Four Wheeler's Health Monitoring by Sound Level Measurement: A Case Study

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Abstract Sound level emitted by vehicle components is having great importance in monitoring their health condition. Higher sound level from a vehicle than the specified not only signifies the sign of fault in the main component of automobile but also dangerous to the pedestrians. Over the time, moving parts of vehicle deteriorates and causes the higher level of sound is merely a guess. In this case study, attempt has been made to check the deterioration level of four different Honda city (diesel variant) cars on the basis of their emitted sound levels measured from various components and conditions. The cars were tested for mainly two conditions idle and moving and sound levels were recorded inside and outside the cabin. The cars have been classified on the basis of odometer reading and tested just after their regular service to remove the conditions of service lag. The measured levels of sound clearly state that the car started emitting the high level of sound over the time and can be said deteriorates with its use. The measured sound levels were also proven to be capable of detecting faults in some of the significant components of the vehicle.

Keywords Health monitoring · Vehicle health · Sound level · Sound level monitoring

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1 Introduction

Sound pollution is term we often come across which is the propagation of disruptive noise in the environment causing a serious impact to the human. The main sources of this disruptive noise close to the human life can be estimated as the traffic noise or the vehicle noise [1–3]. The main concern of noise is not only lying with the manufacturer end to manufacture a vehicle generating less noise but also to the deterioration of the vehicle components over the time. As the vehicle starts aging with the time generally moving components of the vehicle wear out and causes excessive noise [4–7]. This excessive noise generally borne by excessive vibration levels caused due to faulty components [8–12]. There are many techniques available to detect these faults by monitoring the vibration signal and on the basis of that solutions can be derived [13–15]. The five main sources of sound in an automobile are engine, transmission system, cooling system, exhaust system and tires [16]. When engine is turned on and in idle condition then engine sound, partial exhaust sound and partial transmission sound are the mainly contributes to the total sound. Tires and exhaust system are contributing more sound when automobile is in running condition. Each part is having its own significance and reasons for generating sound. By measuring acoustic signal many techniques are available which can detect the faults if it relates with some frequency [17]. The manufacturers are making better designs and using materials having high damping characteristic to absorb sound level to the maximum [18–20]. Even if the sound level of one-part increases then it affects the overall sound level of the automobile.

This study aims to estimate the health condition of four different variants of Honda city (Diesel) with different odometer readings. The sound levels of vehicles were recorded by using sound level meter for the idle and running conditions. All the recorded sound levels were compared for various conditions such as inside cabin and pass-by noise. The condition of the vehicles was explained with the help of recorded sound levels and recommendations were made to the owner.

2 Description of Selected Vehicles

The four selected cars of Honda city (Diesel variant) were categorized as V1, V2, V3 and V4 on the basis of their odometer readings and availability. The car V1 manufactured in year 2018 and driven for 452 kms. The service gap describes how many kms the vehicle was driven after its service. Generally, cars were tested right after their service and the odometer reading was noted right after the sound level recorded. Similarly, other cars with the same data are presented in Table1 and categorized as V2, V3 and V4 on the basis of odometer reading. V1 has only driven for 452 kms and can be considered as benchmark for comparing the other vehicles.

Table 1 Description of tested cars

Honda city (Diesel variant)	Odometer reading in kms	Last service in kms	Service gap in Kms	Manufacturing year
V1	452	NA	NA	2018
V2	44,821	44,819	2	2018
V3	71,827	71,823	4	2016
V4	124,035	124,030	5	2015

3 Test Results with Discussion

The tests were conducted in three different sets, idle condition, cabin noise while vehicle moving and pass-by noise. In first set of experiment, the vehicles were set to idle condition and various sound levels were recorded. Sound level meter having 35–130 dB range, 0.1 dB resolution and frequency range of 31.5–8000 Hz was used for recording the sound levels. Firstly, engine noise was recorded by keeping 1500 rpm of the engine and without turning on cooling system (Air Conditioner AC) and sound level was recorded after placing the sound level meter at a distance one meter from the engine. The V1 has recorded the sound level of 69.8 dB which is minimum as compared to other vehicles. After this AC unit was turned on and engines speed were kept at 1500 rpm and sound level was recorded in the similar manner. The sound level for this condition for V1 was recorded as 70.3 dB and this sound level is combined sound level of engine and AC unit at 1500 rpm. The sound level of AC unit at 1500 rpm can be calculated as 60.7 dB after deducting the 69.8 dB from 70.3 dB. Similarly, other vehicles were tested and their recorded sound levels are shown in Table 2. In all the conditions V1 has been recorded with the minimum sound levels because the vehicle is new and its condition has not deteriorated due to aging. Table 3 represents the percentage of more sound level generated by other vehicles at the same condition in comparison with the minimum level of V1. The noise levels of vehicles in almost all the conditions are showing the upward trend due to aging factor and it is supposed that with the usage main components get wear out and started producing more vibrations and sound levels. The cooling and exhaust system of V2 has recorded

