Estimation of power applied for collapsible pot hauler on the coast of Karawang, Indonesia

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Abstract. Blue swimming crabs (*Portunus pelagicus*) are caught with collapsible pots using the longline fishing operating system for pots stocked up to 1200 – 2000 units per fishing operation. The problem for small crab fishers on the coast of Karawang Regency is that the main line hauler equipment currently used does not consider the amount of fishing gear load borne, and it uses a power source which less environmentally friendly. The hydrodynamic force of the sequence of collapsible pot gear is to be used as a reference for the actual power source of the hauler. The most significant hydrodynamic force in the sequence of collapsible crab pots with a pulling speed of three m/s is 443.42 N, and 531.47 N. The largest hydrodynamic force without considering the rigging on the sequence of collapsible pots if pulled at three m/s speed are 412.65 N and 509.44 N. Furthermore, minimum power of 1568.16 watts is required if it is pulled at a speed of 3 m/s; the power is centered on the line spool plate of the line hauler.

Key Words: blue swimming crab, hydrodynamic force, power, torque.

Introduction. Blue swimming crab (*Portunus pelagicus*) is the main commodity that can improve fishermen's standard of living on the Karawang Regency's coast (Istrianto et al 2021). The crabs are caught with collapsible pots with a longline operating system for a number of pots stocked up to 1200 – 2000 units per fishing operation; the longline system is very common in Indonesia (Arios et al 2013; Muawanah et al 2017; Munir & Zainuddin 2019; Ummaiyah et al 2016; Zulkarnain et al 2020). The collapsible pots are left for 4-6 hours at the bottom of the water. As a marker of the installation location, a sign buoy is used (Kunsook & Dumrongrojwatthana 2017; Ummaiyah et al 2016).

The operation of the crab pot fishing gear with the longline system requires auxiliary equipment to simplify and shorten the hauling of the crab pot onto the fishing boat. The fishermen are already using auxiliary equipment but still have some problems. The issue that fishermen on the coast of Karawang Regency have is that the present auxiliary equipment for crab pots (line haulers) does not consider the amount of load endured and uses a diesel engine, which is a less environmentally friendly power source, generates air pollutants and noise. Fishermen generally make auxiliary equipment based on habitual and functional factors only. The hydrodynamic aspects of the collapsible pots are a significant part of analyzing the force values of fishing gear when operated in the water (Budiman et al 2004; Huang et al 2006; Iskandar et al 2009; Kim et al 2012; Reid 1977; Safingi et al 2020; Wan et al 2020; Wibowo et al 2018). The dimensions of the sequence of collapsible pots are the main factors that affect the hydrodynamic force of the fishing gear. The value of the hydrodynamic force of the sequence of collapsible pots is needed to be used as a reference for the actual power source of the auxiliary equipment.

It is necessary to comprehend the calculation of the hydrodynamic force on the sequence of collapsible pots to get the value of the theoretical hydrodynamic force. This study aims to calculate the estimated load on the existing collapsible pot fishing gear on the coast of Karawang Regency. The estimated value of the attractiveness of the collapsible pots for crabs will then be used as a reference or consideration in improving current line haulers.

Material and Method

Description of the study sites. This study takes place on the north coast of Karawang, West Java, Indonesia, from July to August 2022. The observation was done for two day-long fishing operations and two week-long fishing operations.

Data processing. The dimensions of the fishing gear are the main factors that determine the value of the resistance (hydrodynamic force) of the sequence of collapsible pots. The method used to find the dimensions of the fishing gear is to measure all parts of the fishing gear, including the pot frame, nets, crab catch, and lines, for the framework and netting of the collapsible pot. The measurement is taken by the length, width, and height of the collapsible pot frames and measuring diameter (Dt) and mesh size (ms) of the net, as shown in Figure 1.

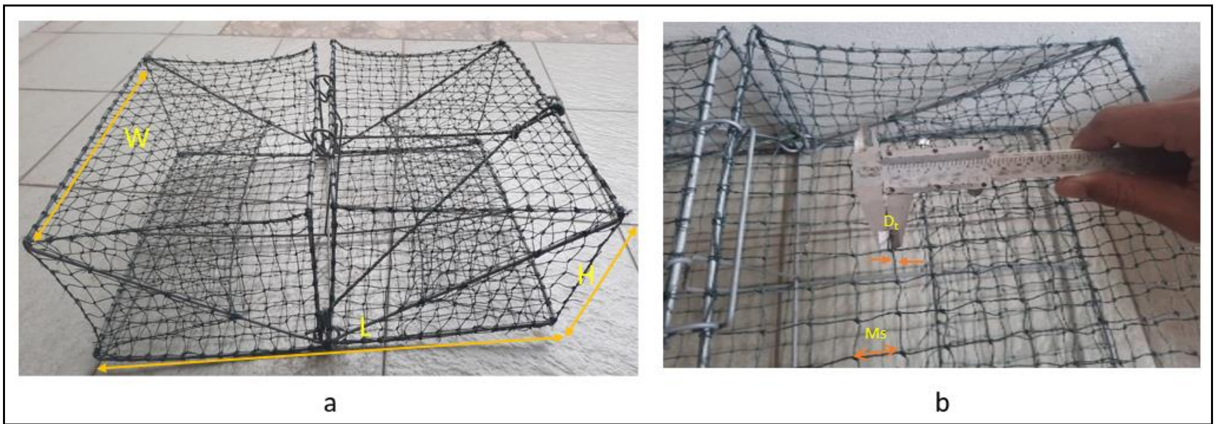

Figure 1. Measuring the pot frame. (a) Measurement of length (L), width (W) and height (H) of the pot frame. (b) Measurement of diameter (Dt) and length of mesh size (ms) of the net.

