RESEARCH ARTICLE | JANUARY 25 2019

Characteristics of seawater ice slurry generation with salinity variation FREE

R. Sidqy; A. S. Pamitran; M. P. Patria; Fajri A. Rayhan

AIP Conf. Proc. 2062, 020024 (2019)
https://doi.org/10.1063/1.5086571

Characteristics of Seawater Ice Slurry Generation with Salinity Variation

R. Sidqy[1] , A.S. Pamitran[1,a)] , M.P. Patria[2] and Fajri A. Rayhan[1]

[1]*Department of Mechanical Engineering, Universitas Indonesia, Kampus UI Depok 16424 Indonesia*
[2]*Department of Biology, Universitas Indonesia, Kampus UI Depok 16424 Indonesia*

[a)] Corresponding author : pamitran@eng.ui.ac.id

Abstract. Seawater ice slurry can be produced with cooling process in evaporator by utilizing salt content in the seawater as freezing point depressing additive. Ice slurry technology can play an important role in the process of storing fish in the open sea because the quality of the fish that cooled with ice slurry is much better than ice cubes. Evaporator with polytetrafluoroethylene (PTFE) coating blade and a certain clearance distance, around five milimeters, can reduce electric power and time consumption in ice slurry generation. PTFE, more commonly known as Teflon, is suitable for a wide range of applications in industries as diverse as aerospace, the food and drink industry, pharmaceuticals and telecoms. The present study used variation of magnetic chemical pump RPM, scraper RPM, and salinity of seawater. The results show that the higher salinity results in the lower temperature of ice slurry generation and decreases ice slurry generation. The experimental condition with higher scraper RPM result in slower ice slurry generation. There is an optimum pump RPM to decreasing the temperature faster. Seawater with lower salinity was changed into ice slurry faster, increased the production of ice slurry, and consumed less electric power than that of higher salinity.

INTRODUCTION

Opportunity of development of fishery business in Indonesia have very high prospect. The economic potential of marine and fishery resources that can be utilized to boost economic growth is estimated at USD 82 billion per year. The potential of the Indonesian sea is huge. National fish stocks in 2015 increased from 6.04 tons to 7.3 tons compared to 2014 [1]. However, the utilization of fishery products in Indonesia has not been maximally overall. This is caused by various factors, among others: the ships used to catch the fish is still traditional, the cost of fishing boat repairs, the low fishermen's welfare, and the lack of utilization of latest technology in fishing and fish management. One technology developed in preserving fish is ice slurry as a cooling media for fish [2]. Ice slurry can cool the fish for 6 days [3]. It states that ice slurry can cool fish better than crushed ice.

Currently, there have been some researches on developing generators to produce ice slurry. The general difference that distinguishes the developed ice slurry generator is the type of scraper, including rod orbital type, screw, blade, etc. Kolesnikov et al. [4] analyses the model of formation of ice-slurry in scraped-surface generators, based on experimental studies of heat transfer processes in the ice slurry generator. In order to overcome the ice blockage, Wang et al. [5] study an ice slurry generator with double supercooled heat exchangers for continuous ice generation using supercooled water. Fumoto et al. [6] generated ice slurry for use in the medical field by the method of pressure shift freezing, which is based on the freezing-point depression of an aqueous solution under high-pressure conditions.

In the present study the generator use the type of scraper with two-symmetric blade. The experiment was performed with a two-symmetrical blade scraper installed in evaporator. The scraper is designed with PTFE coating on the blade hence it is expected to reduce friction on the scraper blade. The evaporator also has an adjustable blade size so it has a certain clearance value. The aim of the present study is to investigate the characteristics and

The 10th International Meeting of Advances in Thermofluids (IMAT 2018)
AIP Conf. Proc. 2062, 020024-1–020024-9; https://doi.org/10.1063/1.5086571
Published by AIP Publishing. 978-0-7354-1790-8/$30.00

performance of the developed ice slurry generator with some experimental conditions. The developed ice slurry generator is expected to produce ice slurry with good cooling quality and with shorter manufacturing time. The study focuses on the performance of ice slurry generators, the effect of seawater flowrate, and the effect of seawater salinity on the ice slurry generation.

METHODOLOGY

Stages of the research are conducted to find the effect of some variables on the performance of the developed ice slurry generator. Each test has run with ten liters of seawater. In the present study, the generation of ice slurry requires two cycles running simultaneously viz. refrigeration cycle and the seawater circulation cycle as shown in Fig. 1. Temperature of ice slurry and refrigerant was measured by thermocouple and recorded by data acquisition device. Pressure of refrigerant is measured at some locations as shown in Fig. 1.

