Electrical Energy Regeneration of Hydraulic-Split Power Transmission System Using Fuel Efficient Controller

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** Presenter

Presentation Outline

Electrical Energy Regeneration of Hydraulic-Split Power Transmission System Using Fuel Efficient Controller

- **Objective:**

- To present an innovative energy management system for a conventional hydrostatic-split power transmission (CH-SPT) system used in front end loader (FEL).
- A fuel efficient controller and a DC generator are additionally connected in parallel with the load shaft of the drive to prevent the engine and the major hydraulic components from over-loading or under-loading conditions.
- To develop a simulation model of the proposed system, so called Regenerative Hydrostatic-Split Power Transmission (RH-SPT) system in the MATLAB®/Simscape environment.
- To investigate the performances and the fuel consumption of the RH-SPT drive and compare with that of the CH-SPT drive through the simulation.

Electrical Energy Regeneration of Hydraulic-Split Power Transmission System Using Fuel Efficient Controller

- **System Model**

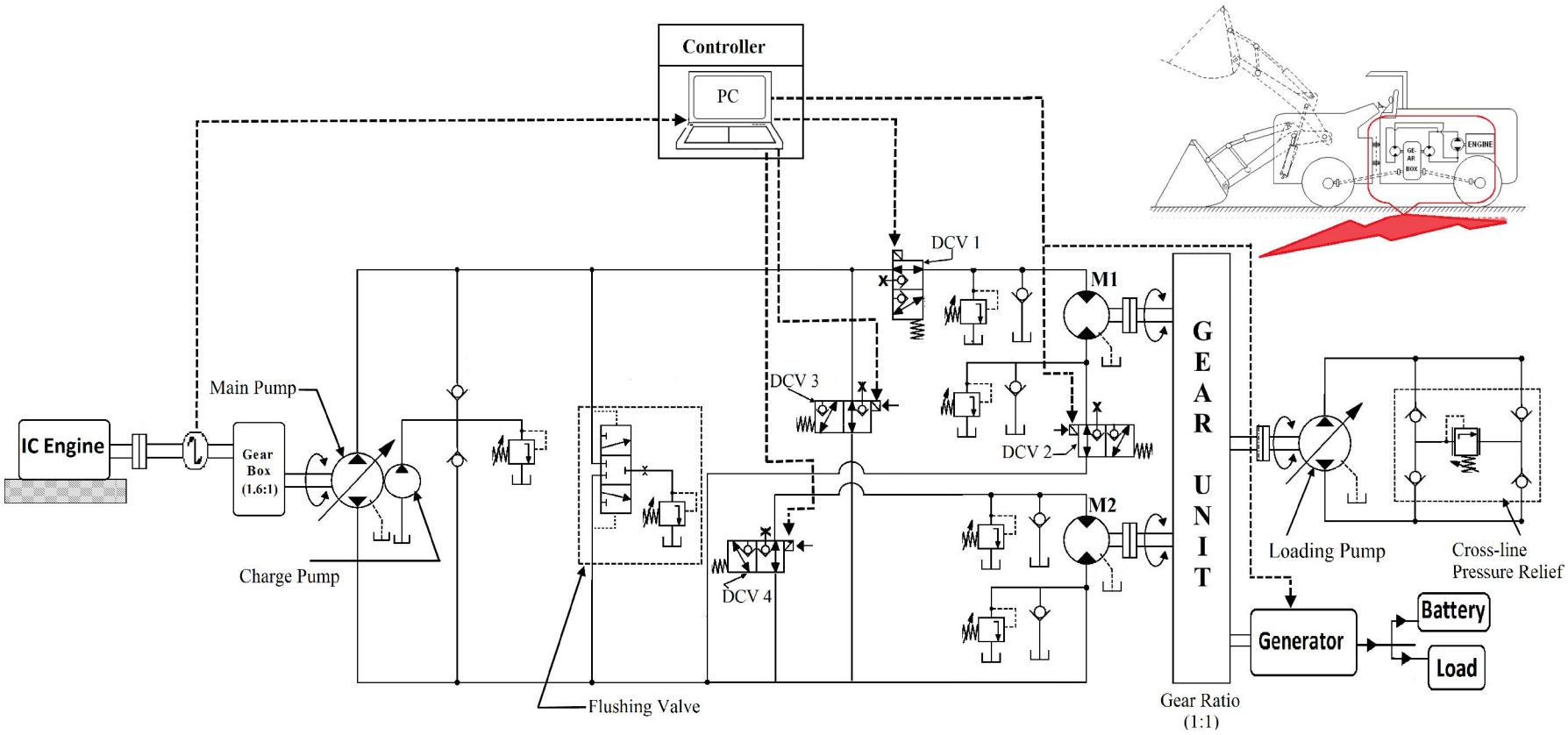

Fig. 1 A Schematic diagram of Regenerative Hydraulic-Split Power Transmission (RH-SPT) drive