The operation of a collapsible pot using the long line system illustrates that not all parts of the fishing gear are in direct friction with seawater during the hauling process. Estimating the number of parts of the fishing gear that rub against the water can be simulated using three-dimensional software (Sutton et al 2010; Uyar & Erdoğdu 2009). The simulation of the number of pots and the length of the lines is the most crucial part of calculating the total hydrodynamic force that occurs in the sequence of collapsible pot gear. Simulations were carried out on 3D image software by describing the current state of the fishing operation with the longline system using the appropriate parameters, namely the angle of incidence of water flow against the line and the maximum sea depth of the fishing operation. Moreover, the number of pots and the line length generated by the simulation can represent the real situation (Arfan 2017; Lin et al 2017; Schroeder & Lee 2013).

Wet surface area is the most important part in calculating the hydrodynamic force on a collapsible pot fishing gear sequence because the object's surface is the part that directly rubs against the seawater. The catch of crab is also a component that gets hydrodynamic force while hauling the fishing gear. Because the body shape of the crab is not regulated, the crab's surface area in the collapsible pot can be estimated using simulations with three-dimensional software (Kuantama et al 2017; Cekus et al 2019; Proano-Pena et al 2020; Vu et al 2021).

A sequence of collapsible pot gears operated by longline systems consists of a pot frame, net, main line, buoy line, branch line, and triangular line. The frame material uses galvanized iron, nets, and lines using polyethylene (PE). The power source is adaptive because of the hydrodynamic force on the collapsible pots caused by their movement in water to create a force in the opposite direction. The fishing gear pulled by the line hauler based on how the long line operates is an object that moves in fluid, thus some of the forces that work can be analyzed and that will affect the load of the line hauler when it is pulled onto the ship. The load of the line hauler is influenced by several things, namely the pulling speed, wet surface area, the density of the liquid (fluid), crab catch and fishing gear. Illustration of the forces that affect the line hauler load are shown in Figure 2.

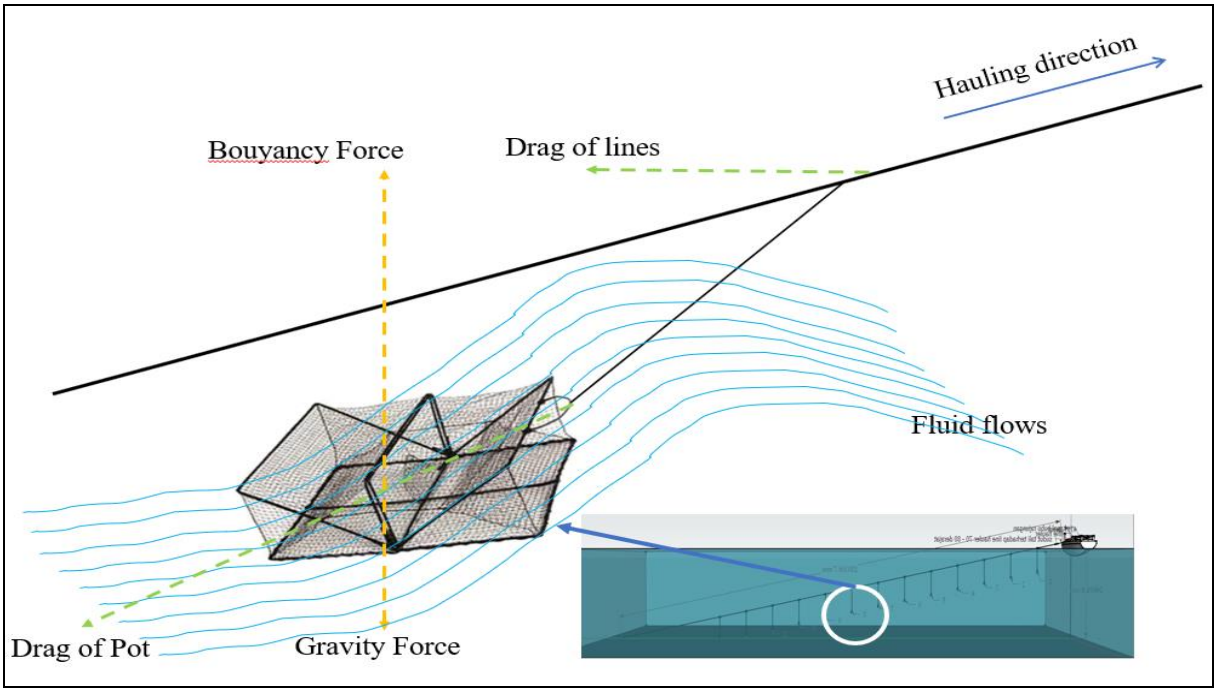

Figure 2. Illustration of the hydrodynamic force on the collapsible pot sequence.

The hydrodynamic force occurs due to differences in the direction of seawater flow and a sequence of collapsible pots and crabs caught in it due to the hauling process by the line hauler. The same thing also happens to the rigging components used in the operation of the collapsible pot gear, namely the main line, branch line, and triangular line. Referring to Figure 2, the scale of the hydrodynamic force on the sequence of the collapsible pot comes from the drag force of the collapsible pot (Cd_p), nets (Cd_j), lines (Cd_t), crab catch (Cd_r), and the force of gravity. The collapsible pot fishing gear moves in the water so that there is a buoyant force opposite to the gravitational drag force (Fridman et al 1986; Munson et al 2020). The calculation is done using the following formula:

$$F = F_{pot} + F_{webbing} + F_{line} + F_{crab} - F_{bouyancy}$$

$$F_{total} = \left(\frac{1}{2}\rho_f U^2 Cd_b A_b + m_b G\right) + \left(\frac{1}{2}\rho_f U^2 Cd_j (D_t/m_s)\, L\, H + \left(\frac{1}{2}\rho_f U^2 Cd_t A_t + m_t G + \left(\frac{1}{2}\rho_f U^2 Cd_r A_r + m_r G\right) - \rho_f\, G\, V_f$$

where:

Cd_p = coefficient drag of pot
m_b = pot frame weight (kg)
A_b = surface area of pot frame (m^2)
Cd_j = coefficient drag of webbings
m_s = length of mesh (m)
L = width of net (m)
H = height of net (m)
Cd_t = coefficient drag of lines