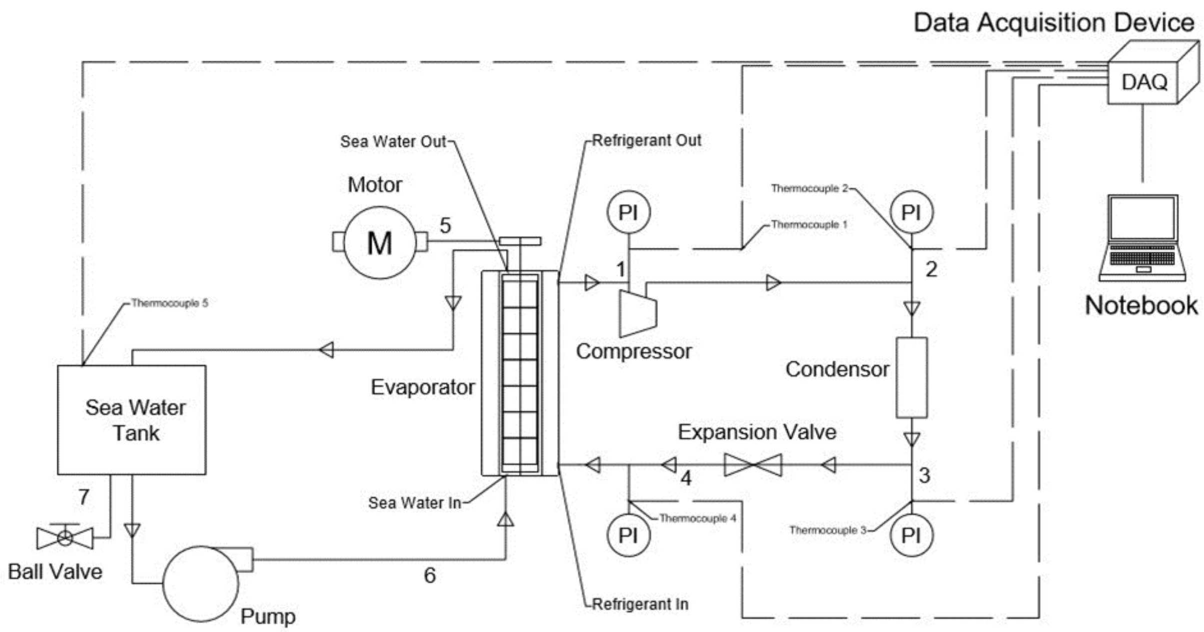

FIGURE 1. Schematic of Ice Slurry Generator System

An evaporator as a main part of ice slurry generator was developed in this study as shown in Fig. 2. The evaporator used a working principle adapted from a concentric tube, or tube in tube heat exchanger. The refrigerant is fed from the bottom side to the larger diameter tube absorbing some heat from seawater through conductive heat transfer hence the seawater change into ice slurry. The evaporator has a clearance of 5 mm between the PTFE coated blade and the inner surface of the smaller tube in order to reduce the friction.

EXPERIMENTAL RESULTS

Effect of Scraper RPM on Ice Slurry Generation

A centrifugal pump is used to circulate the seawater through the evaporator. The pump works with constant RPM in order to observe the effect of scraper RPM on the ice slurry generation. Figure 3 shows that the higher scraper RPM result in longer time of ice slurry generation. High scraper RPM make the heat transfer is more evenly distributed in the evaporator and it scrapes the ice growing on the evaporator surface. Higher scraper RPM needs higher electric power consumption. The result shows that the largest electric power is 0.35 kWh at scraper RPM of

423 and pump RPM of 1242. The fastest ice slurry generation is at condition of scraper RPM of 1005 and pump RPM of 357, viz. it takes 22 minutes start from the temperature of sea water of 15°C, and then the scraper can continue work for 23 minutes until the entire sea water becomes ice slurry.

