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Optimization of Ice Slurry Generator with Scraper Blade Coated by Teflon For Fishery Industry

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Abstract. It is very important to keep the freshness up of fish product because fish will quickly decay after it is caught. Ice slurry is one of the best cooling mediums generated through refrigeration system utilizing sea water as its base material. Ice slurry can keep the freshness and also increase the lifetime of the fish product, because ice slurry suppresses bacterial decomposition rate. In this study, the production rate of the ice slurry generator coated by teflon was investigated. The rotational speed of the pump and scrapper were varied at 1064 – 1242 RPM and 335 – 423 RPM. The sea water was also varied at 10 ppt – 27 ppt. The optimum production rate of ice slurry and salinity variation has been obtained. Increasing the rotational speed of pump and scrapper with higher water salinity of seawater will decrease production rate of ice slurry. It was found that the best production rate of slurry ice generator in this research was 0.284 Ton/12 Hours produced by 10 ppt salinity of seawater with 335 RPM rotation on the scraper and 1064 RPM on the pump. Ice slurry could be a good option for long shipping time by keeping the fish quality.

INTRODUCTION

In order to preserve the fish in large quantities, the flake-ice has been widely used by fishermen. That chilling method has traditionally made it possible to slow down both decaying process of fish. In fact, Indonesian fishermen also still use the conventional cooling system, such as block and flake ice. Providing quality to consumer is important objective in fish industry. However, flake ice can damage the body of fish because sharp edge of its particles. Therefore, an alternative cooling method are required to keep freshness up of fish product. One of the cooling methods is Refrigerated Seawater (RSW). Seawater contains salt which can naturally be preservative. RSW can be improved by using ice generator to generate ice slurry.

It was proved that ice slurry has the potential impact to maintain fish temperatures with better yields than ice blocks [1]. Davies investigated the effect of ice slurry and ice block [2]. Ice slurry has good cooling process instead of flake ice. Ice slurry has a high energy storage density due to the latent heat of its ice crystalline fusion and also has a rapid cooling rate due to the large surface area heat transfer created by many particles [3]. Summarily, ice slurry has two main advantages, such as its cooling rate is faster because of its higher heat exchange capacity, compared with flake ice and reduced physical damage to aquatic food products due to the ellipsoidal particles. This advantage is particularly relevant in the case of soft tissue type products which are characteristic of various water food products [4]. In ice slurry cooling system, the fish will be completely covered by a slurry that leaves no airbag between the product. As a result, cooling process of fish is faster and bacterial growth is slower [5].

The development of ice slurry generator technology has made ice slurry a cooling medium that needs to be considered. There are many types of ice slurry generator depending on its usage. Some previous studies discussed the design of ice slurry generator i.e. scraper type, orbital rod, helical screw, etc. In this study, there is improvement of scraper type with coated teflon in symmetric blade.

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This study was conducted to build new prototype ice slurry generator (scraper type with coated teflon in symmetric blade) with high production rate. An original feature of this study is the ice slurry generator will be optimized by determining the effect of salinity, pump and scraper speed on ice slurry production rate.

EXPERIMENTAL SET UP

Experimental Apparatus

Experimental setup designed and built at the laboratory of refrigeration, Universitas Indonesia consists of a vapor-compression system, a data acquisition system, an ice slurry generator, an ice storage tank, figure. The main components of the vapor-compression system are the hermetic compressor, the condenser, the needle valve and the evaporator/ ice generator as shown as in figure 1.

