Pilot Green Transport Fund

Interim Report
On
Trial of Diesel-Electric Propulsion System for Ferry II
(The "Star" Ferry Company, Limited)

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(Reporting Period: 1 June 2020 – 30 November 2020)

Executive Summary

1. Introduction

1.1 The Pilot Green Transport Fund (the Fund) is set up to encourage transport operators to try out green innovative transport technologies, contributing to better air quality and public health for Hong Kong. The "Star" Ferry Company, Limited (Star Ferry) was approved under the Fund for trial of one diesel-electric propulsion (DEP) system by retrofitting it to an existing ferry (Morning Star). The DEP system replaced the ferry's original diesel engine. The DEP system was expected to lower fuel consumption and air pollutants emissions of the ferry. Through the tendering procedures stipulated in the Subsidy Agreement entered into with the Government, Star Ferry appointed Leung Wan Kee Shipyard to retrofit the DEP system on Morning Star (hereafter called DEP ferry) for trial.

1.2 Star Ferry assigned a conventional ferry, Northern Star, providing the same service as the DEP ferry as the conventional counterpart for comparing with the DEP ferry. Northern Star is ferred to as conventional ferry in this report.

1.3 PolyU Technology and Consultancy Company Limited (PolyU) has been engaged by the Environmental Protection Department (EPD) as an independent third party assessor to monitor the trial and evaluate the performance of the green innovative technology under trial as compared with its conventional counterpart.

1.4 This report summarizes the performance of the DEP ferry in the first six months of the trial and compares it with the performance of the conventional ferry.

2. Trial Ferry and Conventional Ferry

2.1 The DEP system includes two 275 kW Caterpillar diesel generators, two frequency inverters and two 350 kW electric motors and the associated control equipment. The two 275 kW generators meet International Maritime Organization (IMO) Tier II and United States Environmental Protection Agency (USEPA) Tier III emission standards. One diesel generator is used to power the electric motors to propel the ferry. Another diesel generator is for stand-by purpose as required by Marine Department for safety reason. The two frequency inverters are used to control the operation of the electric motors. The DEP system replaced the ferry's original 357 kW pre-1990 diesel engine.

2.2 Key features of the DEP system, the DEP ferry and the conventional ferry are in Appendix 1, and photos of the DEP system, the DEP ferry and the conventional ferry are in Appendix 2. The DEP ferry provides round trip service from Tsim Sha Tsui Pier to Wan Chai Pier or Central Pier.

3. Trial Information

3.1 The trial started on 1 June 2020 and will last for 24 months. Star Ferry was required to collect and provide trial information including the DEP ferry operation data and maintenance records. DEP ferry operation data include passenger carried, operating hours, amount and cost of diesel fuel consumed. Maintenance records include cost and downtime associated with scheduled and unscheduled maintenances of the DEP ferry related to the performance of the DEP system. Similar data are also required from the conventional ferry. In addition to the cost information, reports on maintenance work, operational difficulties and opinions of the captains of the DEP ferry and passengers were collected to reflect any problems of the DEP ferry.

3.2 Since the Government tightened the statutory fuel sulphur content from 0.5% to 0.05% in 2014, the sulphur dioxide (SO_2) emission in the exhaust gas has dropped significantly, the DEP system's contribution to the emission reduction has been small. Hence, the DEP system is mainly used to reduce the emissions of nitrogen oxides (NOx) and particulates (PM). The exhaust emissions were measured before Morning Star was retrofitted with the DEP system and measured again in June 2020 upon commencement of the trial. The exhaust emissions measured mainly included the concentrations of NOx and PM, as well as smoke opacity. Meanwhile, concentrations of carbon monoxide (CO) and hydrocarbons (HC) were also measured in this trial for reference. Star Ferry commissioned an expert team of The University of Hong Kong (HKU) as their contractor to conduct the emission measurements.

4. Findings of Trial

4.1 Operating Costs

4.1.1 The trial was considered to be in a preliminary trial stage for the months of June 2020 to August 2020 as Star Ferry was familiarizing/testing the performance and characteristics of the engine and the ferry though it started providing services, and the data collected were not representative. Therefore, the evaluation was taken from September 2020 onwards. Table 1 summarizes the statistical data of the DEP ferry and the conventional ferry. The fuel consumption of the DEP ferry was 0.4 litre per hour (i.e., 1%) lower than that of the conventional ferry. The fuel cost of the DEP ferry was HK$6 per hour (i.e., 1%) lower.

Table 1: Key operation statistics of ferry (1 September 2020 – 30 November 2020) [1]

	DEP Ferry	Conventional Ferry
Total time travelled (hour)	812.5	1003.6
Average fuel consumption (litre per hour)	32.1	32.5
Average fuel cost (HK$/hour) [2]	599	605
Average total operating cost (HK$/hour)	599	616
Downtime (no. of working day) [3]	1	2.5

[1] As June 2020 – August 2020 were in preliminary trial stage and the data of the DEP ferry are not representative, therefore, the evaluation was taken from September 2020 to November 2020.

[2] Based on the listed price

[3] Downtime refers to the working days the ferry was not in normal operation, which is counted from the first day it stopped normal operation till the day it resumed normal operation.

4.1.2 For the conventional ferry, maintenance work was conducted by the company's own workshop and most of the maintenance work did not involve downtime as the work was conducted when the service of the ferry was not required. Thus, maintenance cost of the conventional ferry mainly involved cost of replacement parts. For the DEP ferry, no maintenance cost was involved as it was under warranty. Compared with the conventional ferry, the average total operating cost for the DEP ferry was HK$17 per hour (i.e., 3%) lower.