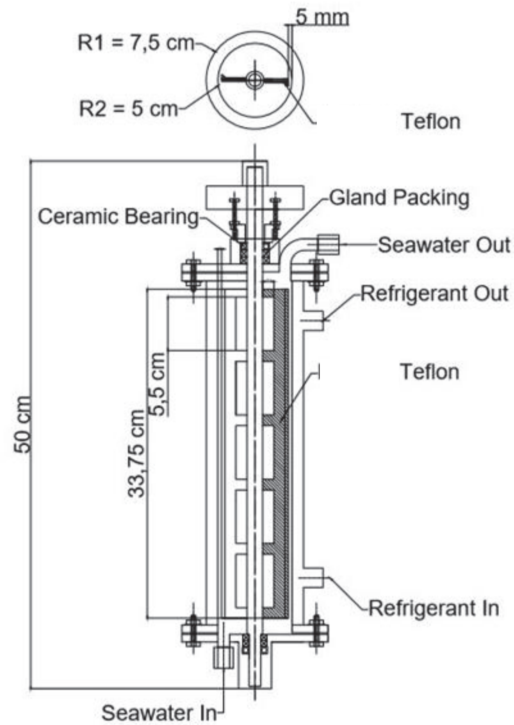

FIGURE 2. Schematic of evaporator

Effect of Pump RPM on Ice Slurry Generation

There are several types of pumps that can be used to circulate ice slurry, including centrifugal, lobe, side-channel, and screw. The pump used must be a pump that can minimize heat transfer to ice slurry, this requirement cannot be met by a water pump usually because this pump produces a large heat and has the potential to destroy ice crystals through the pump vane. The smaller the heat transfer, the less quantity of ice will melt so that the production of ice slurry will be more efficient. Taking into account the availability of goods and prices, centrifugal type pumps are selected in this study, especially chemical magnetic pump.

The function of a scraper on an ice slurry generator system is to stir up the seawater in the evaporator and to scrap the ice growth on the inner wall surface of the evaporator. In order to find the effect of pump RPM, the pump works in some test conditions with constant scraper RPM. Figure 4 shows the higher the pump RPM, the faster the sea water temperature decreases. This is due to the faster RPM of the pump the faster the sea water circulation in the evaporator, thus causing faster heat absorption.

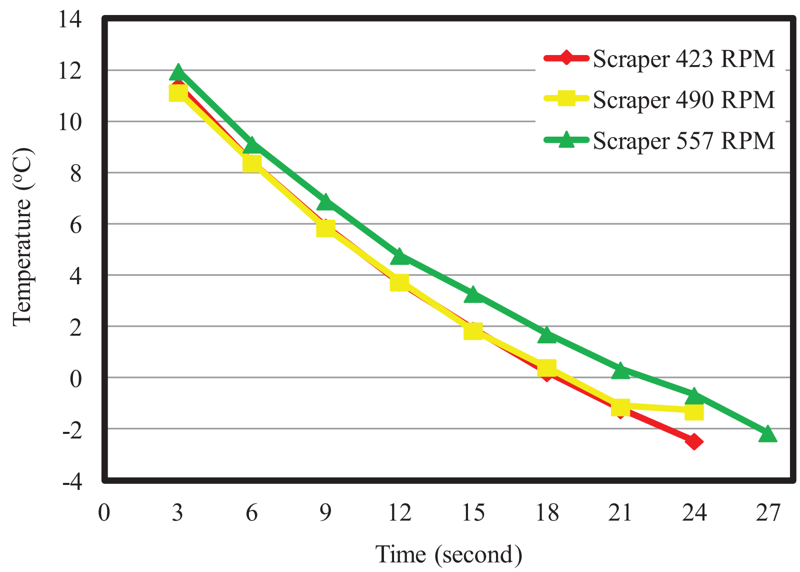

FIGURE 3. Effect of scraper RPM on decreasing of seawater temperature with constant pump RPM of 1005 and salinity of 27 ppt

