

A STUDY ON HIGHLY EFFICIENT CARGO HANDLING SYSTEM

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ABSTRACT: This paper presents the energy saving methods and energy storage system to be required for the highly efficient cargo system in container terminal. The best proper method of energy saving is decided by the operation method of cargo handling system and the saving effect of this method is studied. The advantage and disadvantage of battery as energy saving system is studied. The battery in several kinds of energy saving system has the economical propriety in cost and technological side currently and it is investigated as the expected energy saving system in consideration of the future progress of technology. And also the saving effect and economical propriety of battery energy saving system and hybrid system of transfer system in container port and yard are very highly evaluated.

Keywords: *Yard Tractor, Cargo Handling, Energy Storage System, Battery, Hybrid System, Energy Saving*

1. INTRODUCTION

The fast progress of modern mankind civilization from 18 century is closely related to the amount of used fossil fuel. But the entire earth is faced to the problem such that warm weather is caused by air pollution such as carbon dioxide to be accumulated by continuous consumption of fossil fuel and the survival of mankind is threatened by shortage of limited fossil fuel. To solve these problems the many advanced countries are interested in the research to improve the energy efficiency and to develop energy storage technology and substitution energy. The research to improve the energy efficiency and to develop energy storage technology and substitution energy is very strongly required in case of Korea to be dependent on importing fossil fuel entirely. As mentioned it previously, when foreign dependency of imported fossil fuel is high realistically the energy saving of yard tractor of container transfer in port is essential to design of better than future and high profit.

Recently the research of hybrid system using reduction methods of air pollution gas and storage methods for surplus energy is studied in many research institutions and universities[1,2]. This paper presents the economical

propriety of hybrid and energy storage system for highly efficient yard tractor as cargo handling equipment[3].

2. HIGH EFFICIENCY OF TRANSFER SYSTEM FOR CARGO HANDLING

Recently the international price of crude oil is nearly reached to \$120 because of political instability in Middle Eastern Asia and also the continuity of the unstable psychology of oil supply and increase of over consumption has the extra room to increase the price of oil unstably. The possibility of interruption of oil supply because of the conflict and geopolitical cause between Middle Eastern nations is always existed. And it is predicted that it is difficult in short term to improve the structural problem of oil market that the biggest cause of increase of oil price is increase of demand and restriction of supply capacity.

In 2004, the surplus productivity in entire world is 10% of total demand, 600 million b/d(barrel per day) and it is predicted that annual rate of surplus productivity will be decreased in every year. When current oil product is assumed to 10 billion ton, the increase of energy demand is reached to 16 ~ 18 billion ton in 2030. Until 2030 the fossil fuel is reached to 80~85% of entire energy supply

and it will be slowly substituted by natural gas and there is no radical change in rate of occupation. It is predicted that the huge energy consumption nations such as America, China and Japan in consideration of high price of crude oil in long term try to secure the resource by strong diplomacy of oil production nation, purchase of mining area and security of reserved oil. Because of these, there is the possibility to make the conflict between nations and it is predicted that in view of supply side the unstable cause of supply such as shortage of oil refinery and surplus production facility in OPEC is continued.

The existence of Asia that China is centered in energy demand will be much more important and the increase of energy demand is necessary to continue the steady economical development in middle and long term. The Asian consumption of oil in transportation such as China and India is increased to similar amount of North America in 2030. The political study of the saving of fossil energy and reduction of energy consumption is needed because the regulation of CO₂ emission restriction is reinforced according to CO₂ reduction duty of Kyoto Agreement to protect warming weather in earth. To prepare the possibility of supply constrain and sudden increase of oil price the effort of saving and cost reduction of fossil fuel to be consumed in cargo handling equipment and transportation is immediately required. In container terminal most of cargo handling system uses the fossil fuel as power source. The effort to improve the system of CO₂ reduction and energy saving of fossil fuel is required.

Table 1 shows the oil purchase price when it is assume that oil price is 1.36 dollars and container throughput in nationwide port is 17,926,748 TEUs in 2008. When it is assume that about 281 transfer cranes are operated in container terminal consume 1.42 liters per TEU, annual amount of oil consumption for container throughput 17,926,748 TEUs is about 25.5x10⁶ liters and purchase cost is about 34.68 million dollars. About 652 yard tractors that transfer systems are operated in domestic port consume about 4.17 liters per hour and when it is assumed that they are operated in 12 hours per day and 300 days in year

annual amount of oil consumption is about 6.25x10⁶ liters and purchase cost is about 8.5 million dollars. And assuming that it consumes 11.1 liters per hour, annual amount of oil consumption is 16.6x10⁶ liters and purchase cost is about 22.57 million dollars.