4.1.3 In the period of September to November 2020, the DEP ferry and the conventional ferry had 1 day and 2.5 days downtime, respectively associated with maintenances required, therefore, the utilization rates were 99% for the DEP ferry and 97% for the conventional ferry.

4.2 Performance and Reliability

4.2.1 Several captains had operated the DEP ferry. Four captains were interviewed in the reporting period and they had different opinions on the operation of the DEP ferry. In general, in the first three months, they did not have very positive responses, especially they found the DEP system noisy and the propulsion system slow in response. However, in the last interview, they all expressed no problem in operating the DEP ferry and were satisfactory with its performance.

4.2.2 The passengers' feedback was in general very positive.

4.2.3 During the first three months of the trial, the ferry has trouble in operating with one engine. At high engine load and during manoeuvring operations, the frequency inverter alarm might be actuated causing tripping to the frequency inverter(s) and the motor(s). Such conditions rarely happen when operating with two engines.

5. Air Pollutants Emissions

5.1 The DEP system is mainly used to reduce the emissions of NOx and PM compared to the old engine. Concentrations of NOx, CO, HC and PM in the exhaust gas, as well as smoke opacity of the exhaust gas, were measured to check the environmental performance of the DEP system compared with the old diesel engine in the DEP ferry before it was retrofitted. The emissions were measured in March and April 2019 for the original ferry and measured in June 2020 for the DEP ferry.

5.2 The NOx emission was reduced by 77% after the retrofit.

5.3 The PM emission was reduced by 86% after the retrofit; while the smoke opacity was reduced by 50%.

5.4 Meanwhile, CO and HC emissions were also measured in this trial for reference. After the retrofit, the CO and HC emissions were reduced by 33% and 83% respectively.

6. Summary

6.1 The trial was considered to be in a preliminary trial stage in the first three months of the trial (June to August 2020) as Star Ferry was familiarizing/testing the performance and characteristics of the engine and the ferry though it started providing services, and the data collected were not representative. Therefore, the evaluation was taken from September 2020 to November 2020 in this report.

6.2 The average fuel cost and the average total operating cost of the DEP ferry were 1% and 3% lower than those of the conventional ferry respectively. The DEP system is mainly used to reduce the emissions of NOx and PM compared to the old engine. The measurement results reflected that the replacement of the old engine with the DEP system reduced the emissions of NOx and PM by 77% and 86%, respectively and the smoke opacity by 50%. Meanwhile, CO and HC emissions were also measured in this trial for reference. After the retrofit, the CO and HC emissions were reduced by 33% and 83% respectively.

6.3 The performance and reliability of the DEP ferry will be continuously monitored in the 24 months of the trial.

Appendix 1: Key Features of the Ferries Involved in the Trial and the Diesel-electric propulsion system

1. Diesel-electric propulsion (DEP) system for DEP ferry

Main Generator Set (two sets)

Maker:	Caterpillar
Model:	C9.3 Marine Generator Set
Rating:	275 kW @1800 rpm
Engine:	6-cylinder in line diesel engine
Emission standard:	EPA Tier 3/IMO II

Auxiliary Generator Set (two sets)

Maker:	Perkins
Model:	1004TGM
Rating:	52 kW @ 1500 rpm
Propulsion	Motor (two sets)
Maker:	Dezhou Hengli
Model:	YVF2-4003-6-H
Rating:	350 kW @ 1190 rpm

2. DEP Ferry

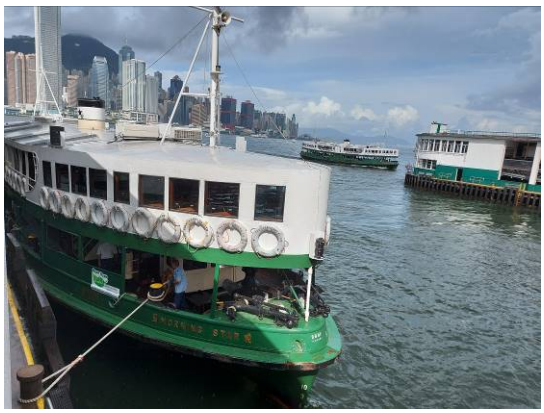
Name of vessel:	**Morning Star**
Type:	Class I Ferry Vessel
Port of Registry	Hong Kong
Length overall:	35.61 meters
Extreme breadth:	8.57 meters
Light Ship Displacement:	235.47 / 250.10 tonnes(without balast / with ballast)
Gross Tonnage:	206 / 164.01 tonnes (after retrofit / before retrofit)
Net Tonnage:	100 / 39.69 tonnes (after retrofit / before retrofit)
Passenger capacity:	399 / 540 people (after retrofit / before retrofit)
Year of manufacture:	1965; retrofitted with DEP in 2020

3. Conventional Ferry for comparison purpose

Name of vessel:	**Northern Star**
Type:	Class I Ferry Vessel
Length overall:	35.63 meters
Extreme breadth:	8.57 m
Light Ship Displacement:	248.55 tonnes
Gross Tonnage:	164.01 tonnes
Net Tonnage:	39.69 tonnes
Passenger capacity:	547 people
Year of manufacture:	1958
Main engine:	Crossley/6HRN; 340 rpm, 357.33 kW
Generator set:	2*Perkins 1004TGM; 52 kW @ 1500 rpm

Appendix 2: Photos of the Ferries and the Diesel Electric Propulsion System

1. DEP Ferry and DEP system

	
Front view of DEP Ferry	Side view of DEP Ferry
	
#1 main diesel generator (for propulsion)	#2 main diesel generator (for propulsion)
	
Auxiliary diesel generator	Propulsion motor

2. Conventional Ferry

Northern Star