D_t = diameter of net yarn (m)
A_t = surface area of lines (m^2)
Cd_r = coefficient drag of crabs
m_r = weight of crabs (kg)
A_r = surface area of crabs (m^2)
U^2 = pulling velocity (m/s)
m_t = weight of lines (kg)
$\mathcal{G}$ = acceleration of gravity (m/s)
ρ_f = density of fluids (kg/m^3)
V_f = volume of fluids (m^3)

The amount of the drag coefficient (Cd) in the sequence of the collapsible pot is different because the object's shape influences it. The coefficient of resistance in the pot frame and rigging shaped like a cylinder (regular body) and moves against the fluid transversely can use the Reynolds number approximation. So, the value of Cd is calculated as follows:

$$Cd = \frac{5{,}93}{\sqrt{Rn}}$$

where:
Cd = coefficient drag
Rn = Reynolds number

Reynolds number (Rn) is a dimensionless number related to the density of molecules in water, Re is the ratio between the inertial force and the viscosity force (Munson et al 2020; Suhendra 2019). Finding the value of Rn is distinguished based on the components in the sequence of the collapsible pot. Pot frames, nets, and rigging are objects that have a length or diameter because they are essentially tubular. To find the Reynolds number, the methods of Giancoli (2001) and Rosyid et al (2018) are used as follows:

$$Re = \frac{Inertial\ force}{viscosity} = \frac{\rho.u.L}{\mu} = \frac{u.L}{v}$$

where:
Re = Reynolds number
U = fluid velocity (m/s)
v = kinematic viscosity of seawater
L = length (m)

The hydrodynamic force in the net webbing is calculated in the previous studies with a resistance coefficient of 1.25. This value was taken as a result of the angle between the main line and the direction of the water flow during the pulling operation, precisely 70° (Puspito 2009). The calculation of the hydrodynamic force on the catch (blue swimming crab) also concerns previous studies where the resistance coefficient is based on the Reynolds number. Reynolds number is gained by calculation with the formula described above, where "L" is the carapace width of the crab, which is the longest part that gets friction with seawater flow (Blake 1985). Drag resistance occurs on the crab due to seawater flowing on the crab's carapace against and across the fluid. Furthermore, to find the value of the coefficient of resistance, the second formula for Cd calculation can be used.

The need for a power source to pull a sequence of collapsible pot gears will depend on the moment of force or torque (τ) that occurs on the line spool (sheave). The total amount of torques is influenced by the multiplication of the distance vector (r) at a point with the force (F) that occurs at that point and the angle formed (Gupta & Gupta 2019; Katz 2015). Angle formed between the sheave and the main line angle while pulling the collapsible pot fishing gear sequence is shown in Figure 3. The torque will affect the power needed to pull the sequence of collapsible pot gears.

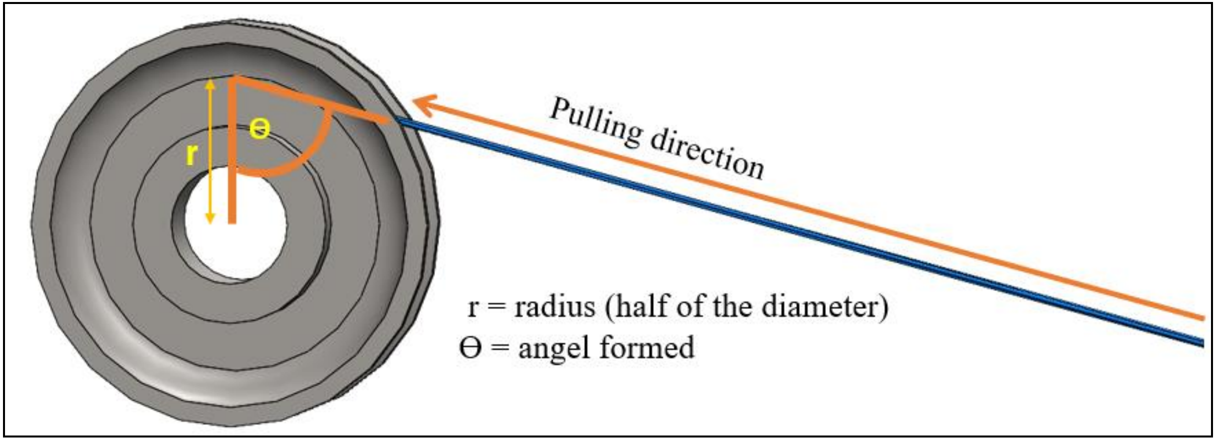

Figure 3. The moment of force (torque) that occurs on the line spool plate (sheave)
The power calculation is done by finding the torque in the line spool (sheave) and the required power.

Finding the amount of torque is done using the following equation:

$$\tau = F \, . r . \sin\theta$$

where:

τ = torque (Nm)

F = forces (N)

r = Sheave (line spool) radius (m)

The torque that occurs on the line spool plate (sheave) will then be calculated to get the amount of power needed (power source needs), using the following formula:

$$P = 2\pi . \tau . \frac{rpm}{60}$$

where:

P = power (watt)

τ = torque (Nm)

Data analysis. To determine the quantity of actual power source we analyzed the amount of the hydrodynamic force values quantitatively on a sequence of collapsible pots. The force value will compare to the Sukakerta village and Sukajaya village pots to find the most significant value of the hydrodynamic force (F), which is then used to find the amount of power required for the power source. The necessary amount of power will be compared again in a comparative manner against two conditions, namely at the beginning of the hauler time and when the first pot rises to the fishing boat and comparing the size of the line spool plate (sheave) diameter which are 50 and 30 cm. Moreover, this is done to determine the maximum power, which will be used as a reference for actual power requirements.

Results

The construction of collapsible pot gears sequence. The construction of collapsible pot gear is widely used by fishermen on the coast of Karawang, especially in Sukakerta and Sukajaya villages. Measurements were made on the parts according to Figure 2, with the measurement results of the Sukakerta pots being L: 49 cm, W: 36 cm, H: 17 cm and the Sukajaya pots being L: 50, L: 30 cm, H: 20 cm. The pot frames are made of 3 mm diameter galvanized wire with a density of 7135 (coated Zn steel). Then the pot frames are covered with a polyethylene (PE) net webbing with a diameter (Dt) of 0.15 mm and a length of the mesh (ms) of 15 mm.

