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DEVELOPMENT OF A KL RIVER DRIVING CYCLE FOR PHERB POWERTRAIN

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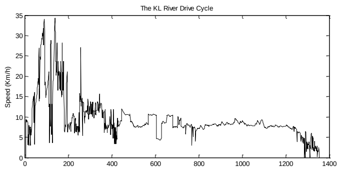
Graphical abstract



Abstract

This paper presents the development of a Kampung Laut (KL) river driving cycle for plug-in hybrid electric recreational boat (PHERB). A hybrid energy storage system between batteries and ultracapacitors are used in PHERB powertrain, which is effectively function together to enhance the driving performance and energy efficiency. The real world speed-time data for KL river driving cycle is collected using global positioning system. The route is selected based on daily traffic of KL river boat. The developed driving cycle consist of 1361 s, with a distance of 1.27 km, and an average speed and a maximum speed of 9.34 km/h and 34.30 km/h, respectively. The results obtained from this analysis are within reasonable range and satisfactory.

Keywords: Driving cycle, powertrain, PHERB, fuel economy, emissions

1.0 INTRODUCTION

The study of driving cycle has been used worlwide and had been developed in several parts of the world including America, Europe, Australia and Asia. Conducting a driving cycle analysis using data trip collection from vehicles in real life operation is very challenging. Successful driving cycle analysis on the other hand can greatly benefit technology. By conducting driving cycle analysis, the performance can be assesed. [1 - 2] also highlighted that some study tackles three major task that are data collection, route selection and cycle construction. In order to measure the plug-in hybrid electric recreational boat (PHERB) powertrain emissions and fuel consumption as shown in Figure 1, the simulation of actual driving cycle characteristics is executed [3]. The actual driving cycle is the cycle derived from the movement of test boat under real traffic conditions [4].

2.0 KL RIVER DRIVING CYCLE DEVELOPMENT

Generally, to obtain and tabulate the driving cycle data, there are two methods that can be emphasized, which are chase boat or on board techniques using global positioning system (GPS) or both. In this study, the GPS technique is implemented, in order to collect the speed-time data of a boat. Once the data is obtained, it will be analyzed and characterized based on the 12 variables as listed in Table 1. The speed-time data picturized a real world KL river driving cycle. The flowchart for KL river driving cycle development is illustrated in Figure 2.

The representative route throughout the interested area are selected as in Figure 3. For KL river driving cycle, the data will be collected based on regularly route used by locals. Driving speed data was collected using GPS technique. This technique involves recording a set of real world speed-time data, where the boat speed with respect to time will be recorded. This process will be repeated, in order to obtain large amount of data.

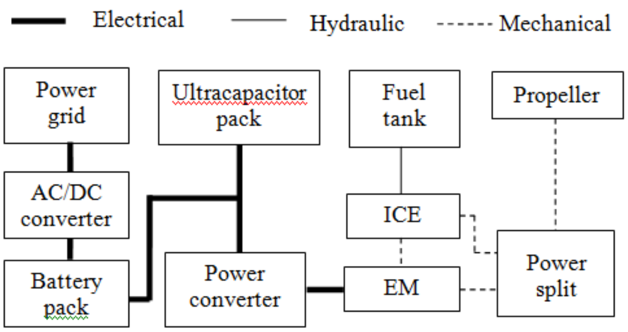


Figure 1 Schematic illustration of series-parallel PHERB powertrain

Table 1 Variables used in KL river driving cycle development [5]