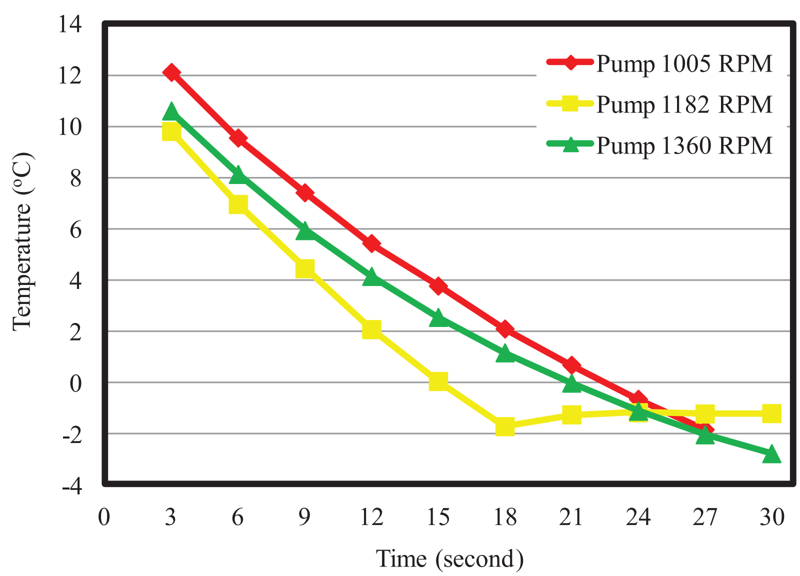

FIGURE 4. Effect of pump RPM on decreasing of seawater temperature with constant scraper RPM of 357 and salinity of 27 ppt

Effect of Seawater Salinity on Ice Slurry Generator Performance

The experimental result shows that the higher salinity of the seawater will take a longer time to generate ice slurry. The same results have shown by Pamitran et al. [7] that higher salinity needs longer time and lower temperature for ice fraction formation. Time operation affects the electric power needed to generate ice slurry. Therefore, this study used the three most optimal combinations of pump rotation and scraper rotation to observe the effect of seawater salinity on the ice slurry generation.

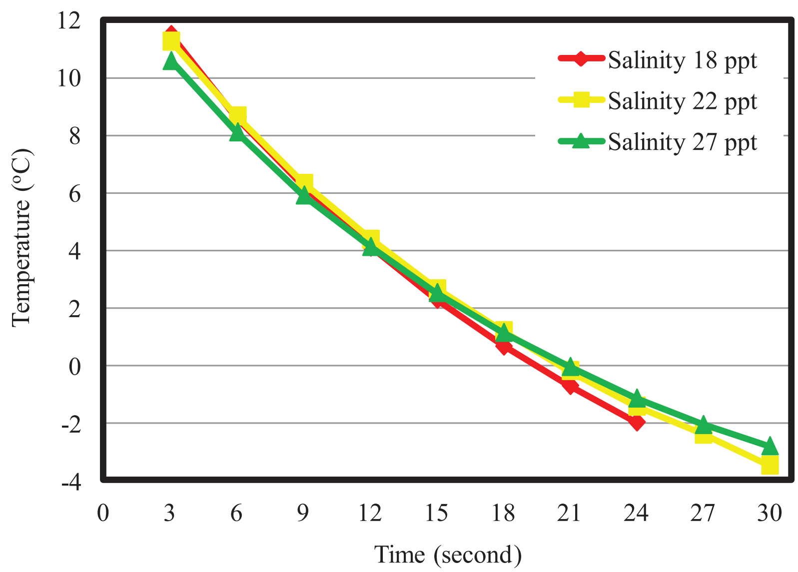

FIGURE 5. Decreasing temperature with salinity variation, pump RPM of 1360, and scraper RPM of 357

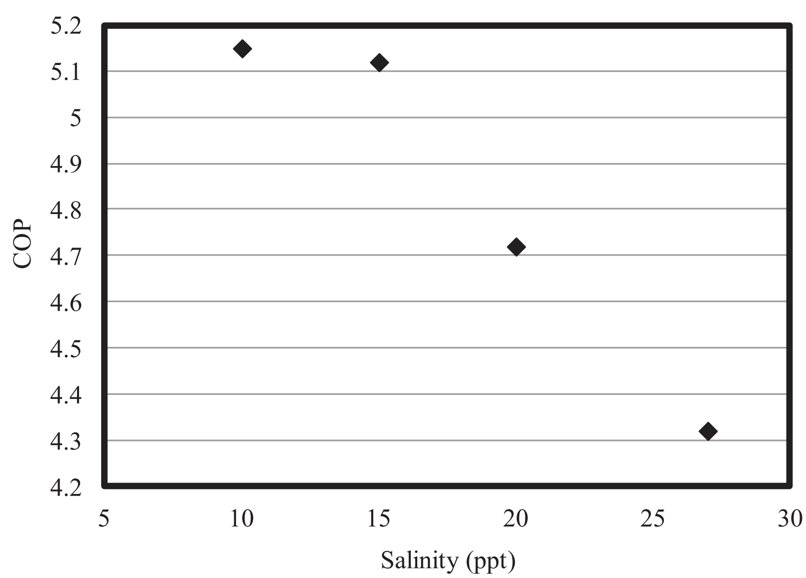

FIGURE 6. Effect of salinity on COP with pump RPM of 1242 and scraper RPM of 423.5

Fig. 5 shows the effect of salinity on decreasing seawater temperature. The higher salinity results the seawater cooled down slower than the lower salinity. Seawater is a collagen solution hence the greater the dissolved fraction of the solvent there will be a decrease in vapor pressure, increase in boiling point, and decrease in freezing point. Therefore, seawater can reach temperatures well below the water freezing point of 0°C.

