VIBRATION ANALYSIS AND NOISE MAPPING OF AUTOMOTIVE RADIATOR SYSTEM

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MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

Dedicated with love and affection
to my beloved parents, family, lecturers and friends
who have supported me till the end.

Live, Love, Appreciate

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ABSTRAK

Kipas penyejuk yang beroperasi pada kelajuan tinggi sering digunakan untuk mengawal suhu cecair penyejuk dengan memastikan aliran udara yang mencukupi melalui radiator automotif, terutamanya ketika kenderaan beroperasi pada kelajuan rendah atau dalam keadaan normal. Walaubagaimanapun, kesan sampingan yang tidak diingini daripada kipas ini telah menjana getaran yang disebabkan oleh aliran udara dan getaran mekanikal, yang merupakan gangguan kepada persekitaran khususnya kepada penumpang. Selain itu, cecair penyejuk yang mengalir di dalam tiub radiator juga menghasilkan getaran di dalam sesebuah sistem kerana ketidakseimbangan hidraulik. Konfigurasi aliran yang tinggi dan sifat cecair penyejuk yang likat ini juga turut menjejaskan tahap getaran. Tesis ini membentangkanan alisis eksperimen dan teori untuk menyiasat perubahan ciri-ciri getaran yang diukur dan tahap bunyi pada radiator automotive hasil daripada variasi kadar aliran cecair penyejuk, kelajuan kipas penyejuk dan jenis cecair penyejuk yang berlainan. Ia juga untuk mengenalpasti hubungan antara getaran dan bunyi yang dihasilkan oleh variasi kadar alir cecair penyejuk, kelajuan kipas penyejukan dan jenis penyejuk sekaligus mengetahui lokasi tahap tekanan bunyi maksimum (SPL) radiator automotif. Air (100%) dan Etilena Glikol (EG)-berasaskan air (40:60) digunakan sebagai cecair kerja yang beroperasi dengan suhu enjin dari 80 hingga 90 ℃. Kelajuan kipas penyejukan radiator berubah daripada 250 hingga 1250 RPM dengan kadar aliran cecair penyejuk yang beroperasi dari 8.0 hingga 14.0 L/min. Pengukuran getaran menggunakan sensor "accelerometer" sementara analisis bunyi dijalankan dengan menggunakan kaedah pemetaan intensity bunyi menggunakan ½ inci sepasang mikrofon sebagai sensor. Dalam analisis getaran, hasil getaran meningkat 4-18% apabila kadar aliran cecair penyejuk meningkat disebabkan oleh gerakan dinamik aliran bendalir yang meningkat di dalam tiub radiator. Terdapat peningkatan yang lebih besar (2-21%) halaju getaran apabila kelajuan kipas berputar pada kelajuan tinggi yang mana menghasilkan lebih banyak pergeseran. Selain itu, terdapat sedikit peningkatan 4-10% dalam tahap getaran apabila kelikatan cecair penyejuk meningkat oleh kerana daya penolakan meningkat. Dalam analisis bunyi, paras kebisingan dijana dalam julat kekerapan daripada 25 hingga 10 kHz. Hasil keputusan SPL sangat dipengaruhi oleh kelajuan putaran kipas di mana bunyi radiasi daripada 750 hingga 1250 RPM menjadi penyebab yang paling ketara terhadap bunyi sistem radiator keseluruhan dengan sekitar peningkatan 32 dBA apabila kelajuan kipas dipertingkatkan. Nilai SPL meningkat dalam lingkungan 10 dBA apabila kadar alir cecair penyejuk dan kelikatan cecair penyejuk di tingkatkan. Lokasi SPL maksimum telah dikenalpasti dan kebanyakannya adalah terletak di bahagian tepi permukaan sedutan. Kesimpulannya, bunyi meningkat apabila getaran meningkat dan kipas penyejukan yang berputar pada kelajuan tinggi adalah penyumbang utama kepada bunyi radiator keseluruhan, seterusnya diikuti oleh kadar aliran dan kelikatan cecair penyejuk yang tinggi.

ABSTRACT

High speed of cooling fan operation is frequently used to manage the coolant temperature by ensuring adequate air flow through an automotive radiator, especially at low vehicle speeds or idle. However, an undesirable side effect of these fans is generation of flow-induced vibration and mechanical vibration, which is an annoyance to the society specifically to the passengers. Besides, internal flow of coolant inside the radiator's tube also generates the vibrations into the system due to hydraulic imbalance. High flow configurations and high viscous properties of this coolant particularly affected the vibrations level. This thesis presents the experimental and theoretical analysis to investigate the changes in the characteristics of vibration measured and noise level on an automotive radiator resulting from variations of coolant flow rate, cooling fan speed and different type of coolant fluids. Also, this study aims to analyse the relationship between vibration and noise due to change in coolant flow rate, cooling fan speed and different types of coolant fluids hence the location of maximum sound pressure level (SPL) of automotive radiator can be identified. Water (100%) and Ethylene Glycol (EG)-water based (40:60) was used as working fluids operate with engine temperature range from 80 to 90 °C. The radiator cooling fan speed were varied from 250 to 1250 RPM with coolant flow rates operating from 8.0 to 14.0 L/min. The measurement of vibrations used an accelerometer as a sensor while noise analysis is carried out by utilizing sound intensity mapping method where ½ inch a pair of microphones is used as a sensor. In vibration analysis, the vibration result increases 4-18 % when the coolant flow rate increases due to the dynamic motion of fluid flow inside the radiator's tube increases. There is a larger increase (2-21 %) of vibration velocity when the fan speed increases which caused by high rotating fan speed that produced more frictions. Moreover, there is a slightly increased 4-10 % in vibrations level when the viscosity of coolant increases because of the repulsion force increases. In noise analysis, the noise level is generated in the frequency range from 25 to 10 kHz. The SPL result is strongly influenced by the rotational fan speed where the radiation noise from 750 to 1250 RPM makes the most significant contribution to overall noise of radiator system with around 32 dBA increases when increasing the fan speeds. The SPL value increases within 10 dBA when the coolant flow rate and coolant viscosity increase. The location of maximum SPL is identified and most located on the blade trailing edge area of the suction surface. In conclusion, noise increase when the vibration increased and high rotating of cooling fan speed is a dominant contributor to overall radiator noise, then it is followed by high coolant flow rates and high viscosity of coolant fluids.

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LIST OF SYMBOLS

W	Watt
dB	Decibel
P	Power
I	Intensity
a	Amplitude
λ	Wavelength
f	Frequency
Hz	Hertz
T	Period
m	Metre
p	Sound Pressure
L_{eq}	Equivalent Continuous Sound Level
$p_{a(t)}$	A-weighted instantaneous acoustic pressure
ρ	Air density
L_w	Sound Power Level
p_0	Reference acoustic pressure
ω	Angular Frequency
Δx	Separation distance between two microphones
SI_x	Sound intensity at any point
T	Averaging time
$w_{x(t)}$	Particle velocity
$h(t)$	Instantaneous sound pressures
Δf	Bandwidth

LIST OF ABBREVIATIONS

NSI	Noise Source Identification
NI	National Instrument
SI	Sound Intensity
EG	Ethylene Glycol
SPL	Sound Pressure Level
FFT	Fast Fourier Transform
A2LL	Advanced Auto Liquid Laboratory

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