No	Variable	Unit	Formula
1	Average speed , v_1	km/h	$v\_avg = 3.6\dfrac{dist}{T_{total}}$
2	Average running speed, v_2	km/h	$v\_run = 3.6\dfrac{dist}{T_{drive}}$
3	Average acceleration of all acceleration phases, a	m/s²	$a\_avg = \left(\sum_{i=1}^{n}\begin{cases}1 (a_i > 0)\\ 0\ (\text{else})\end{cases}\right)^{-1}\sum_{i=1}^{n}\begin{cases}1 & (a_i > 0)\\ 0 & (\text{else})\end{cases}$
4	Average deceleration of all deceleration phases, d	m/s²	$d\_avg = \left(\sum_{i=1}^{n}\begin{cases}1 (a_i < 0)\\ 0\ (\text{else})\end{cases}\right)^{-1}\sum_{i=1}^{n}\begin{cases}1 & (a_i < 0)\\ 0 & (\text{else})\end{cases}$
5	Mean length of a driving period, c	s	-
6	Time proportion of idling, P_i	%	$\%drive = \dfrac{T_{drive}}{T_{total}}$
7	Time proportion of acceleration, P_a	%	$\%acc = \dfrac{T_{acc}}{T_{total}}$
8	Time proportion of cruise, P_c	%	$\%cruise = \dfrac{T_{cruise}}{T_{total}}$
9	Time proportion of deceleration, P_d	%	$\%dec = \dfrac{T_{dec}}{T_{total}}$
10	Average number of acceleration-deceleration changes within one driving period, M		-
11	Root mean square of acceleration, RMS	m/s²	$RMS = \sqrt{\dfrac{1}{T_{total}}\sum_{i=1}^{n} a_i^2}$
12	Acceleration energy per kilometer, PKE	m/s²	$PKE = \dfrac{1}{dist}\sum_{i=2}^{n}\begin{cases}v_i^{\,2} - v_{i-1}^2 & (v_i > v_{i-1})\\ & (else)\end{cases}$