Fig. 6 shows that COP increases with lower salinity. It means that the refrigeration process with lower salinity seawater is more efficient. The results also can be explained by Fig. 5 that the decreasing temperature of the lower salinity seawater is faster than that of the higher salinity. As a consequence of the results in Figs. 5 and 6, the process with lower salinity seawater showed lower electric power consumption, as shown in Fig. 7. The same results have also shown by Pamitran et al. [7] that higher salinity takes more energy for ice slurry formation.

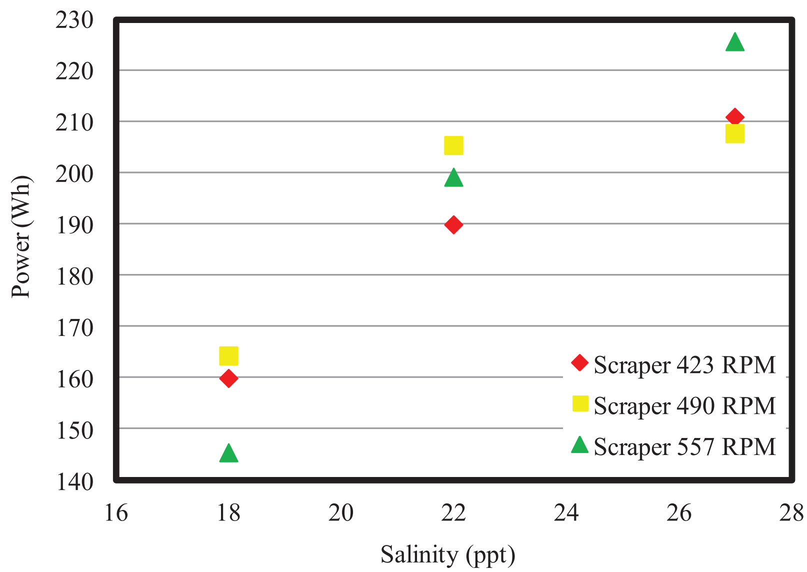

Figure 7. Effect of salinity on electric power consumption with some test conditions

Effect of Scraper RPM on Ice Slurry Production Rate

Seawater circulation is done using a magnetic pump that drains the seawater through the evaporator to the ice slurry receiver. In order to observe the effect of scraper RPM on ice slurry production rate, this test was conducted with variation of scraper rotation and constant pump rotation. The results are shown in Figs. 8 and 9.

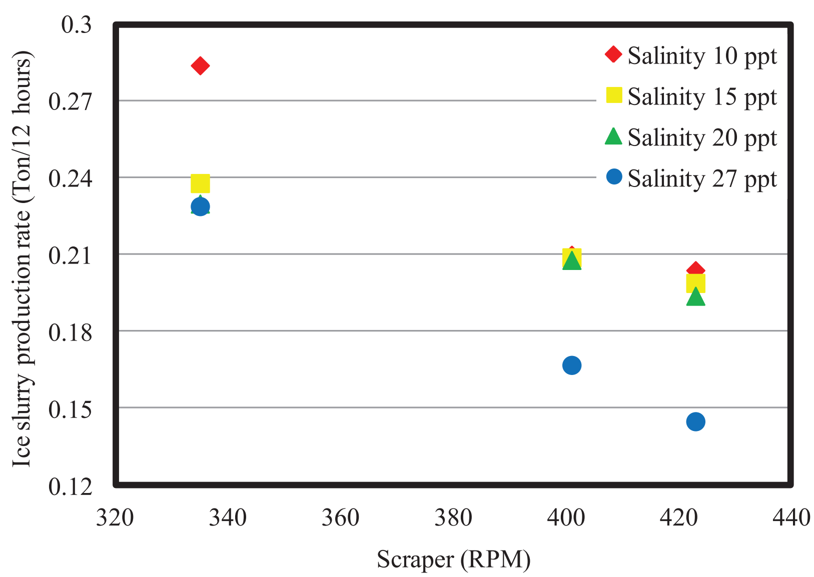

FIGURE 8. The effect of scraper RPM on ice slurry production with constant pump RPM of 1064