When it is assumed that about 141 transfer systems including reach stacker and fork lift and excluding container chase consume about 0.7 liter per TEU, annual amount of oil consumption for annual container throughput 17,926,748 TEU is 12.5x10⁶ liters and purchase cost is about 17.0 million dollars.

Table 1. Energy consumption amount of cargo handling system in domestic port

Item	Unit	Oil consumption per unit	Oil price (\$)	Annual throughput	Annual amount of oil consumption (liter)	Total (million dollars)
Transfer Crane	281	1.42 Liter/TEU	1.36	17,926 (thousand TEU)	25.5x10 ⁶	34.68
Yard Tractor & Yard Crane	652	4.17 Liter/Hr	1.36	1,500 (thousand unit)	6.25x10 ⁶	8.5
		11.1 Liter/Hr	1.36	1,500 (thousand unit)	16.6x10 ⁶	22.57
Reach Stacker & Fork Lift	141	0.7 Liter/TEU	1.36	17,926 (thousand TEU)	12.5x10 ⁶	17.0
Total	933	-	-	-	60.85x10 ⁶	82.75

In case of yard tractor the difference of the oil consumption rate according to yard path and driving habit of driver is shown in Table 1. In collected data the first data of oil consumption are about 4.17 liters per hour and the second data of oil consumption are about 11.1 liters per hour. Generally, in case of manual operation, container throughput rate of transfer crane is about 30~40 TEU per hour and amount of oil consumption is about 42.6 ~ 63.9 liters per hour.

3. ENERGY STORAGE EQUIPMENT OF TRANSFER SYSTEM IN CONTAINER TERMINAL

By applying hybrid system used battery as energy storage equipment to transfer system, the high efficiency of energy use and reduction of consumption of fossil fuel is accomplished.

A. Energy Storage Equipment

For the high efficient use of energy by saving energy of fossil fuel used in container transfer system, the battery and super capacity is studied as energy storage equipment. The special features of secondary battery such as yes or no of recharge, high power density, discharge of high power, flat discharge curve and performance in low temperature are classified. Generally, the secondary battery has the disadvantage of energy density and storage life in comparison with the first battery. On the other hand, it has the capability of high power density and discharge of high power and it has no change of special feature by temperature. The secondary battery as energy storage equipment has several kinds of special feature and Li-Ion battery of the secondary battery is best for energy storage equipment of cargo handling system has because of advantage of high voltage, energy density, life and environmental factor. The advantages and disadvantages of battery as energy storage equipment are summarized in Table 2.

B. Reduction Method of Energy

Hybrid system is complex power system to combine more than two power systems such as electrical and internal combustion engine. In early time this system was started as the study to reduce the emission of contamination materials and to improve the efficiency of fuel use by solving the problem such as emission of contamination materials and over consumption of energy in vehicle.

Table 2. Advantage and disadvantage of energy storage equipment

Storage Equipment	Advantage	Disadvantage
Battery	<ul style="list-style-type: none"> • High energy density • High output density 	<ul style="list-style-type: none"> • Chemical contamination material emission • Low storage characteristics and short cycle life (thermal phenomena of chemical material) • Risk of explosion • No permanent use
Super capacity	<ul style="list-style-type: none"> • Eco-environmental • Low impedance • Fast charge speed • Semi-permanent cycle life • Extension life in simultaneous use with battery 	<ul style="list-style-type: none"> • Low energy density(No high continuous output) • Low cell voltage • Slow charge speed • Fast discharge speed



Figure 1. Hybrid System of Yard Tractor

Recently the hybrid vehicle of high performance such as effective reduction of pollution and energy efficiency is realized by the engine system to reduce energy consumption rate of fuel. And also this hybrid technology is applied to the all system to use the internal combustion engine and the applied system has obtained the positive effect such as energy reduction and constraint of contamination materials.

4. HYBRID TRANSFER SYSTEM OF CARGO HANDLING SYSTEM

The hybrid systems are classified into the electrical hybrid system that reduces the power load of diesel engine by

storing the electrical energy at energy storage equipment by changing surplus energy of diesel engine into electrical energy and the hydraulic hybrid system that reduces the power load of the engine-pump-motor by generating the power by using the hydraulic flowing from high pressure to low pressure. These two systems have the advantage to reduce 30% ~ 60% of fuel consumption of transfer system and the hydraulic hybrid system obtains the reduction effect of maximum 70% of fuel consumption. These system have the advantage of environmental factor because of reduction effect of CO₂ emission by energy saving.