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- **Simulation Model**

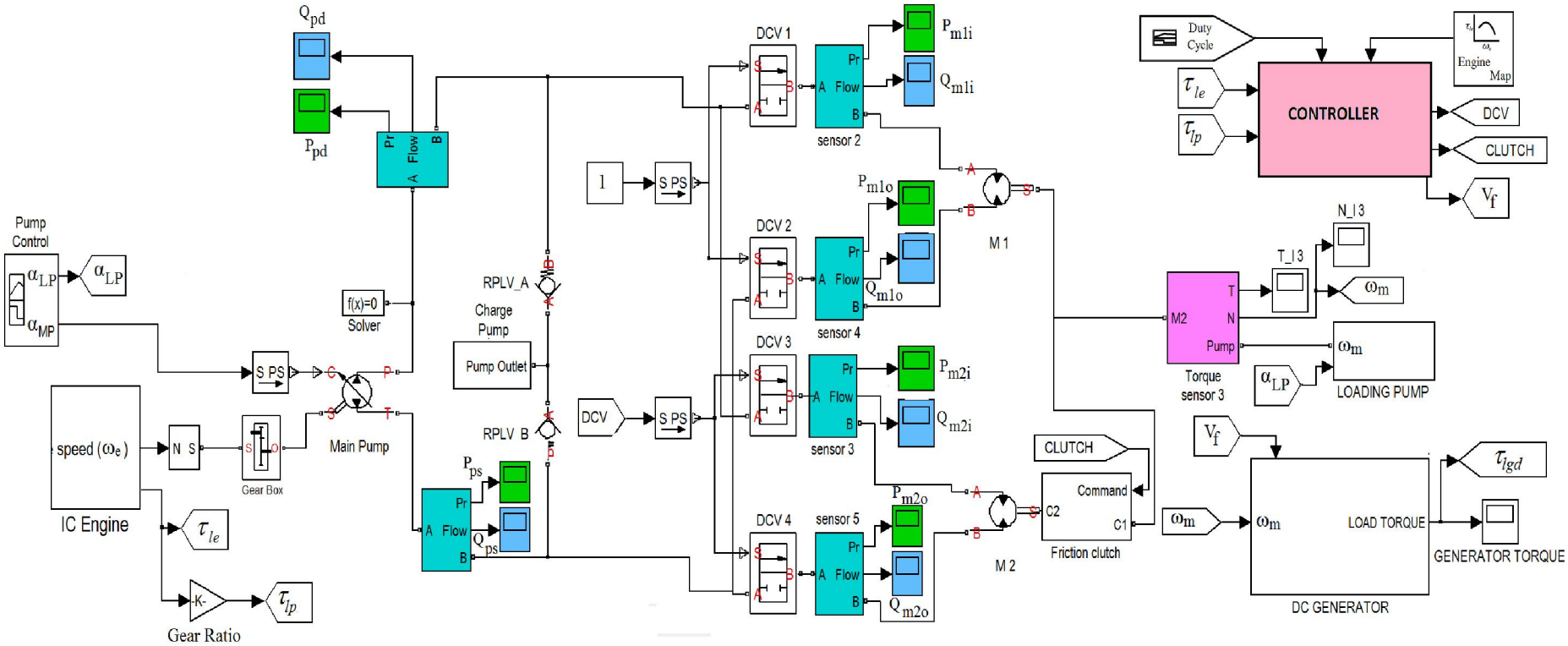

Fig. 2 MATLAB/Simscape model of the RH-SPT drive

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- The load cycle considered with respect to the Y-cycle of a FEL used for simulation is shown in below figure:

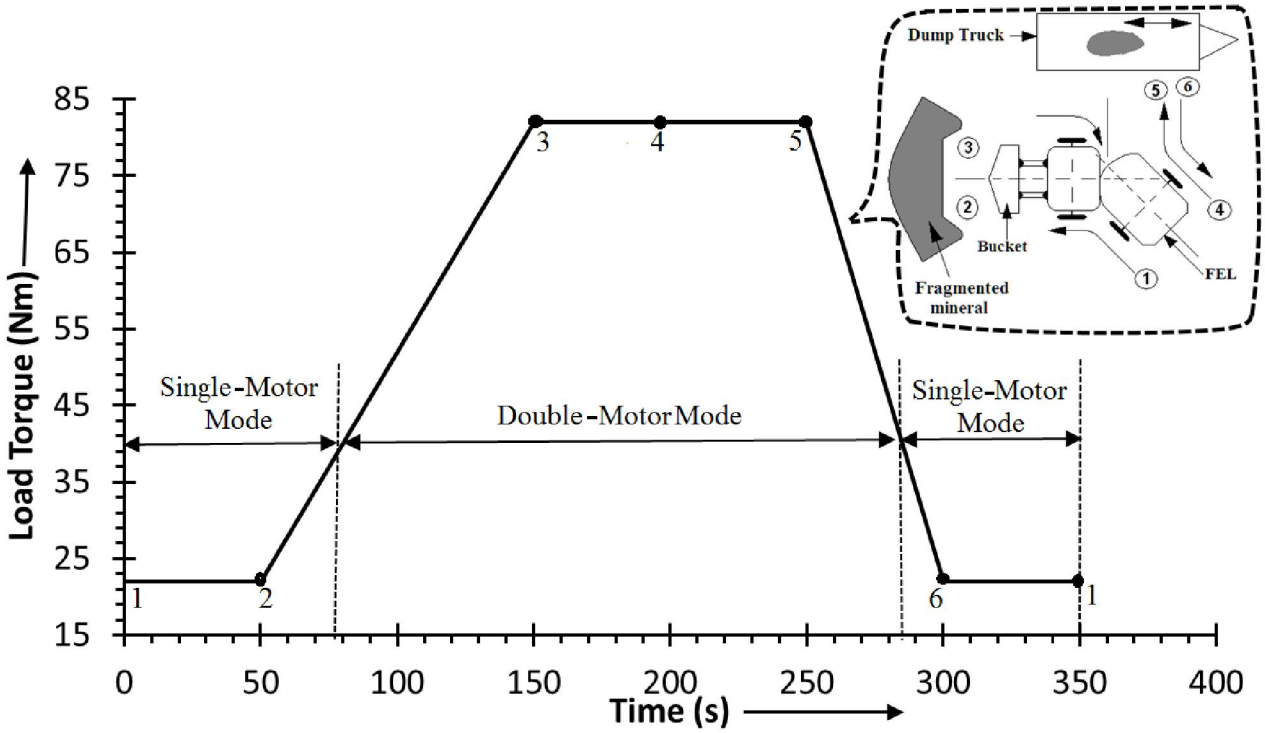

Fig. 3 Load cycle of a FEL used for simulation /14/

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- **Energy Management Algorithm**