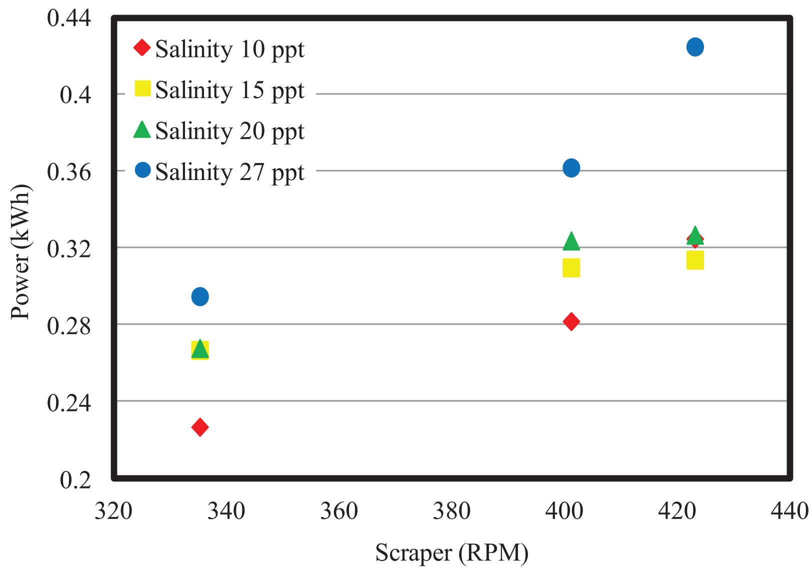

FIGURE 9. Scraper RPM versus power consumption (kWh) with constant pump RPM of 1064

Fig. 8 shows that the higher scraper RPM results in lower production rate of ice slurry. Mechanical friction increases with higher scraper RPM hence the ice slurry production decreases. It means that the process with higher scraper RPM is more inefficient. Therefore, the higher scraper RPM results in higher electric power consumption as shown in Fig. 9.

Effect of Pump RPM on Ice Slurry Production Rate

The effect of pump RPM on ice slurry production rate is shown in Fig. 10. It shows that the higher pump RPM results in lower production rate of ice slurry. The results can be explained with the same explanation as the effect of scraper RPM on ice slurry production rate. Mechanical friction and pressure drop increases with higher pump RPM hence the ice slurry production decreases. Moreover, the higher flowrate makes the contact effectiveness of seawater and evaporator surface become low. It causes a slower absorption of seawater heat by the refrigerant flowed in the evaporator. It means that the process with higher pump RPM is more inefficient. Therefore the higher pump RPM results in higher electric power consumption as shown in Fig. 11.

The entire experiment succeeded in producing full slurry with the highest ice slurry production rate achieved by the lowest scraper RPM and the lowest pump RPM. It is founded that the optimum process of the developed ice slurry generator is in scraper RPM of 335 and pump RPM of 1064.

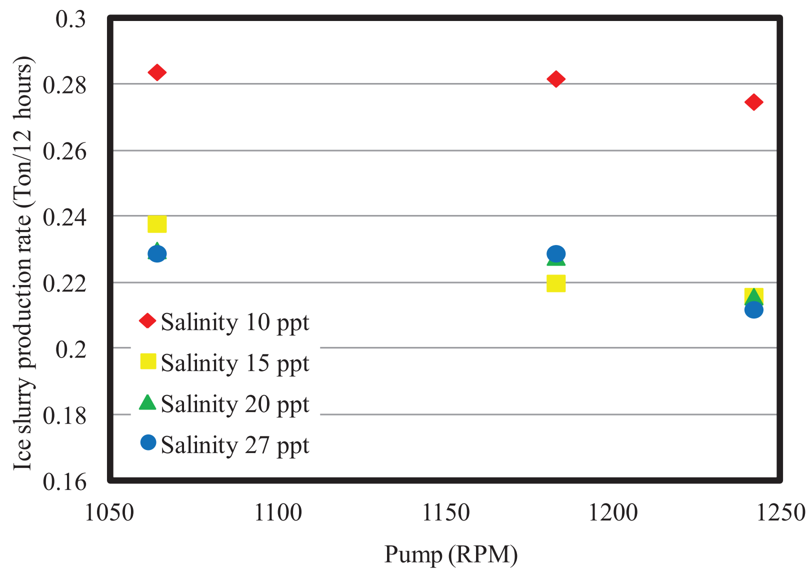

FIGURE 10. Effect of pump RPM on ice slurry production with constant scraper RPM of 335