The number of collapsible pots subjected to hydrodynamic forces can be estimated using a simulation on the SketchUp Pro-2021 software (License Certificate No. 1528981) by entering the parameters of the water depth and the angle of the line pull. The simulation provides a virtual reality of the state of the collapsible pot gears, thus representing the actual situation (Abdulhassan 2020; Syam 2021; Yu 2017). The angle of pulling the line to the direction of seawater flow based on field observations varies according to the ship's movement, namely 40^o-70^o. Meanwhile, the depth of the waters during the operation of the collapsible pot gear of Sukakerta and Sukajaya was very varied, namely 6-19 fathoms (11-35 m). A depth of 15-25m is the most frequent location for setting the collapsible pots by fishermen because more crabs are caught following research that depth is the ideal depth (Agus et al 2016; Lisna et al 2020).

The calculation of the hydrodynamic force used the maximum parameter. The depth parameter is 35 m, and the angle of incidence is 70^o to obtain the maximum values of the hydrodynamic force on a sequence of collapsible pot gear. The simulation was conducted with two conditions: the beginning of the gear hauler time and after the first pot boarded on the boat. This is done because at the beginning of the hauler time of the gear, there is a buoy line where there is no hanging pot then, when the first pot boarded to the boat all the pots are entirely dependent on the main line.

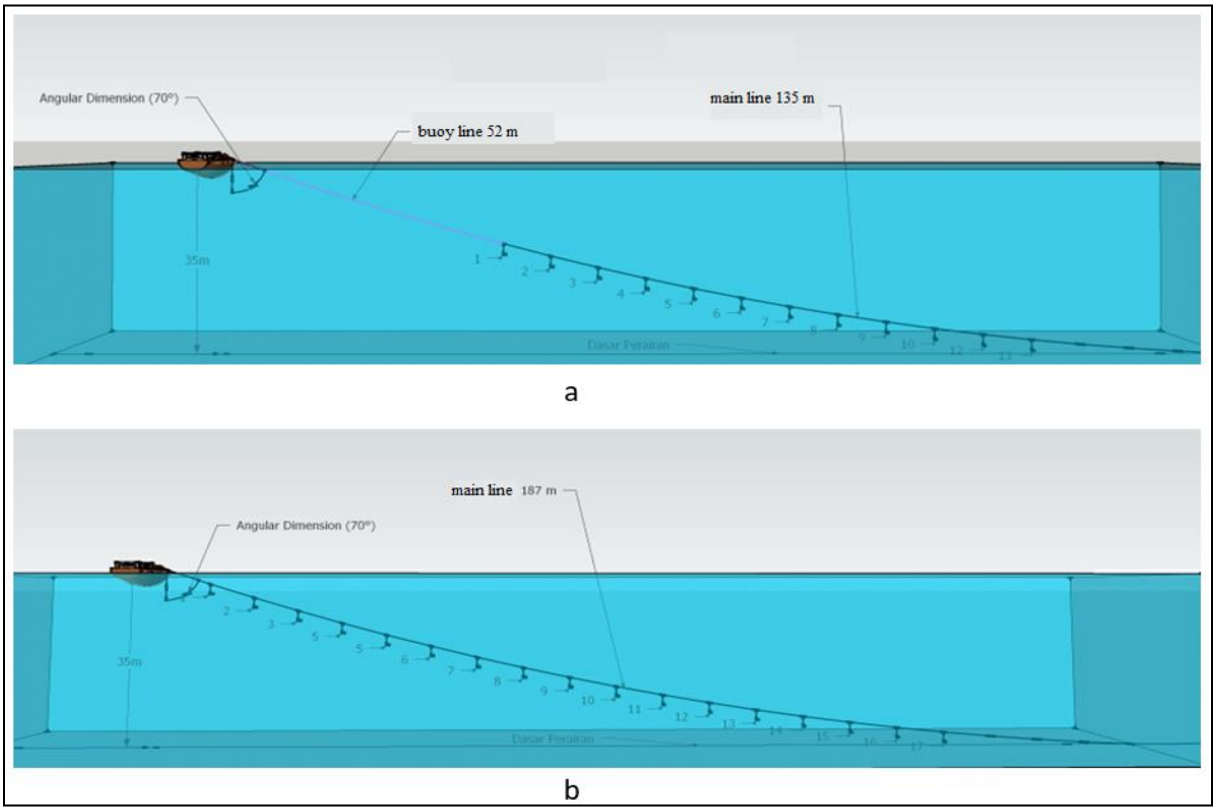

Figure 4. Simulation of sequence of collapsible pot gear while in the water, before the first pot rises (a). Simulation after the first pot boards the fishing boat (b).

Based on the simulation shown in Figure 4, the number of collapsible pots that get the hydrodynamic force at the beginning of the withdrawal of the fishing gear is 13 units, and when the first pot is aboard the fishing boat is 17 units. The length of the rigging in both conditions can be seen in Table 1. For the type and diameter of the float, main and branch lines, fishermen generally use 6 mm Polyethylene (PE) lines and 4 mm PE triangular lines.

Table 1

The length of lines in a sequence of collapsible pot gear

No	*Condition of gear*	*Length of lines (m)*			
		Buoy	*Main*	*Branch*	*Triangular*
1	The beginning of hauler time	52	135	13 x 2 = 26	13 x 0.40 = 5.2
2	After first pot abroad on the fishing boat		187	17 x 2 = 34	17 x 0.40 = 6.8

Wetted surface area. Wet surface area is one of the most important in calculating the total hydrodynamic force of a sequence of collapsible pot gears. Wet surface area is the entire surface of a sequence of collapsible pot gears in contact with seawater, including collapsible pot, lines, and crab catch. The sequence of collapsible pot gear for the pot frames, nets, and rigging are symmetrically shaped like round tubes; thus, the surface area is calculated mathematically. The results of the calculation of the wet surface area for the Sukakerta pot frame were 0.0602 m^2, the pot nets were 0.00126 m^2, while the Sukajaya pots frame was 0.0655 $m^{2,}$ and the pot nets were 0.001504 m^2. The rigging of the Sukakerta and Sukajaya pots has the same wet surface area; a calculation based on the total length through the simulation in Figure 4 generated for a buoy line of 0.98 m^2, the main line of 3.32 m^2, a branch line of 0.528 m^2, and a triangular line of 0.086 m^2.