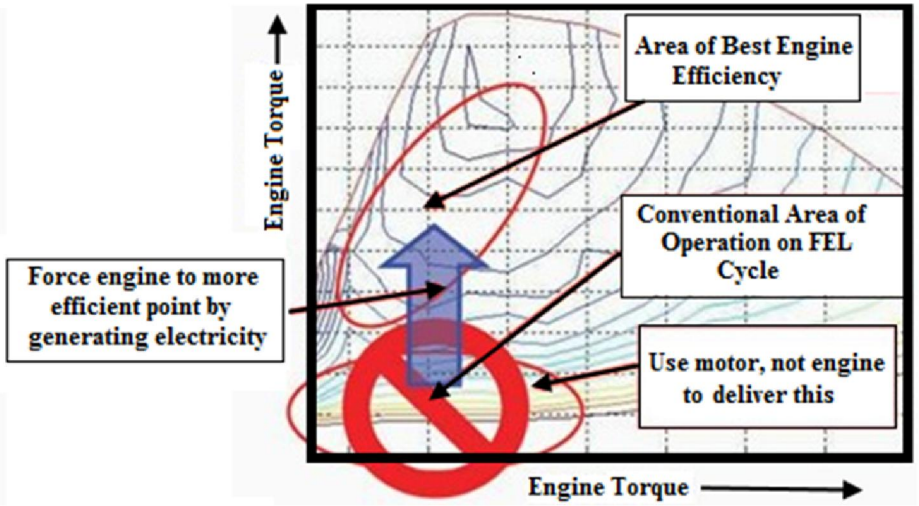

Fig. 4 (a) Force engine to operate engine in its efficient zone /9/

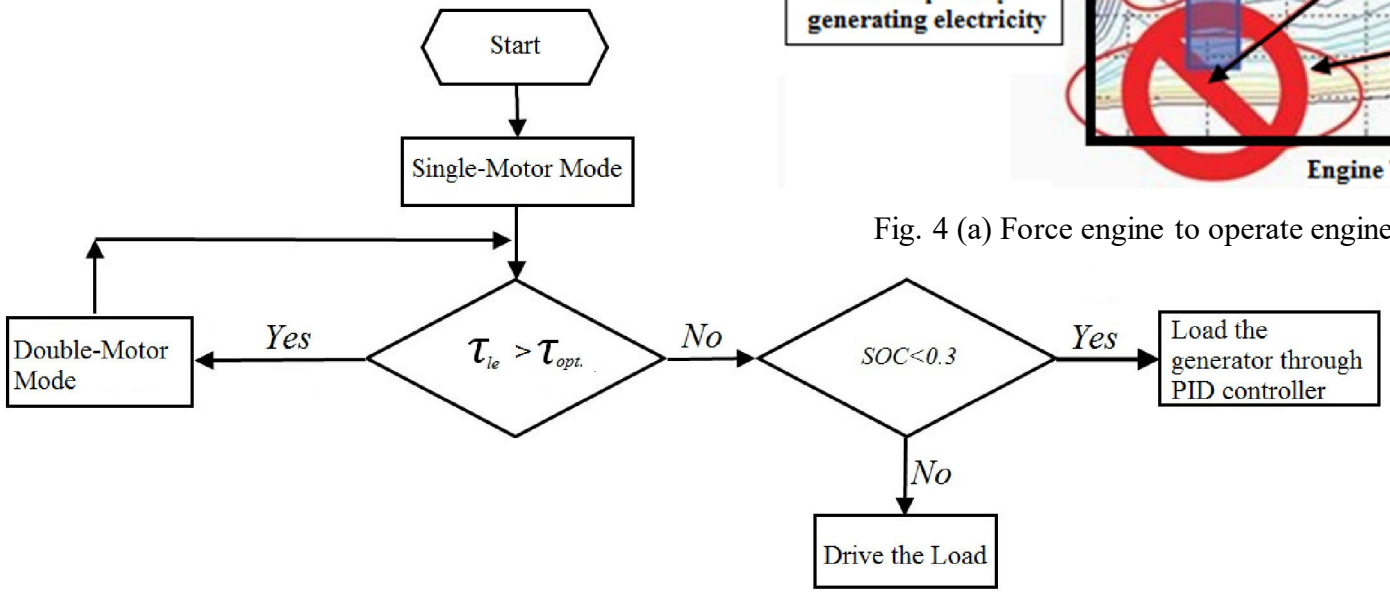

Fig.4 (b) Energy management algorithm for the proposed RH-SPT drive

- **Control Strategy**

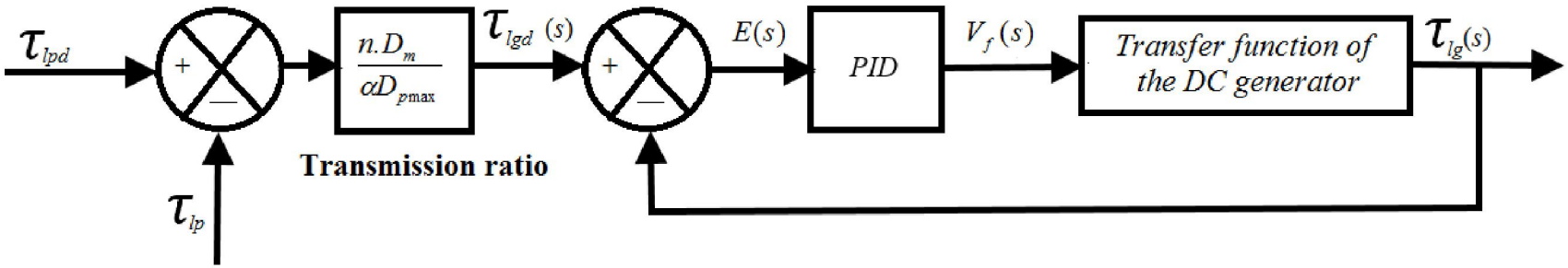

Fig. 5 Signal flow of the controller for loading the DC generator