Table 2 Recorded sound levels for the idle conditions without loading

Conditions @1500 rpm	V1	V2	V3	V4
Engine noise with AC unit turning off	69.8	77.6	78.2	80.2
Engine noise with AC unit turning on	70.3	78.9	78.9	80.7
Cooling system noise	60.7	73	70.6	71
Exhaust sound	66.4	81.4	80.2	80.5
Cabin noise with AC unit turning off	52.1	61.4	62.7	63.5
Cabin noise with AC unit turning on	56.8	63.5	64.2	66.1
Cooling system noise in cabin	55.0	59.3	58.8	62.6

Table 3 Percentage of more sound level generate by other cars in comparison with the minimum level for the idle conditions

Conditions @1500 rpm	V1	V2	V3	V4
Engine noise with AC unit turning off	0	502.5	591.8	996.5
Engine noise with AC unit turning on	0	624.4	624.4	996.5
Cooling system noise	0	**1598.2**	877.2	971.5
Exhaust sound	0	**3062.2**	2298.8	2470.4
Cabin noise with AC unit turning off	0	751.1	1048.1	1280.4
Cabin noise with AC unit turning on	0	367.7	449.5	751.1
Cooling system noise in cabin	0	**169.1**	139.9	475.4

for more sound level than V3 and V4. During inspection, the defect was identified in the radiator fan belt and muffler of V2. The recommendations were made to the owner of the V2 for these defects. The cabin noise levels were also recorded for the similar conditions by turning off and on the AC unit.

In the similar manner, the cooling system sound was calculated by subtracting the sound level without turning on the AC unit from the sound level with turning on the AC unit. The cooling system of V2 is having more sound level than V3 and V4 due to faulty belt.

In the second set of experiments, cars were made to run in the first and second gear at engine speed of 1500 rpm and sound levels were recorded inside cabin by turning on and off the AC unit. The recorded sound levels are presented in Table 4 along with percentage more sound level from the reference sound level of V1 and presented in Table 5. In all the conditions the sound levels are showing the upward trend with the aging of the vehicles. Despite having problem in the fan belt of V2, the cooling system sound for V2 is not recorded for higher values than V3 and V4 in the running conditions. The reason for the same might be due to running condition radiator starts taking air directly and the radiator fan might get turned off. So, the other parts of the cooling system of V2 can be said to be in the right order.

In the third set of experiments, cars were made to run in the first and second gear at 1500 rpm and pass-by sound levels were recorded at various conditions. The pass-by sound levels were recorded by keeping the sound level meter 3 m apart.

Table 4 Recorded sound levels inside cabin for the running cars with various conditions

Cabin noise for moving cars @ 1500 rpm	V1	V2	V3	V4
Cabin noise @ 1st gear with AC unit turning off	0	1521.8	2087.8	2654.2
Cabin noise @ 1st gear with AC unit turning on	0	1188.2	1678.2	2190.9
Cooling system noise in 1st gear	0	771.0	1130.3	1598.2
Cabin noise @ 2nd gear with AC unit turning off	0	751.1	877.2	1598.2
Cabin noise @ 2nd gear with AC unit turning on	0	560.7	658.6	1188.2
Cooling system noise in 2nd gear	0	134.4	169.2	280.2

Table 5 Percentage of more sound level generate by other cars in comparison with the minimum level for the running car recorded inside cabin

Cabin noise for moving vehicles @ 1500 rpm	V1	V2	V3	V4
Cabin noise @ 1st gear with AC unit turning off	51.2	63.3	64.6	65.6
Cabin Noise @ 1st gear with AC unit turning on	53.7	64.8	66.2	67.3
Cooling system noise in 1st gear	50.1	59.5	61.0	62.4
Cabin noise @ 2nd gear with AC unit turning off	55.4	64.7	65.3	67.7
Cabin noise @ 2nd gear with AC unit turning on	57	65.2	65.8	68.1
Cooling system noise in 2nd gear	51.9	55.6	56.2	57.7