The wet surface area of the catch, namely blue swimming crabs, is obtained by performing simulations by entering size parameters on the crabs. The crab used refers to the size of the giant carapace crab caught by fishermen in Sukakerta Village, which was 100 cm long, 180 cm wide, and 46 cm thick with a weight of up to 442 grams (Istrianto et al 2021). We used the reference to the largest crab caught in the Sukakerta Village, because we wanted to calculate the biggest hydrodynamic force required. The surface area of blue swimming crabs was estimated using software based on simulations using Solidworks Student Edition 2022-2023 (AKD-73699524110). Carried out on the giant crab that has ever been captured, the surface area is 0.059 m^2. The simulation can be seen in Figure 5.

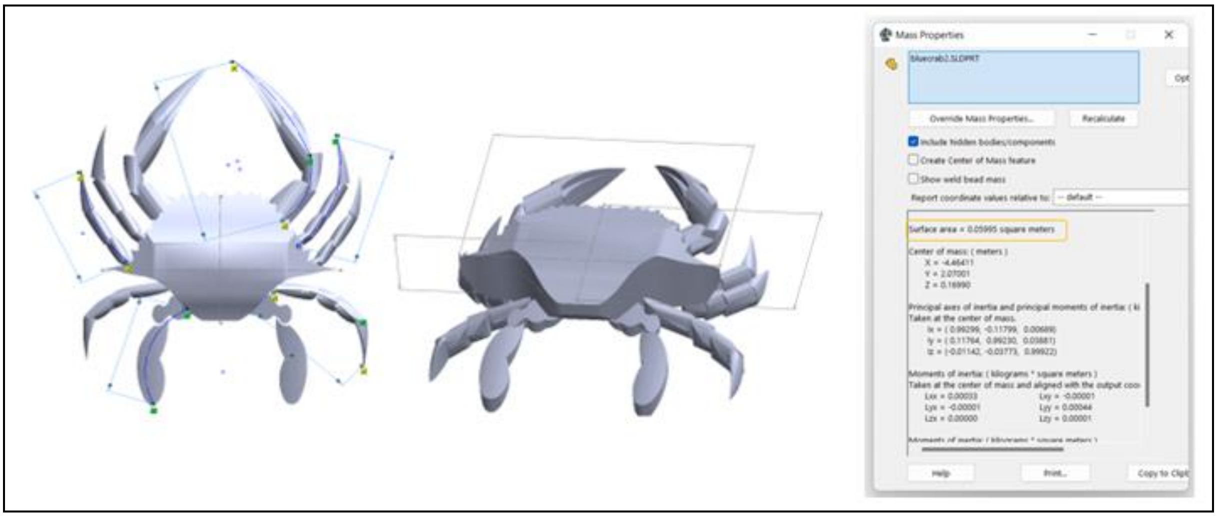

Figure 5. The wet surface area of blue swimming crab calculation using Solidworks Student Edition 2022-2023 (AKD-73699524110).

The hydrodynamic force occurring on the sequence of collapsible pot gear. The drag velocity parameter during the operation of the collapsible pot dramatically influences the value of the hydrodynamic force of the sequence of collapsible pot gears. The higher the pull speed, the greater the hydrodynamic force that occurs due to the amount of friction in the cross-sectional area of the fishing gear sequence with fluid (sea water). The force values were calculated on two types of collapsible pots, namely Sukakerta and

Sukajaya pot types, and with the condition before and after the first pot boarded to the fishing boat.
Calculations under different pulling conditions are carried out to distinguish which collapsible pots have the most significant hydrodynamic force. The Sukakerta pot gears pulled at a speed of 0.65 m/s, and the hydrodynamic force values before and after the first pot rise to the fishing boat are 271.45 N and 337.55 N, while the Sukajaya pots are 276 N and 351.32 N. The Sukakerta pot is pulled with a speed of 3 m/s; the hydrodynamic force values before and after the first pot rise to the fishing boat are 416.44 N and 517.64 N, while the Sukajaya pots are 443.42 N and 531.47 N. The hydrodynamic force values of both Sukakerta and Sukajaya pots can be seen in Figure 6.