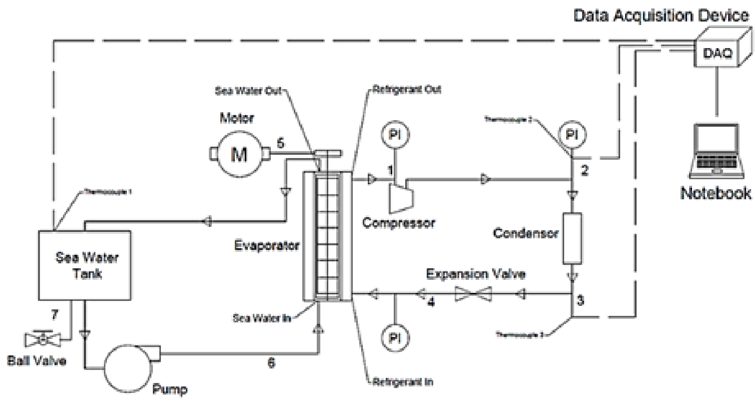

FIGURE 1. Schematic diagram of the experimental apparatus

In this study, R290 or propane is used as refrigerant. Refrigerant with a certain molecular structure has been known as a substance that can harm the environment. Two important attributes worth noting in the selection of refrigerant are Ozone Depleting Potential (ODP) and Global Warming Potential (GWP) [6]. propane has the advantage of working on a high-pressure ratio with lower temperature output results, which means that the evaporating temperature level will be lower which in the cooling system will be very good [7].

The pressure measurements are adjusted at a 2-3 bar by using the needle valve. The measuring apparatus consisted of K-type thermocouples and pressure gauges that well insulated. Thermocouples had been calibrated in the thermostatic bath with an accuracy of 0.1 ^{0}C. Refrigerant temperature and the pressure were measured by four thermocouples and four pressure gauges that installed separately in four components of the vapor-compression cycle. One thermocouple was inserted in an ice storage tank. The list of measuring apparatus is summarized in table 1.

TABLE 1. List of measuring apparatus

Apparatus	Type	Range	Accuracy
Temperature sensors	K-type thermocouples	$-50 - 500$℃	$\pm$ 0,1 ℃
Pressure gauge	Wika EN 837-1	$0 - 16\ bar$	$\pm$ 0,1 bar
Salinity meter	Digital Microscope	0 – 90 ppt	-
Power meter	Mini Ammeter – D02A	$0 - 3000\ W$	$\pm$ 1%
Rotation sensor	Tachometer CEM AT-8	$0 - 3000$ RPM	$\pm$ 0,05 RPM
Data Acquisition Unit	NI cDAQ - 9174	-	-

Experimental Procedures

The results data will be collected after the preparation of ice slurry system procedures. The test was carried out at ambient temperature 27°C and using 10L of sea water. Temperature, power, and pressure were recorded every 3 minutes. Pumps and motors run continuously until the scraper undergoes ice agglomeration or the entire seawater becomes ice slurry. variation of pump rotation was in range 1064, 1183, 1242 RPM, respectively. Motor variation was in range 335, 401, 423 RPM and salinity variation 10, 15, 20, 27 ppt (part per thousand).

RESULTS AND DISCUSSION

In this study, ice slurry with parameters variation of the pump and motor rotation with the subsequent variation of pump 1064, 1183, 1242 RPM, motor variation 335, 401, 423 RPM and salinity variation 10, 15, 20, 27 ppt were obtained, as results as below:

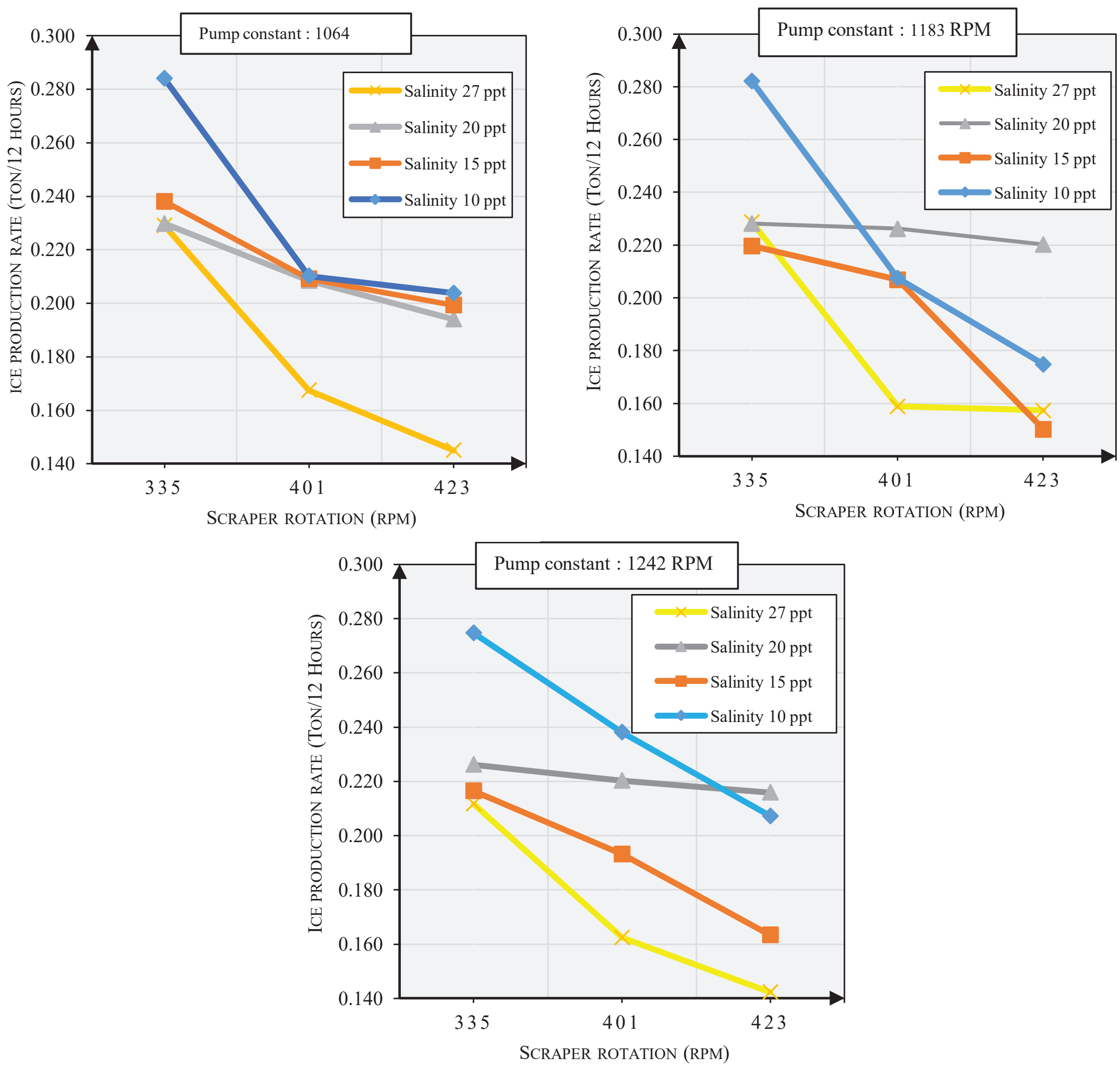

FIGURE 2. Graphs of the effect scraper rotation against production rate with constant pump rotation of 1064,1183 and 1242 RPM

Referring to the results of the data retrieve shown by the graph in figure 3, it can be deduced that the higher rotation of the scraper with constant pump rotation causes the production rate of ice slurry longer with increasing power being used. In this study, scraper did not stop unexpectedly or freeze up due to the addition of clearance between the tube wall with the scraper on scraper design for ice slurry generator used in this research.

The results of the research data that shown in table 3 indicate that the higher the pump rotation the ice slurry production rate will be lower in constant scraper rotation as shown in the graph in figure 3.7 until 3.10. The cause of the lower production rate when the pump rotation is increased is because the faster the rotation of the pump the circulation of the seawater passing through the inner wall of the cooled evaporator tubes is also faster. This causes the slower absorption of seawater heat by the inner wall of the evaporator that flowed the refrigerant. The entire experiment succeeded in producing a full slurry with the highest production rate achieved by the lowest scraper rotation and the lowest rotation. This trend has similar results based on Rayhan investigation [9].