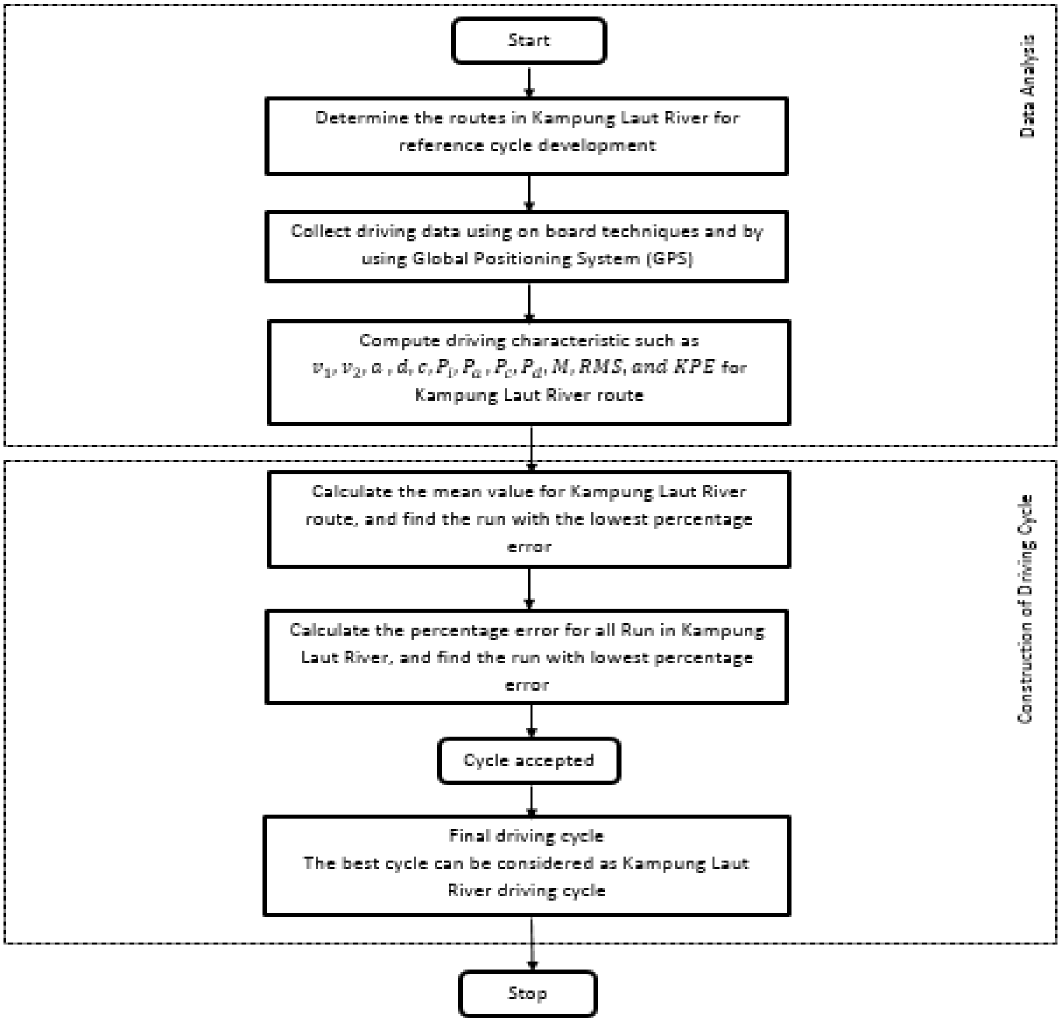


Figure 2 Flowchart for KL river driving cycle development

Figure 3 The selected route for KL river driving cycle

3.0 RESULTS AND DISCUSSION

Speed-time data is an important criteria to measure and indicate the route flow and is most significance influencing the emissions of the recreational boat. By using GPS along the selected route around KL river, the real world speed-time data is collected. As many as 20 runs are recorded for 1 run per day during 20 days at the peak hour. The data is collected during the period of 8.00 a.m to 10.00 a.m for 20 days on February 2015. The value of 12 data variables are listed in Table 2, then the mean values are calculated and listed in Table 3. After that, the percentage error for all run is calculated as in Table 4. The lowest percentage error was run 2, therefore it is considered as the best KL river driving cycle. The average speed for KL river driving cycle is 9.34 km/h and the average running speed is 9.41 km/h. According to the obtained result, it can be concluded that the speed is low, as expected. During the test run, the mode of the boat is divided into four operating modes, which are idling, cruising, acceleration and deceleration are calculated. The time proportion of idling, cruising, acceleration and deceleration are 0.73, 3.16, 47.13 and 49.04, respectively. The rate for acceleration and deceleration are approximate identical given ratio 1:1, which is 0.21 m/s^2 and 0.20 m/s^2. The value of mean length of driving period is 1361 s. It can be concluded that the higher value of mean length of driving period, the traffic is less congested hence it indicates that the path is smooth and clear without any obstacles or resistance. The root mean square for this run is 0.54 m/s^2 and the acceleration energy per kilometer is 0.26 m/s^2. The best KL river driving cycle is constructed as presented in Figure 4.

Table 2 KL river driving cyce data analysis

Criterion	v_1 (km/h)	v_2 (km/h)	a (m/s^2)	d (m/s^2)	c (s)	P_i (%)	P_c (%)	p_a (%)	P_d (%)	M	RMS (m/s^2)	KPE (m/s^2)
j	1	2	3	4	5	6	7	8	9	10	11	12
Run 1	8.70	8.74	0.20	0.19	1365	0.51	3.30	47.29	48.97	0.96	0.52	0.26
Run 2	9.34	9.41	0.21	0.20	1361	0.73	3.16	47.13	49.04	0.96	0.54	0.26
Run 3	10.05	10.14	0.23	0.23	1363	0.95	3.01	47.28	48.83	0.96	0.58	0.30
Run	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Run 19	10.79	10.87	0.29	0.26	1368	0.73	1.32	45.87	52.16	0.98	0.49	0.28
Run 20	11.88	11.99	0.30	0.26	1369	0.95	0.80	46.20	52.12	0.98	0.49	0.29

Table 3 Mean values of the assessment parameters of grouped runs

Criterion	v_1 (km/h)	v_2 (km/h)	a (m/s^2)	d (m/s^2)	c (s)	P_i (%)	P_c (%)	p_a (%)	P_d (%)	M	RMS (m/s^2)	KPE (m/s^2)
j	1	2	3	4	5	6	7	8	9	10	11	12
Mean Value Route 1 (run 1 – run 20)	9.45	9.52	0.21	0.20	1368.25	0.77	2.21	47.77	49.32	0.96	0.47	0.23