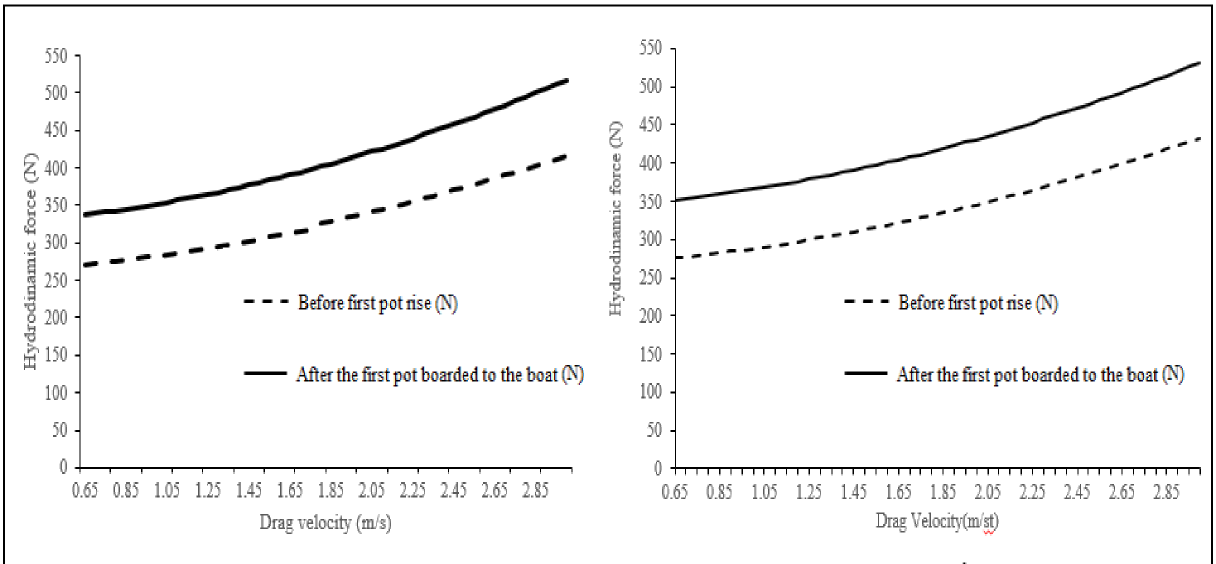

Figure 6. The drag velocity against hydrodynamic forces on the Sukakerta pot (a) and the Sukajaya pot (b).

The force values on the collapsible pots without the rigging component must be calculated to determine whether the main line can stand the load (hydrodynamic force). The Sukakerta pot type is pulled at a speed of 0.65 m/s; the hydrodynamic force values before and after the first pot boarded to the boat are 243.11 N and 318.64 N. The Sukajaya pot is 261.73 N and 334.73 N, pulled at a speed of 3 m/s, produced hydrodynamic forces before and after the first pot boarded the ship of 381.58 N and 493.64 N, while the Sukajaya series of pots were 412.65 N and 509.44 N. The amount of the hydrodynamic force on the pot (nets and crabs caught) can be seen in Figure 7.

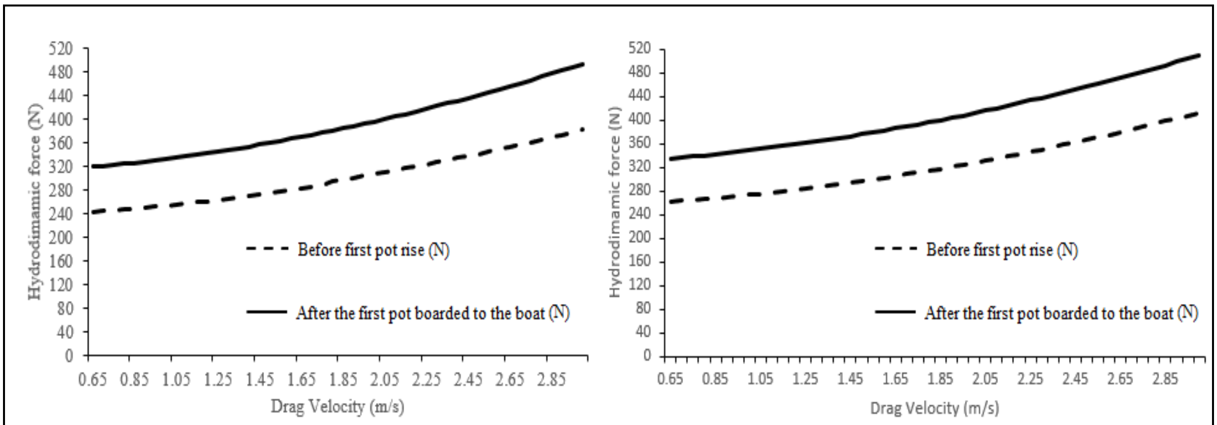

Figure 7. The drag velocity against hydrodynamic forces on the Sukakerta (a) and Sukajaya (b) pots without the main line.

The most significant value of hydrodynamic force occurs in the Sukajaya pots with a hauling speed of 3 m/s, which is 509.44 N. The main line will bears the load value of 509.44 N when pulling the fishing gear onto the fishing boat. Compared to the main line's breaking strength of the Polyethylene (PE) line with a diameter of 6 mm is 3700 N, the load value is still within safe limits (Donaghys 2018). The main lines will not break down if it receives a load of 509.44 N.

Torque and power on the line hauler's line spool plate (sheave). Based on observations, the existing line hauler generally uses the line spool plate size of 50 cm (d50) in diameter. The size of the diameter and rotation of the line spool plate will affect the amount of torque on the line spool plate. As a comparison between the diameter of the existing line spool plate and the 30 cm (d30) line spool plate, it can be seen in Figure 8 and Figure 9.

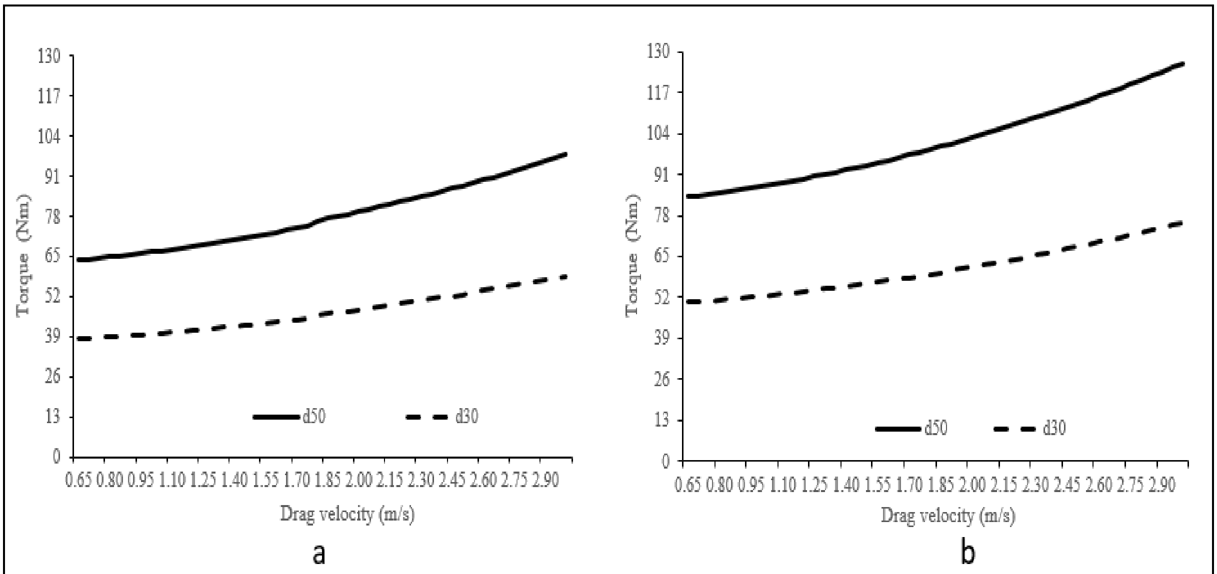

Figure 8. Torque on the existing line spool plate (sheave) (d50) and the new design (d30) for Sukakerta pot type, before (a) and after (b) the first pot boarded into the fishing boat.