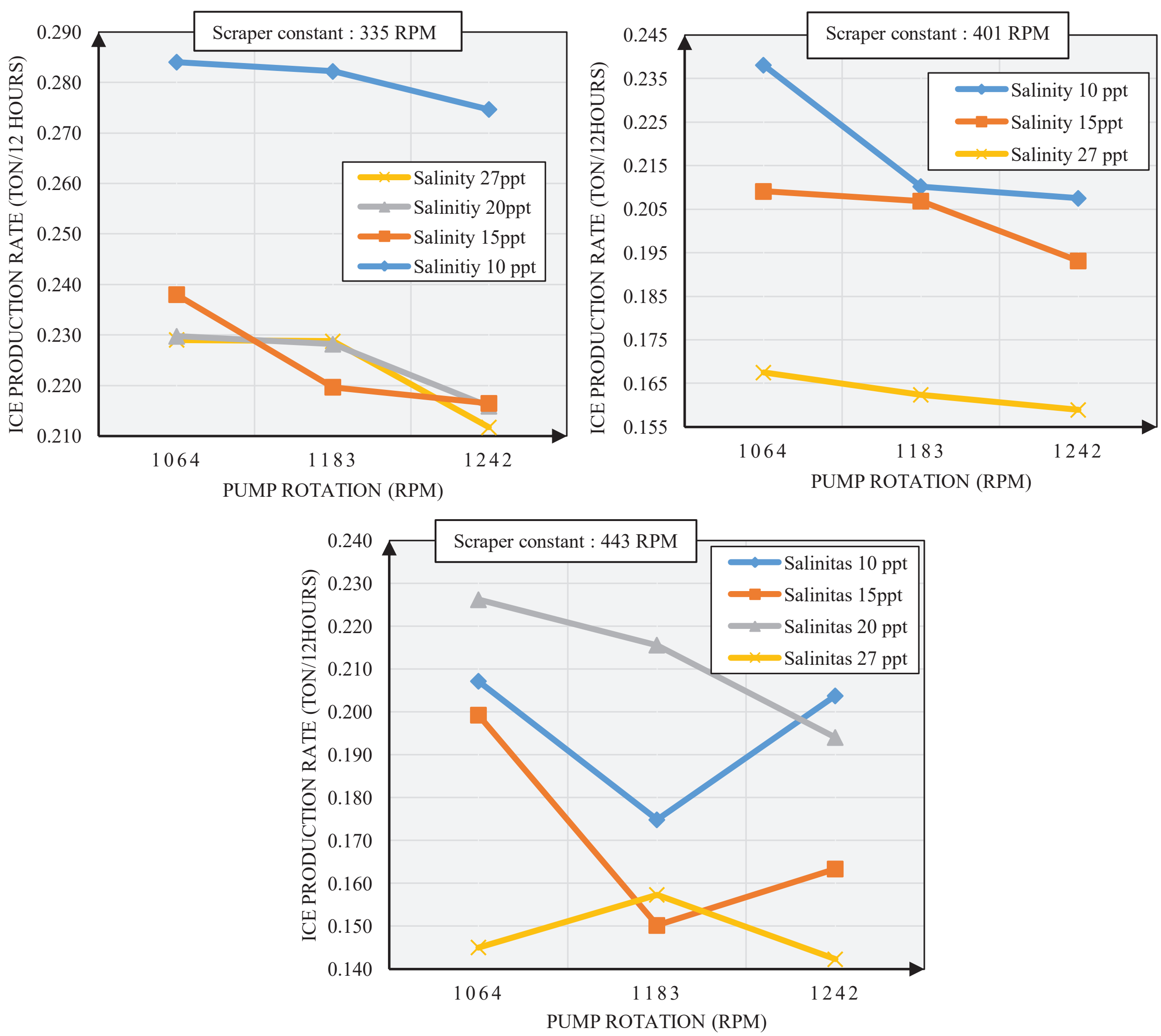

FIGURE 3 Graph of Effect of Pump Rotation on Production Rate with a Constant Scraper Rotation of 335, 401 and 443 RPM

From figure 3, the results of the data show as increasing the RPM of scraper, the longer time is needed to generate ice. Despite needed long time to generate, scraper can maintain performance in preventing ice agglomeration. It is based on a high RPM of scraper, the heat transfer process more equitable on the evaporator and with a big moment on the scraper can continue to grind the ice layer that grows on the inner walls of the evaporator. Figure 4 shows the power requirement of system will increase as salinity increase.