The recorded pass-by sound levels at various conditions are presented in Table 6 along with percentage more sound level from the reference sound level of V1 at the same condition and presented in Table 7. The cooling system sound effect outside the vehicle is calculated in the similar manner as done in the previous set of experiments. The V2 is showing excessive sound level in all the cases except cooling system sound than V3 and V4. During inspection, it has been identified that the tires of V2 were more worn out than the tires of V3 and V4. The worn-out tires of V2 were causing excessive vibrations and noise which results in higher sound level recorded for V2 in pass-by conditions. The worn-out tires of V2 were not causing any significant effect

Table 6 Recorded pass-by sound levels for the running cars for various conditions

Pass-by noise for moving cars @ 1500 rpm	V1	V2	V3	V4
Pass-by noise @ 1st gear with AC unit turning off	65.2	74.4	70.8	71.4
Pass-by noise @ 1st gear with AC unit turning on	66.6	75.7	73.6	74.2
Cooling system noise in 1st gear	61.0	69.8	70.3	70.9
Pass-by noise @ 2nd gear with AC unit turning off	64.2	74.6	68.6	69.5
Pass-by noise @ 2nd gear with AC unit turning on	65.6	75.5	71.5	72.2
Cooling system noise in 2nd gear	60.0	68.2	68.3	68.8

Table 7 Percentage of more pass-by sound level generate by other cars in comparison with the minimum level for the running cars

Pass-by noise for moving cars @ 1500 rpm	V1	V2	V3	V4
Pass-by noise @ 1st gear with AC unit turning off	0	**731.8**	263.1	316.9
Pass-by noise @ 1st gear with AC unit turning on	0	**712.8**	401.2	357.1
Cooling system noise in 1st gear	0	658.6	751.1	877.2
Pass-by noise @ 2nd gear with AC unit turning off	0	**996.5**	175.4	238.8
Pass-by noise @ 2nd gear with AC unit turning on	0	**877.2**	289	357.1
Cooling system noise in 2nd gear	0	560.7	576.1	658.6

inside the cabin as observed in the previous set of experiment. The faulty radiator belt of V2 is not showing any signs while in the running conditions.

The sound levels for all the conditions of each vehicle are shown in Figs. 1, 2, 3 and 4 respectively. In all the cases the sound level with turning on the AC unit was coming out to be more due to additional sound addition due to cooling system. The pass-by sound level for engine and cooling system in all the cases was coming out to be more in comparison with the cabin noise. This is because all the vehicles have designed with proper sealing inside the cabin to restrict the sound entering into the cabin. The sound of cooling system was coming out to be more in the 1st gear in comparison with 2nd gear except the cabin noise of V1. This signifies that the cooling system is taking more load in 1st gear in comparison with second gear. The other gear conditions were not tested due to the space restrictions and specified speed limit.