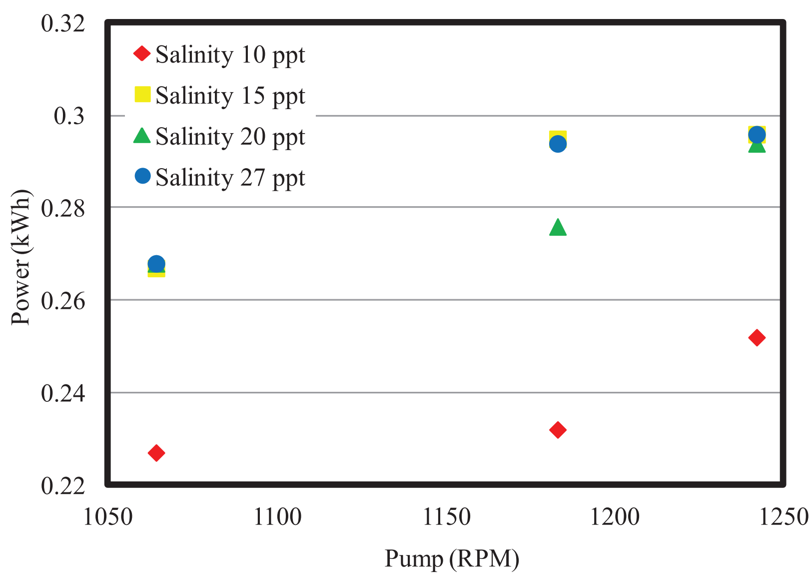

FIGURE 11. Pump RPM versus power consumption (kWh) with constant scraper RPM of 335

CONCLUSION

A study of ice slurry with developed evaporator was conducted in order to observe the ice slurry generator system performance with some experimental conditions of pump RPM, scraper RPM, and seawater salinity. The developed ice slurry generator has an optimum operation with pump and scraper RPMs of 1005 and 357, respectively. The experimental condition with higher scraper RPM result in slower ice slurry generation. The higher the pump RPM the faster the sea water temperature decreases. Seawater with lower salinity was changed into ice slurry faster than that of higher salinity. Power consumption is greater with higher salinity conditions. The higher salinity showed lower COP. Ice slurry production rate increases with lower scraper and pump RPMs.

ACKNOWLEDGEMENT

This work is supported by Hibah PITTA 2018 funded by DRPM Universitas Indonesia No.5000/UN2.R3.1/HKP.05.00/2018

REFERENCES

1. Kementerian Kelautan dan Perikanan RI, 2015. Laporan Kinerja Satu Tahun Kementrian Kelautan dan Perikanan.
2. A.S Pamitran, H.D. Ardiansyah, M. Novviali, 2013, A review paper of sea-water ice slurry generator and its application on Indonesian traditional fishing, Applied Mechanics and Materials, 388, pp.128-132
3. Kitamura, K. et.al., 2015, Introduction of slurry production apparatus capable of making ice from 1 wt% salinity, J Fishing Boat and System Engineering Association of Japan, 122, pp.2
4. Kolesnikov, A., Buzukashvili, I., Krotov, A., Klyachko, L., Umanskiy, V., Makarov, B., 2015, A study of ice-slurry production process in scraped-surface type generator, 24^{th} IIR International Congress of Refrigeration, ICR 2015, Yokohama, Japan, pp. 2075-2082
5. Wang, H.Email Author, Feng, R., Duan, H., Chen, A., 2016, Investigation into the ice generator with double supercooled heat exchangers, Applied Thermal Engineering, 98, pp. 380-386
6. Fumoto, K., Kawanami, T., Inamura, T, 2015, Study on generator for ice slurry using the pressure shift feezing method, 24^{th} IIR International Congress of Refrigeration, ICR 2015, Yokohama, Japan, pp. 2083-2090
7. Pamitran, A.S., Ardiansyah, H.D., Novviali, M., 2013, Characteristics of Sea-water Ice Slurry for Cooling of Fish, Applied Mechanics and Materials 388, pp. 123-127