Steady State Characteristics of Hydraulic Components for Estimating Parameters

- **Leakage Resistance of Pump and Hydro-motor**

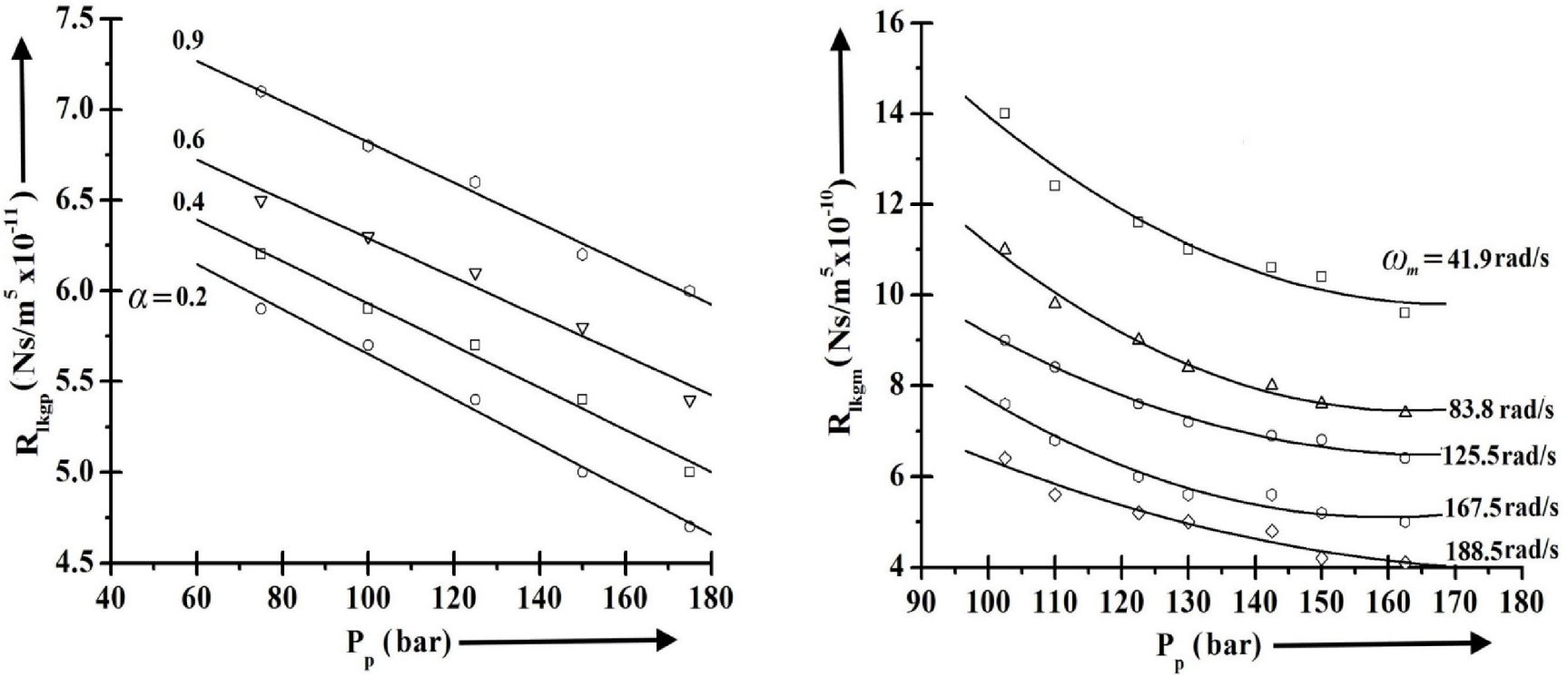

Fig. 6 Leakage resistance of the pump and the hydro-motor /14/

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- **Results and Discussions**