Table 4 Percentage difference relative to target summary statistics

Criterion	v_1 (km/h)	v_2 (km/h)	a (m/s^2)	d (m/s^2)	c (s)	P_i (%)	P_c (%)	p_a (%)	P_d (%)	M	RMS (m/s^2)	KPE (m/s^2)	Total Error (%)
j	1	2	3	4	5	6	7	8	9	10	11	12	
Mean Value	9.45	9.52	0.21	0.20	1368.25	0.77	2.21	47.77	49.32	0.96	0.47	0.23	
Run 1	7.94	8.19	4.76	5.00	0.24	33.77	49.32	1.00	0.71	0	10.64	13.04	134.61
Run 2	1.16	1.16	0	0	0.53	5.19	42.99	1.34	0.57	0	14.89	13.04	80.87
Run 3	6.35	6.51	9.52	15.00	0.38	23.38	36.20	1.03	0.99	0	23.40	30.43	153.19
Run	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Run 19	14.18	14.18	38.10	30.00	0.02	5.19	40.27	3.98	5.76	2.08	4.26	21.74	179.76
Run 20	25.71	25.95	42.86	30.00	0.05	23.38	63.80	3.29	5.68	2.08	4.26	26.09	253.15

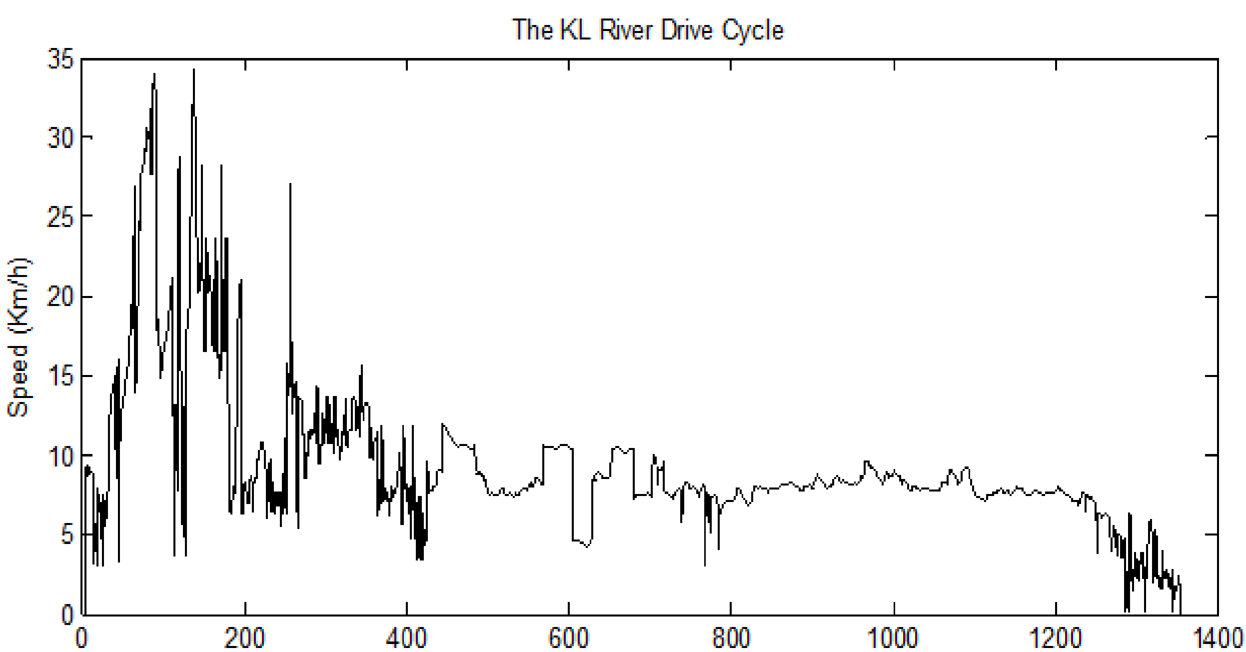


Figure 4 The KL river driving cyle

4.0 CONCLUSION

The result of the 12 variable is within reasonable and expected range of a real world KL river driving cycle. Based on the results of this study, it can be concluded that the proposed method is possible to generate a recomended KL river driving cycle that can be used for PHERB powertrain, in order to measure fuel economy and emissions.

Acknowledgement

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