A. Hybrid System Configuration

The electrical hybrid system to save the energy of transfer system by independent or dependent using of electrical motor and diesel engine in each other. The configuration of electrical hybrid system is composed of gasoline engine (or diesel engine), electrical motor and large scale battery to store surplus energy. Here, the high torque motor and large scale battery are placed between engine and transmission. This system is classified serial and parallel type and the serial type has the same type of electrical automobile by using engine as auxiliary power.



Figure 2. Hybrid Yard Tractor in Commercialized

This system is not efficient because that the loss rate of energy is high in the process to convert mechanical energy into chemical energy and to convert chemical energy into electrical energy.

On the other hand, the parallel type of electrical hybrid transfer system is much more efficient than the serial type because of using engine and electrical motor

simultaneously. Therefore, in general the hybrid system to be used in transfer system is the parallel type.

In the parallel electrical hybrid transfer system the engine in the first starting time is not operated and the motor to be connected to battery is started and then the engine is used as the main power if the speed is increased by pushing the paddle of acceleration. At this time, the electrical motor is converted to the auxiliary power equipment and it is used for adding the output of engine or transferring the additional power. When the transfer system under operating is stopped the electrical motor is played as generator by the inertia of transfer system. At this time the electrical energy to be generated is stored at battery.

B. Characteristics of Hybrid Transfer System

The characteristics of hybrid transfer system to be combined with of energy storage of battery and diesel engine of main power are summarized in Table 3.

Table 3. Advantage and disadvantage of energy saving equipment

Equipment	Advantage	Disadvantage
Hybrid Yard Tractor	<ul style="list-style-type: none"> • Energy saving in case of using battery: minimum 20% ~ maximum 70% • Eco-friendly system - Reduction of contamination material emission 	<ul style="list-style-type: none"> • Large investment in early purchase • Replacement cycle of battery : 4 ~ 6 years -additional investment is required • additional maintenance cost

5. ECONOMICAL PROPRIETY EVALUATION OF HYBRID TRANSFER SYSTEM

Table 4 shows the comparison of economical propriety between conventional and hybrid transfer system and the conditions of computation are summarized in the follows. First of all, the oil consumption amount per hour of conventional transfer system according to reporter of D company is about 11.1 liters. Second, energy saving rate is about 47% according to report of V, S and K company. And also to compute the turn-over time of investment of hybrid transfer system the cost to install the component of hybrid system on the conventional system and not to manufacture the new vehicle is computed. The cost to

remodel conventional system into hybrid system with battery system is computed as about 136 thousand dollars. And also the annual amount of oil consumption is computed in operation of 12 hours per day, 300 days per year and oil price 1.36 dollars per liter. Table 4.1 shows that the turn-over time of hybrid transfer system to use battery as storage equipment is about 5.3 years.

Table 4. Economical propriety in comparison of conventional system and hybrid system

Equipment	Oil consumption per hour (liter/hr)	Oil consumption per year (liter/yr)	Oil cost per year (million/unit)	Annual saving cost (million/unit)	Energy saving rate (approximation)	Turn-over time (year)
Conventional system	11.1	39,960	59.94	-	-	-
Hybrid Transfer System	5.9	21,179	31.77	28.17	47%	5.3

Table 5 shows that the energy saving methods of conventional system and hybrid system to be combined with battery are analyzed and compared. The realization and business of energy saving method to use battery as storage equipment is very high. And also in the effective of cost saving the battery is low in comparison with other energy storage because the blazing phenomena of battery degrades the performance of battery to be replaced with new one in period of 4-5 years. In the application of technology the battery has very high realization. In consideration of starting investment and turn-over time in field of storage technologies the batter type of hybrid system has the best propriety of energy saving.

Table 5. Analysis and comparison in energy saving methods

Item/Characteristics	Saving method /Easiness	Cost saving /Effective	Technology /Application	Application	
				Period	Equipment
Battery	High	Middle	High	Middle /Short	Transfer Crane Yard Tractor

6. CONCLUSION

To improve the energy efficiency of port cargo handling equipment the connection with the installed conventional equipments is carefully investigated. To improve the productivity of container terminal and the environmental condition of consumption energy the advanced cargo handling equipment is positively introduced.

Most of port cargo handling equipments in container terminal is very high price and the replacement of them in the middle of life time is very difficult because of the long life time of equipments and to reduce the waste of investment cost the careful and detailed examination is required.

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