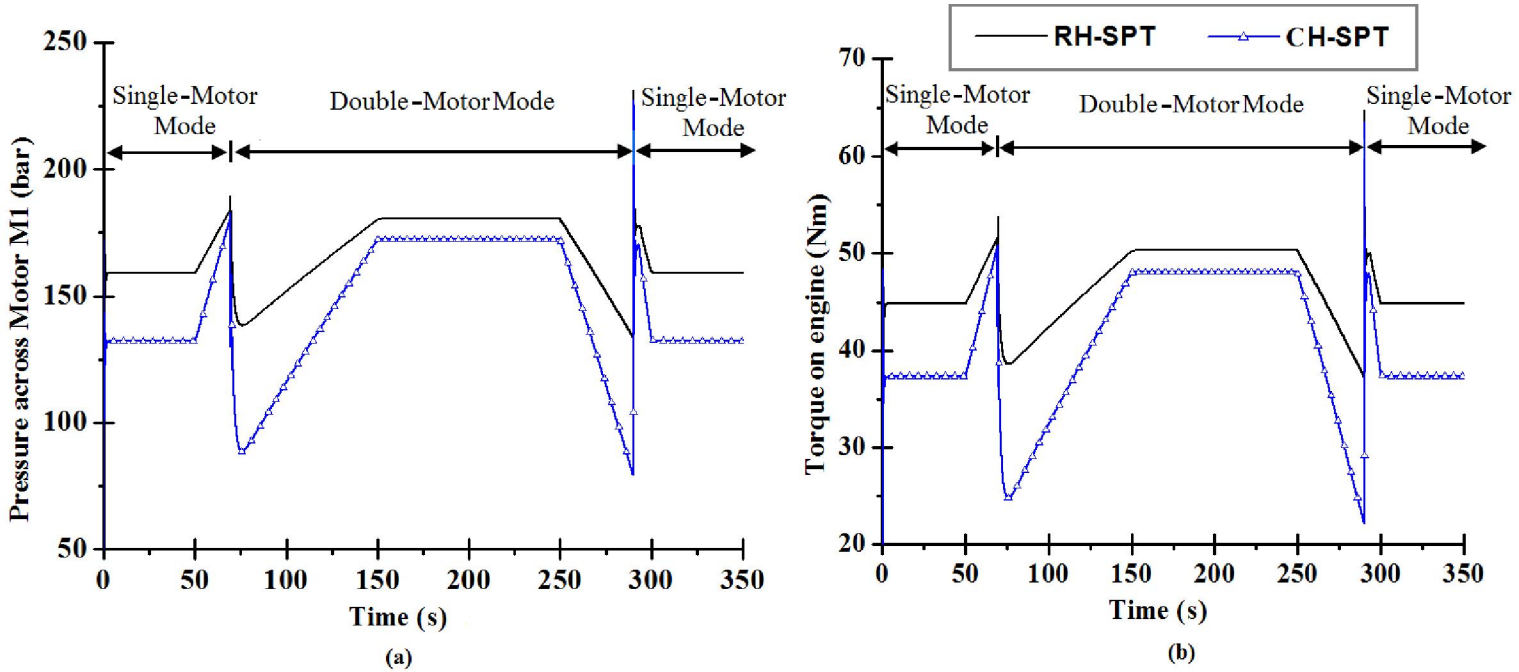

Fig. 7 Comparison of motor pressure and engine load torque between the RH-SPT and the CH-SPT drive

Electrical Energy Regeneration of Hydraulic-Split Power Transmission System Using Fuel Efficient Controller

