UNIVERSITI TEKNOLOGI MARA

ANALYSIS ON THE FACTORS AND EFFECTS OF ENGINE TAPPING NOISE BY DESIGN OF EXPERIMENT (DOE)

MOHD SHAHRUDIN BIN MOHD ALIAS

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science

Faculty of Mechanical Engineering

October 2016

ABSTRACT

Studies on the effect of various factors on engine noises have been conducted in many ways involving component simulation, sound quality analysis, and product testing. However, the solution remains exclusive and testing may be expensive yet to solve the engine noise issues totally for several Original Equipment Manufacturers (OEMs). Manufacturing has many factors that much to be considered and this includes the uncontrolled factors that exist within the production system and engine operation. The main research objective is to investigate the most significant factors affecting the valvetrain tapping noise level by using Design of Experiment (DOE) via Taguchi method. The aim is to determine the optimum combination of valvetrain parameters in order to reduce the valvetrain tapping noise level. The intention is also to compare the optimum valvetrain tapping noise on bench and vehicle test, while further testing to verify and validate the engine performance and emission. The Orthogonal Array design for seven factors, two-level experiment and eight runs ($L_8 2^7$) was employed with the pre-test run conducted at the manufacturing plant in the actual engine running condition. The data were collected and analyzed using Signal-to-Noise (S/N) ratio, ANOVA, Main Effects Chart, Box Plot and Interaction Plot available in Minitab software. Through Minitab software, the predicted optimum combination of factor was proposed according to Signal-to-Noise (S/N) ratio value. The optimal valvetrain parameters were then built into a completed engine to confirm the valvetrain noise level on bench test. The optimal valvetrain parameters was further verified and validated by the performance test, emission test and vehicle integration for noise level inspection. From DOE experiment result, as the most significant factor, the Camshaft Exhaust Waviness was further taken for improvement and implemented at the engine production line. The pilot batch of engine production was continuously monitored and 10 unit production cars were measured for noise level in one week duration. The study had discovered the optimum factors combination which comprised of the Cylinder Head Bore Diameter (Max: 32.018 cm), Mechanical Tappet Diameter (Min: 31.973 cm), Spring Force (Max: 367 N), Camshaft Intake Waviness (Min: 0.5μm WCM), Camshaft Exhaust Waviness (Min: 1.5μm WCM), Tappet Clearance Intake (Max: 0.326 mm) and Tappet Clearance Exhaust (Max: 0.205 mm). The confirmation of the optimal valvetrain setting on bench test yields a lower noise level around 70.4 dB SPL and identical with the value predicted by the software (70.3 dB SPL). The validation result shows a positive outcome with the vehicle integration test recorded around 69.5 dB SPL (main location) which had met the maximum allowable noise at 72.0 dB SPL. Meanwhile for the performance and emission level, the results were complied with the target as specified by PROTON designer. The results of the experiment clearly showed that, the most significant factor affecting the engine valvetrain tapping noise is the Camshaft Exhaust Waviness (P-value 0.044 < α-level 0.05) with the optimal parameter found to be at minimum level (< 2.0μm WCM). From the verification of production vehicles with improved camshaft parameter, the valvetrain tapping noise is reduced approximately 7.9% from the average 73.8 dB SPL to the average 68.0 dB SPL. Since the performance and emission data on the improved engine samples were complied with the OEM standard, the improved camshaft parameter implementation was justified as successful. In overall, this research had met the main objective to apply Taguchi methodology in investigating and determining the factors causing the product failures through a structured experimentation.

ACKNOWLEDGEMENT

Thank you for the blessings of ALLAH SWT, The Almighty in the completion of my thesis. Foremost, I would like to acknowledge my supervisor, Assoc. Professor Dr. Nor Hayati Saad, who has been most encouraging, understanding and provided tremendous support, ideas, thoughts, commitment and guidance throughout her supervision of my thesis. I also would like to thank my co-supervisors, Dr. Juri Saedon (Faculty of Mechanical Engineering) and Mrs. Nor Hidayahti Hassan (Industrial Supervisor, PROTON) for being supportive during the study. I would like to acknowledge the contribution and support from both PROTON and Universiti Teknologi MARA (Faculty of Mechanical Engineering) in providing the financial support and facilities in order to complete the research and testing. Not to forget Mr. Nor Azizi Che Soh for his supports in utilizing the laboratories and other facilities.

I wish to gratefully acknowledge the personnel of the case company for their cooperation and contribution to the case studies especially Mr. Zulkifli Senu (Senior Manager, PROTON) for the greatest support, cooperation and approval in conducting the research. Huge thanks to others at Manufacturing Quality Powertrain and Design Department who have directly or indirectly contributed in providing their technical knowledge, expertise and insight such as Mr. Ungku Salleh, Mr. Saidi Harun, Mr. Hasznil, Mr. Noor Azuary, Mr. Jeffree, Mr. Nazli Naimun, Mr. Suhaili Sidek, Mr. Jauhari, Mr. Zulkifli Razak, and Mr. Rostam. Not to forget Mr. Mohd Azli Hassan and Mr Nasharuddin Hashim for assisting the testing at emission facilities.

Most of all, a special thank you and my deepest gratitude to my beloved wife Siti Hanisah for all her patience and unwavering supports, which were so essential throughout the study years. To my child, Safwan and Sufi, thanks for their love. I would highly appreciate the support and prayers from my beloved parents, Mr. Mohd Alias Wagiran, and Mrs. Huzaimah Hussein. Not to forget Hj. Mohd Shariffudin Adnan and Hjh. Fatimah Omar for all their kindness throughout the years of study.

TABLE OF CONTENTS