The torque on the sheave of the Sukakerta pot type with a diameter of 50 cm at a pulling speed of 0.65 m/s before and after the first pot boarded is 63.77 Nm and 79.30 Nm, respectively. Meanwhile, at a pulling speed of 3 m/s, the torque values before and after the first pot boarded are 97.8 Nm and 121.61 Nm, respectively. The sheave with 30 cm of diameter at a pulling speed of 0.65 m/s and the torque that occurs before and after the first pot boarded is 38.26 Nm and 47.56 Nm, respectively. Meanwhile, at a pulling speed of 3 m/sec, the torque values before and after the first pot boarded are 58.70 Nm and 72.96 Nm.

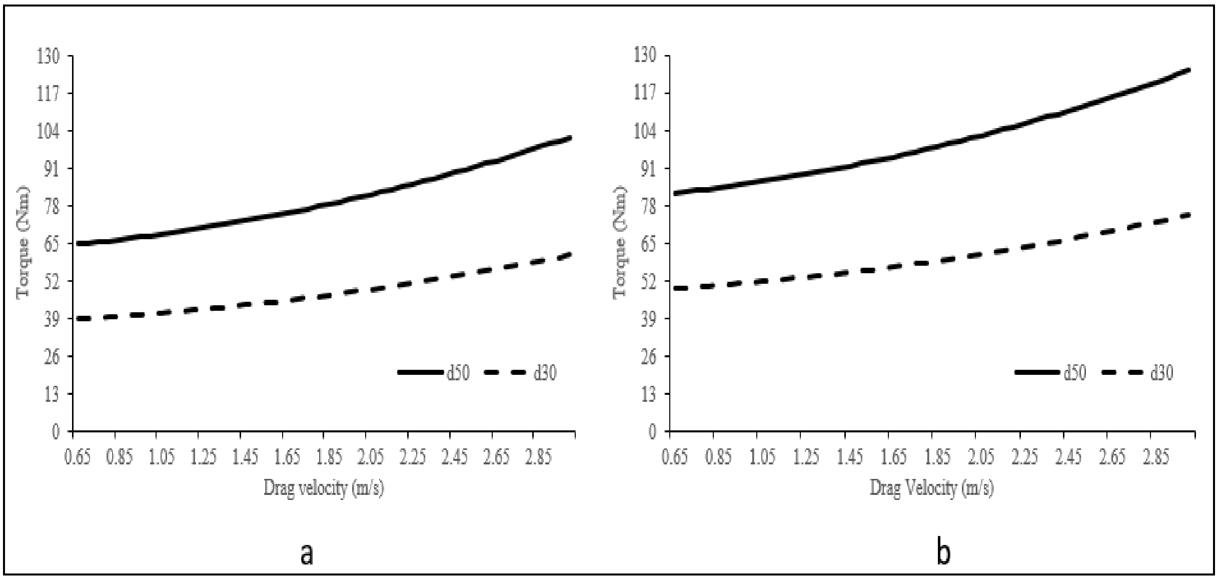

Figure 9. Torque on the existing line spool plate (sheave) (d50) and the new design (d30) for Sukajaya pot type, before (a) and after (b) the first pot boarded into the fishing boat.

The torque on the sheave of the Sukajaya pot type with a diameter of 50 cm at a pulling speed of 0.65 m/s before and after the first pot boarded is 68.48 Nm and 82.53 Nm, respectively. Meanwhile, at a pulling speed of 3 m/s, the torque values before and after the first pot boarded are 101.82 Nm and 124.85 Nm, respectively. The sheave with 30 cm of diameter at a pulling speed of 0.65 m/sec and the torque that occurs before and after the first pot boarded is 38.26 Nm and 50.37 Nm, respectively. Meanwhile, at a pulling speed of 3 m/sec, the torque values before and after the first pot boarded are 61.09 Nm and 74.91 Nm.

Supposing the greater the torque in the sequence of collapsible pot gear, the power source required to drive the sheave will be greater. A comparison of the amount of driving power required for the existing and designed towing wheels at various speeds can be seen in Figure 10 and Figure 11.