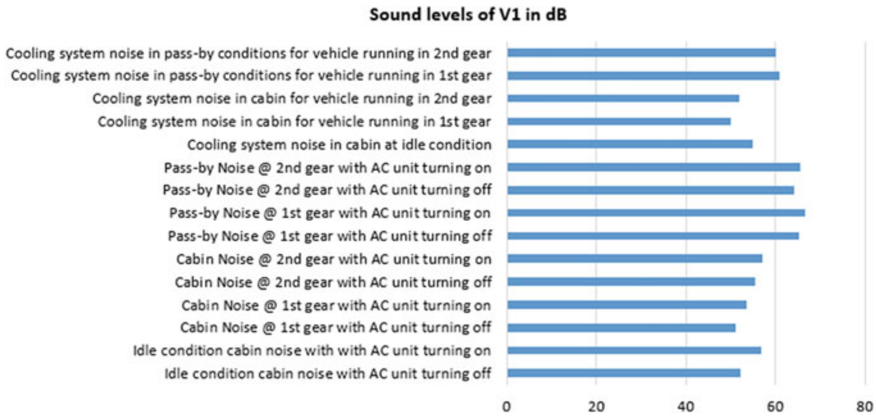

Fig. 1 The recorded sound levels of vehicle 1 for all the conditions

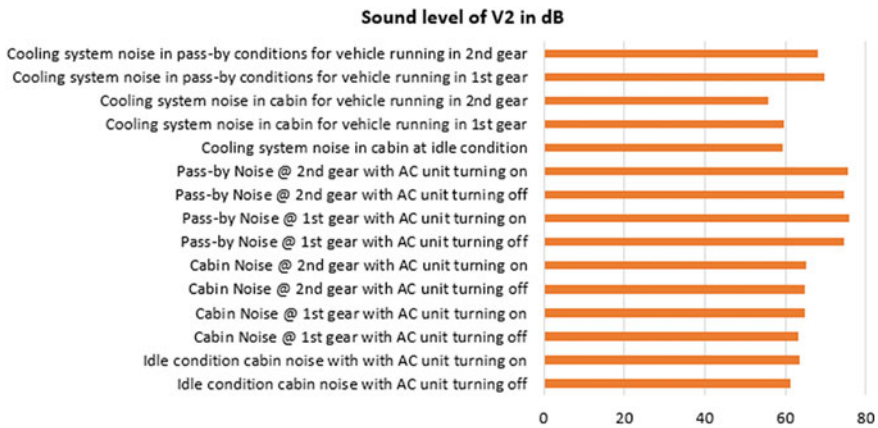

Fig. 2 The recorded sound levels of vehicle 2 for all the conditions

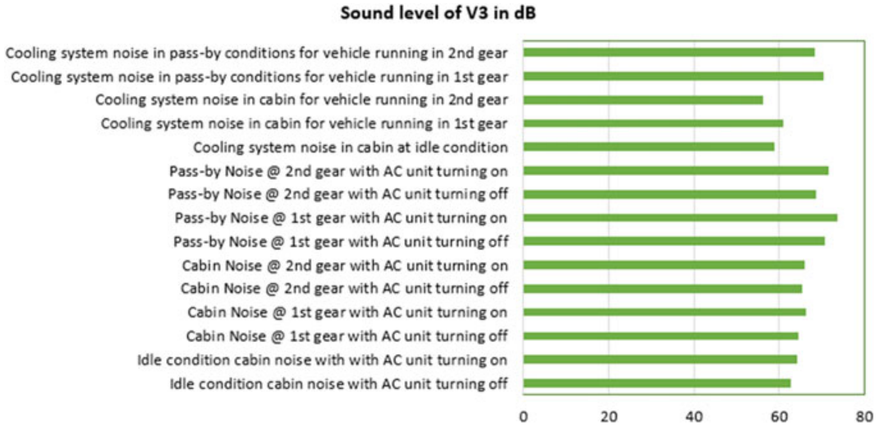

Fig. 3 The recorded sound levels of vehicle 3 for all the conditions

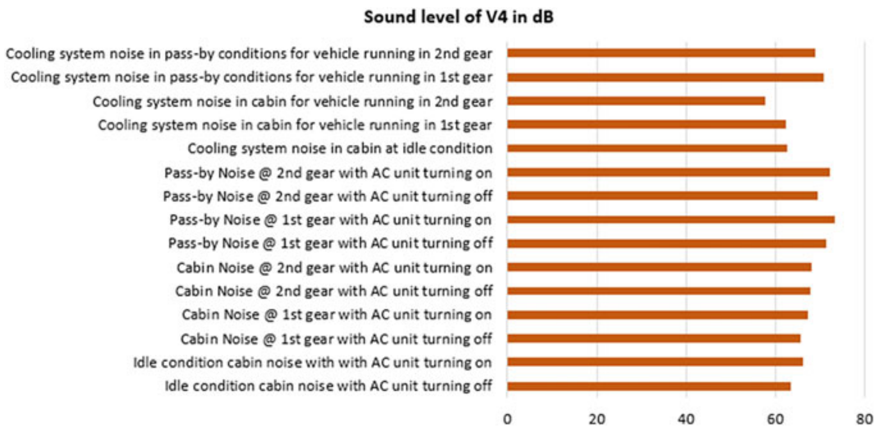

Fig. 4 The recorded sound levels of vehicle 4 for all the conditions

4 Conclusion

The case study done on the Honda city cars has helped in drawing the following conclusion.

1. With the use of vehicles, the moving components deteriorates significantly over time and resulting in emitting higher sound levels. In all the cases the sound level has found to be increased for the components of vehicles with its usage.
2. The sound level of vehicles at various levels has helped in identification of faults in significant components such as radiator fan belt, muffler and worn-out tires.

3. The manufacturer of the Honda city car has provided good sound sealing arrangement for the cabin as in all the cases sound levels were significantly more when recorded outside the vehicles.
4. The cooling system takes more load in 1st gear than in 2nd gear this was evident from the higher sound level recorded for the cooling system in 1st gear than 2nd gear under same speed of engine.
5. The sound level recording system does not include any complex equipment and still it is capable of identifying the deterioration of vehicles and faulty components.

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