- **Results and Discussions**

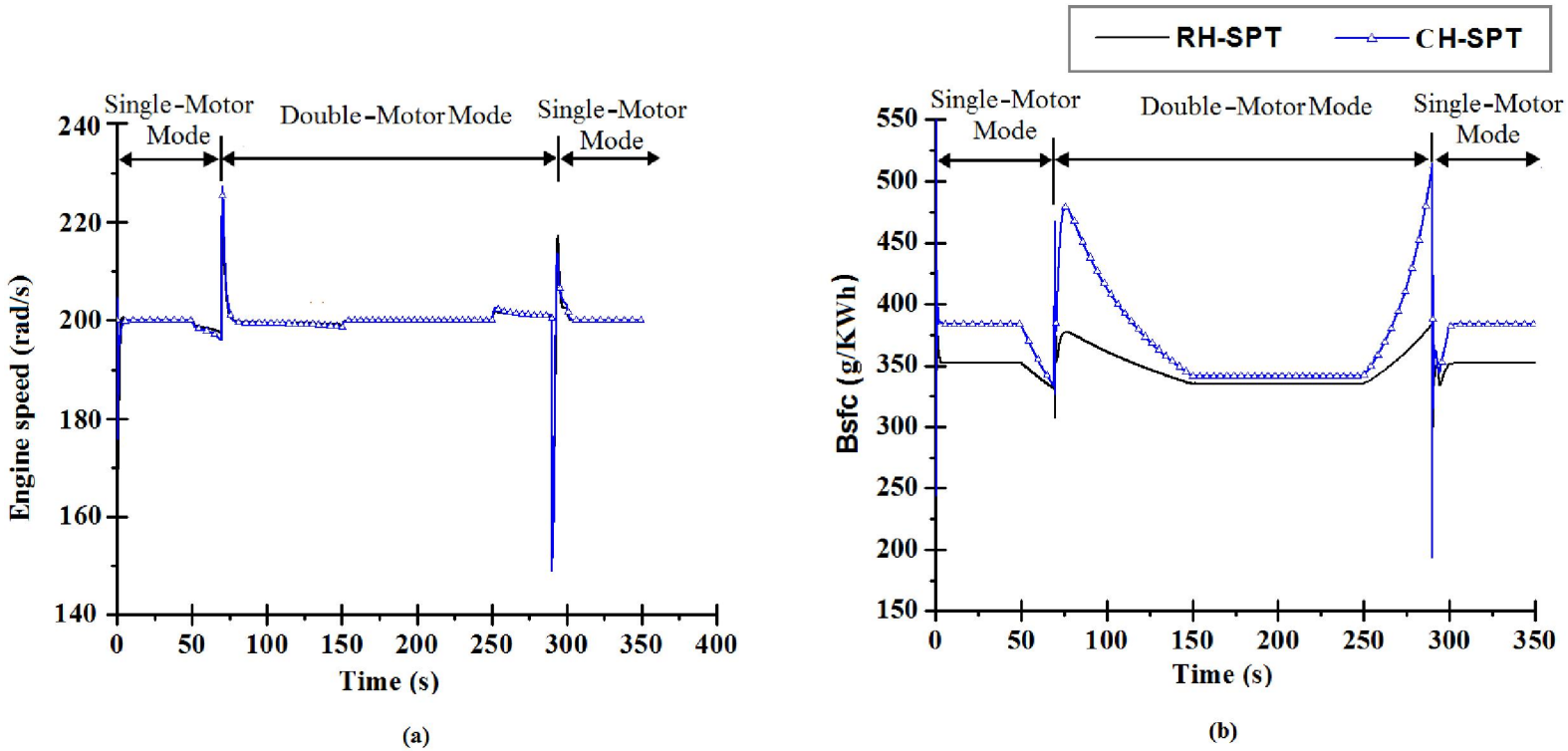

Fig. 8 Comparison of engine speed and bsfc between the RH-SPT and the CH-SPT drive

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- **Results and Discussions**

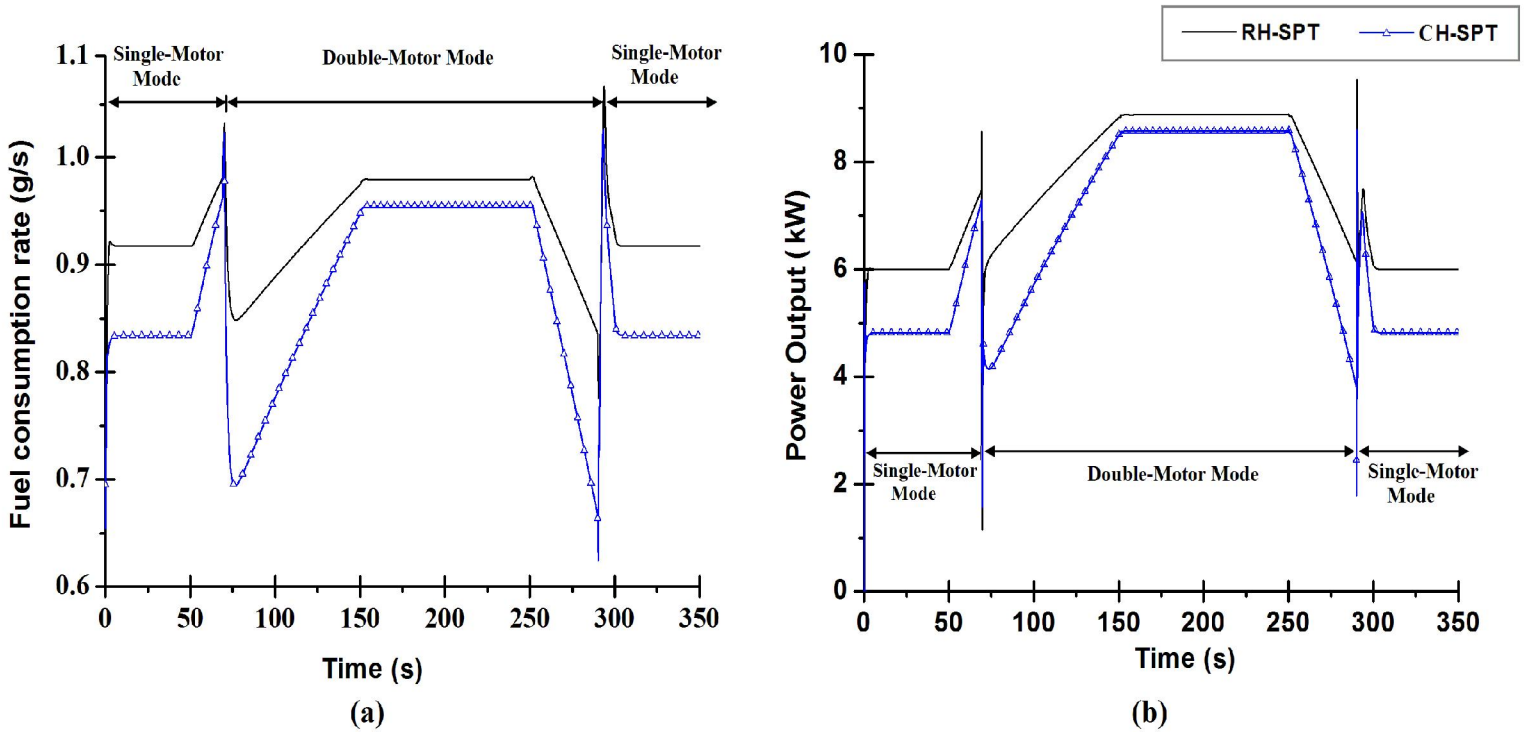

Fig. 9 Comparison of fuel consumption rate and power output of the RH-SPT and the CH-SPT drive