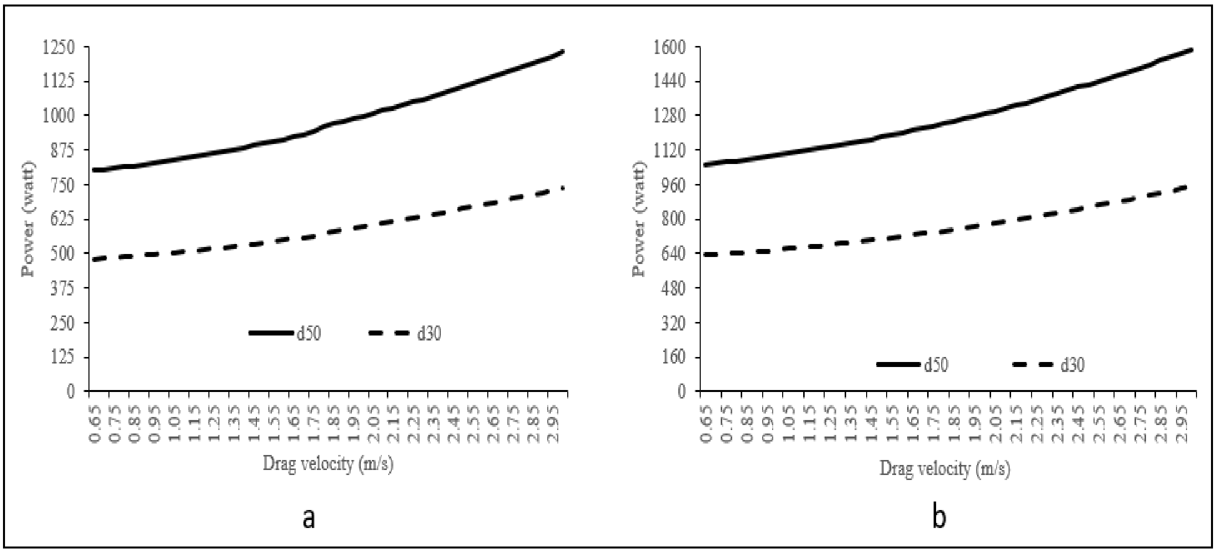

Figure 10. The power source needs of the existing Sukakerta pot type (d50) and the new design (d30), before (a) and after (b) the first pot boarded into the boat.

The power requirements of the Sukakerta pot type with a 50 cm diameter sheave at a pulling speed of 0.65 m/s before and after the first pot boarded are 800.96 watts and 996 watts, respectively. Meanwhile, at a pulling speed of 3 m/sec, the power requirements before and after the first pot boarded are 1228.75 watts and 1527.36

watts. The sheave with a diameter of 30 cm with a pulling speed of 0.65 m/s, the power requirements before and after the first pot boarded are 480.58 watts and 597.60 watts, at a pulling speed of 3 m/s the power requirements before and after the first pot boarded was 737.25 watts and 916.42 watts.

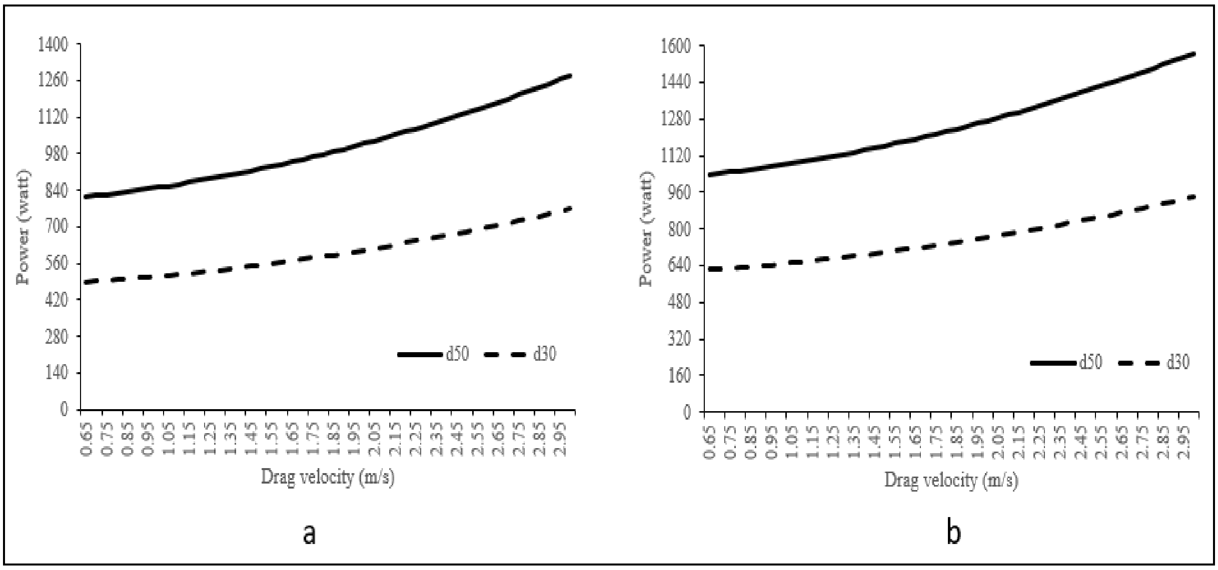

Figure 11. The power source needs of the existing Sukajaya pot type (d50) and the new design (d30), before (a) and after (b) the first pot boarded into the boat.

The power requirements of the Sukajaya pot type with a 50 cm diameter sheave at a pulling speed of 0.65 m/s before and after the first pot boarded are 814.36 watts and 1036.63 watts, respectively. Meanwhile, at a pulling speed of 3 m/sec, the power requirements before and after the first pot boarded are 1278.88 watts and 1568.16 watts. The sheave with a diameter of 30 cm with a pulling speed of 0.65 m/s, the power requirements before and after the first pot board into the boat are 488.62 watts and 621.98 watts at a pulling speed of 3 m/s the power requirements before and after the first pot board into the boat was 767.33 watts and 940.90 watts.

Discussion. The largest hydrodynamic force in the Sukakerta and Sukajaya collapsible pot gear with a pulling speed of 3 m/s is 443.42 N, and 531.47 N. For the largest hydrodynamic force without considering rigging on the Sukakerta and Sukajaya crab fishing gear series, if it is pulled at 3 m/s, it is 412.65 N, and 509.44 N. The value of the force is still within the safe limit of the breaking strength of the 6 mm diameter PE line, which fishermen commonly use up to 3700 N.

The torque that occurs on the line spool plate while pulling the Sukakerta and Sukajaya collapsible pots is in the range of 38.26 Nm – 124.85 Nm. Meanwhile, the required power requirements range from 480.58 watts to 1568.16 watts. Considering the results of these calculations, the collapsible pot puller equipment to be designed must be able to pull a minimum load of 531.47 N with a propulsion power requirement of more than 1568.16 watts.

Conclusions. The auxiliary hauling equipment of the collapsible pot must be able to pull the collapsible pot gear load, and the catch at 531.47 N. A minimum power of 1568.16 watts is required if it is pulled at a speed of 3 m/s, and the power is centered on the line spool plate.

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Conflict of interest. The authors declare that there is no conflict of interest.

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