1967).
7. Norvelle, F. *Fluid power technology*. Minneapolis/St. Paul: West Pub, (1995).
8. Schwartz, C., V. J. De Negri, and J. V. Climaco. "Modeling and analysis of an autoadjustable stroke end cushioning device for hydraulic cylinders." *J. Braz. Soc. Mech. Sci. Eng.* 27.4 (2005): 415-25.
9. Naseradinmousavi P, Machiani SG, Ayoubi MA, et al. Coupled operational optimization of smart valve system subject to different approach angles of a pipe contraction. *Struct Multidisc Optim.* 2017;55(3):1001– 1015.
10. Manasek R. Simulation of an electro-hydraulic load sensing system with AC motor and frequency changer. In: Scheidl R, Sobczyk A, editors. *Proceeding of 1st FPNI-PhD Symposium*; Sep 20–22; Hamburg, Germany. Hamburg: Technical University of Hamburg; 2000. p. 314–324.
11. Ding HG, Zhao JY, Li GZ. Analysis of valve-pump combined high power hydraulic speed regulation schemes. *J China Coal Soc.* 2013;38(9):1703–1709.
12. M. Axin, B. Eriksson, and P. Krus. "Flow versus pressure control of pumps in mobile hydraulic systems". In: *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*. 228(4) (2014), pp. 245–256.
13. SHARANAGOUDA HADIMANI, G.R.SELOKAR and B NAGESHWAR RAO, 2020. REVIEW ON DYNAMIC RESPONSE IN HYDRAULIC EQUIPMENT. *International Journal of Advanced*

AUTHORS PROFILE



Sharanagouda Hadimani, Pursuing Ph.D at Sri Satya Sai University of Technology & Medical Science, Sehore. Completed his M.Tech in Machine Design from Maratha Mandal Engineering College, Belgaum in 2016. Received his B.E degree in Mechanical Engineering from S.J.M Institute of Technology, Chitradurga in 2013. He has 5 years of teaching experience. He has

published 8 papers in International Journals and presented 2 papers in International Conferences.



Dr. Nilesh Diwakar, Professor and Dean in the Department of Mechanical Engineering at Sri Satya Sai University of Technology and Medical Sciences, Sehore. Previously worked as Professor & Head of the Department at Truba Institute of Engineering & Information Technology, Bhopal. Completed his Ph.D in Mechanical Engineering from Rajiv Gandhi Technical University, Bhopal (M.P). He has published papers in various journals and presented papers in National & International conferences. He is having 20+ years of Teaching Experience.



Dr. G.R. Selokar, Professor in the department of Mechanical Engineering of Sri Satya Sai University of Technology and Medical Sciences, Sehore is erudite professor, motivational teacher, eminent researcher and excellent institute builder with a dream to use science and technology for better community life. Prof. Selokar, an alumnus of

Visvesvaraya National Institute of Technology (VNIT) Nagpur hold B.E. (Mechanical), M.Tech (Prodn Engg.) and Ph. D. in Mechanical Engineering. In addition, he also earned PGDBM and MA (Pub. Adn) From RTM Nagpur University Nagpur in 1985 and 1995 respectively. Prof. Selokar is having Meritorious Academic track- record at every level of his qualification. Production Engineering, Reliability Engineering, Productivity Engineering and Instrumentation are his key research areas. During rich and vast experience in teaching, research and administration of three and half decades, he has guided 11 Ph.D. research scholars and supervised more than 75 M.Tech projects. Presently 8 Ph.D. research scholars are working under him. He has more than 145 research publications in reputed international and national journals to his credit. At present he has one patent in his name and four are in pipe-line.



Dr. B Nageshwar Rao, presently working as Professor and In-charge Principal at Mahaveer Institute of Science & Technology, Hyderabad. Completed his Ph.D in Mechanical Engineering, Faculty of Engineering, Jawaharlal Nehru Technological University, Hyderabad, Telangana. Received his M.Tech Specialized in Advanced Manufacturing

Systems, Jawaharlal Nehru Technological University, Hyderabad, Telangana and received B.Tech Specialized in Mechanical Engineering, R.V.R & J.C.O.P, Guntur, Affiliated to Nagarjuna University, Andhra Pradesh. He has 26 years of experience. He has published 17 papers in international journals and presented in 28 conferences.