- **Conclusion**

- It is observed that a marginal increase in fuel consumption by 10% occur due to application of additional load on the generator per cycle, of which approximately 70% of the power from engine is used for electrical energy regeneration.
- It is also observed that the RH-SPT drive facilitates comparatively lesser fluctuations of pressure, engine torque and significant reduction of bsfc value.
- This assists in efficient operation of the hydraulic components as well as the engine and leads to modification of the engine load cycle without effecting the duty cycle of the transmission.

- **Conclusion**

- From the study, it is also observed that bsfc for RH-SPT system is lower than that of CH-SPT system which is desirable.
- The proposed innovative idea may be helpful to the engineers to design the construction equipment subjected to fluctuated load profile to operate the major components and the engine, in particular to operate in the efficient zone during the maximum span of the duty cycle.
- This will also assist in complete combustion of the fuel and may lead to reduction in CO_x in the exhaust gas.

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- **References**

\1\ T. Lin, Q. Wang, B. Hu and G. Wen, “Development of Hybrid powered hydraulic construction machinery,” Automation in Construction, vol. 19, pp. 11-19, 2010.

\2\ S. Valente and H. Ferreira, “Braking Energy Regeneration using hydraulic systems,” 2008.

\3\ M. Heskitt, T. Smith, Hopkins and Jeff, “Design & Development of the LCO-140H series hydraulic hybrid low floor transit bus,” Altair ProductDesign, Michigan, 2012.

\4\ C.-K. Chen, T.-V. Vu and C.-W. Hung, “System Modeling and control strategy development for a series hydraulic hybrid vehicle,” in Proceedings of the International MultiConference of Engineers and Computer Scientists, Hong Kong, 2013.

\5\ L. Cheong, Y. Li and R. Chase, “Optimal design of power-split transmissions for hydraulic hybrid passenger vehicles,” in American Control Conference, San Francisco, 2011.

\6\ R. Kumar and M. Ivantysynova, “An Instantaneous optimization based power management strategy to reduce fuel consumption in hydraulic hybrid,” International Journal of Fluid Power, vol. 2, no. 12, pp. 15-25, 2011.

\7\ L. Tianliang, Qingfeng and WANG, “Hydraulic Accumulator-Motor-Generator Energy Regeneration System for a Hybrid Hydraulic Excavator,” Chinese Journal of Mechanical Engineering, vol. 25, no. 6, pp. 1121-1129, 2012.

\8\ T. Wang, Wang and Qingfeng, “Design and analysis of compound potential energy regeneration system for hybrid hydraulic excavator,” Proc IMechE Part I:J of Systems and Control Engineering, vol. 226, no. 10, pp. 1323-1334, 2012.

\9\ http://www.libralato.co.uk/technology/hybrid.html

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- **References**

\10\ Y. Xiao, C. Guan, Y. Li, Wang and Fei, “Optimal Design of a Compound Hybrid System consisting of Torque Coupling and Energy Regeneration for Hydraulic Hybrid Excavator,” IEEE International Conference on Advanced Intelligent Mechatronics (AIM), Busan, 2015.

\11\ J. Backas, R. Ghabcheloo, S. Tikkanen and K. Huhtala, “Fuel optimal controller for hydrostatic drives and real world experiments on a wheel-loader,” International Journal of Fluid Power, vol. 17, no. 3, pp. 187-201, 2016.

\12\ M. Vukovic, Roland Leifeld and H. Murrenhoff, “Reducing Fuel Consumption in Hydraulic Excavators-A Comprehensive Analysis,” Energies 2017,10.687.

\13\ M. Schneider, O. Koch and Jurgen Weber, “Green Wheel Loader- improving fuel economy through energy efficient and control concepts,” 10th International Fluid Power Conference, Dresden, 2016.

\14\ N. Kumar, K. Dasgupta and S. Ghoshal, “Dynamic analysis of a closed-circuit hydrostatic summation drive using bent axis motors,” Proc IMechE Part I:J systems and Control Engineering, pp. 1-17, 2015.

\15\ J. Ivantysyn and M. Ivantysynova, Hydrostatic Pumps and Motors: Principles, Design, Performance, Modelling, Analysis, Control and Testing, New Delhi: Tech Books International, 2003.


Thank
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