The effect of salinity on the ice slurry production rate is the higher salinity of seawater then the ice slurry production rate will be low. Referring to these results, it can be concluded that sea water with higher salinity will require greater energy to form and produce ice slurry. From overall data, it found that optimum performance of ice slurry generator in 335 RPM of scraper, 1064 RPM of pump and 10 ppt of saline content where it resulted 0.28 (ton/12hour) ice slurry.

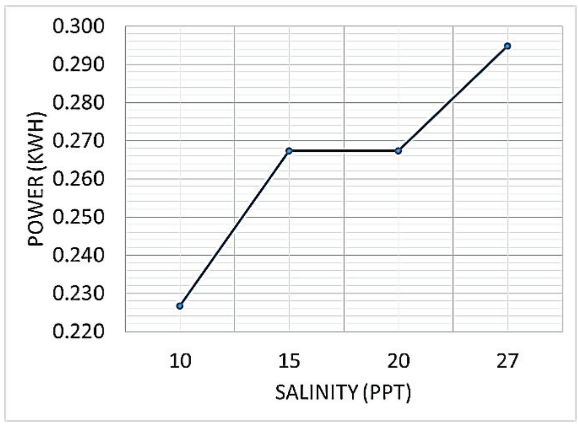

FIGURE 4. Graph of Power VS Salinity

Calculation of Ice Slurry Needs to Cool the fish

In general, the total amount of ice required to cool fresh fish from the initial temperature to the final temperature (ideal 0 ^{0}C) using ice slurry can be calculated by the following formula [8].

$$M_i = \frac{M_f \times 0.8 \times T_{fi}}{80} = \frac{M_f \times T_{fi}}{100} \quad (1)$$

Specific heat for fish that is not too big where its specific heat value is 0.8 (kcal / kg ^{0}C) and for large fish is 0.75 (kcal / kg ^{0}C). Specific heat to be used in this study is 0.8 (kcal/kg ^{0}C) [8]. Fish cooling is done with the initial temperature of the fish catch is 40 ^{0}C. Based on the above calculation, the amount of ice slurry mass required to cool the fish catching 600 GT tuna from 40^{0}C to 0 ^{0}C is 16960 Kg. the total ice slurry mass required is shown as in table 6:

TABLE 2. Total Mass Ice Slurry Required

Consumption Loss/Factor	Ice Requirements (kg)
To cool down 42.4 ton of fish from 40 °C to 0 °C	16960
To compensate for bad ice-handling practices	848 (estimated as 5% of total ice used)
To compensate for water in equilibrium in ice	2374 (estimated as 14% of total ice used)
Total consumption	20182 Kg

The total mass of ice slurry required on a 600 GT tuna boat is 20182 Kg/day assuming the fish hold on the vessel is well insulated.

CONCLUSIONS

Optimization of ice slurry generator with scraper blade coated by teflon had been investigated. Based on the results of research and data processing, it can be concluded that increasing rotation of scraper against constant pump rotation will result lower production rates and then increasing the rotation of the pump against constant scraper rotation leads lower production rates. The effect of salinity on the production rate was investigated. It was found that the greater salinity of seawater, the slower ice slurry production and the greater power consumption. The best production rate of this ice slurry generator was 0.284 Ton/12 Hours produced by 10 ppt salinity of seawater with 335 RPM rotation on the scraper and 1064 RPM on the pump. On the application, its recommended to use low salinity of seawater in order to get optimum production rate.

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