Design of Fishing Vessel of Catamaran Type In Waterways of East Kalimantan (40 GT)

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Abstract. Fishing vessel craftsmen in the East Kalimantan area have made several changes to the design of fishing vessels to get more catch. Changes were made to the main dimension which resulted in changes in ship characteristics such as speed and stability of the ship. This purpose of research to determine the main dimensions and stability analysis of catamaran hull fishing vessels. The method used is the parent ship method and optimization using maxsurf software. The results obtained were as follows: LOA = 16.2 [m], B = 6 [m], B1 = 1 [m], T = 1 [m], H = 2 [m], Cb = 0.192, Vs = 6.5 [knots], and number of crew = 5 person. The required of Catamaran is a power of 134,498 [HP] consist of two engine 70 [HP]. Based on the results of critical analysis stability on catamarans, the maximum GZ value occurs at a heeling of 20°. The maximum GZ value in loadcase 1 is 2.326 [m], loadcase 2 is 2.15 [m], and loadcase 3 is 2.18 [m]. The GM values for all loadcase scenarios are not less than 0.15 [meters]. All of them accepted the IMO and HSC 2000 Annex 7 Multihull criteria.

1. Introduction

Most fishermen in East Kalimantan (Nunukan) use trawlers, gill nets, scoop, lift nets and seashell catchers. The fishing gear amounts to more than one hundred units each year. Therefore it can be said that the fishing gear used is still relatively traditional with a relatively small level of fishing productivity because it still uses a small traditional boat (below 5 GT) as a transportation medium for fishing [1]. Traditional boat design used in the fisheries sector in Indonesia are monohull vessels. However, with the development of fisheries in the coastal area, the need for new ship design in the area is increasingly apparent. Fishermen have tried to design traditional vessels that can be used for various types of fish, as a result the ship is too wide or too broad when compared to its length which results in inefficient speed and inappropriate decks [2].

Fishing vessel construction in Kalimantan is still traditional in nature, that is, based on community habits for generations without being based on naval architecture calculations and general design drawings, line plan drawing, deck profile, body profile and profile construction [3]. The term more traditionally refers to the methods used by fishing vessel craftsmen in building their ships, where the methods applied are the legacy of their predecessors [4]. To get various types of fishing vessel craftsmen have made some changes to the design of the ship, it causes the ship with a ratio of length and width (L / B) to be very small [2]. A relatively small (L/B) value close to the lower limit indicates that the motion resistance experienced by the ship is large enough to negatively impact the speed of the ship [5], however, in terms of stability, it will increase the stability of the ship [6]. To get the stability value, the ability of motion and motion resistance in accordance with the needs of fishing vessels, it is necessary to study to determine the optimal value of the main dimensions of the ship [7]. The right main dimension ratio value can be used as a design control for ships to be built now and in the future [8]. Besides the construction of fishing vessels traditionally less adopting some aspects of safety at sea, this can be seen in the design of the stability of the ship [9].

The size of the ship that is not in accordance with the main dimension ratio will give effect to the function of the ship which is ineffective and inefficient when the vessel operates. This problems bring...
up 2 (two) options that can be used as a solution, the first is redesign existing traditional ships with the main dimension ratio according to the standard, and the second is bringing up new ship design innovations using the form of a catamaran hull or hull double in terms of meeting a greater capture capacity. In this study only discusses the second option which is to bring up a new design of a ship with a catamaran hull shape. The form of a catamaran hull has several advantages when compared to the form of a single hull or monohull, among others; has relatively small obstacles, fairly good stability, wider deck surface area and has a good level of safety [10, 11]. Some of the advantages of fishing vessels by using catamaran hull types, among others, the engine power used is about 45% smaller, the fuel saved reaches 40% [10, 12]. In addition, it is very possible to use the sails as movers, because the decks on the ship become wide and do not interfere with fishing activities and produce relatively small angle [10].

2. Methods
The method used is the parent ship method and the optimization method using maxsurf software. A sample ship is used as the initial reference in designing a design ship. Furthermore, the main size will be optimized in such a way as to get the design we want with some boundary conditions. This study uses 1 (one) fishing vessel sample. Technical data in the form of the main measurements and body plan of the sample vessels can be as shown in Table 1 and Figure 1 [13].

![Figure 1. Lines Plan of Parent Ship](image)

| Catamaran hull |       |
|----------------|-------|
| L_{OA}         | 16 meters |
| L_{WL}         | 15,5 meters |
| B              | 6 meters |
| H              | 1,8 meters |
| T              | 0,8 meters |
| B_1            | 1,25 meters |

To get the catamaran hull ship design, this research was conducted with several stages which are described in the research flowchart. The research flowchart can be as shown in Figure 2:
Figure 2 shows the stages of the research. The first stage begins with a literature study. The second stage is to determine the main size of the designed ship using the ship parent method. This method initially uses an existing ship sample that has been tested during operation. The advantage of this ship parent method is that the resulting ship design has a performance similar to that of the parent ship sample. The third stage ensures that the GT size of the design vessel is in accordance with the initial planning requirements (40 GT) using the approach formula. The fourth stage is modeling the design ship using the maxsurf modeler. In this maxsurf modeler optimization occurs automatically when inputting the main size of the design vessel. Several ship variables will be determined based on the formulas used by maxsurf and the availability of ship types and data at maxsurf. The fifth stage is analyzing the stability of the ship with several cargo scenarios. The scenario planned is appropriate when the ship operates. The results of the ship stability analysis were evaluated based on IMO and HSC. The sixth stage is making a general plan for the ship including the LWT and DWT values, spatial layout, determining engine power, fishing gear, and safety equipment.

3. Results and Discussion

3.1 Determine of Main Dimension of Ship

The process of determining the primary size by optimizing the sample ship (parent ship). The Gross Tonnage (GT) value of the ship is used as an optimization parameter. In this study the GT value was determined from the beginning at increase 5 ~ 10 the GT of the existing ships. The GT size of the ship is determined based on the "International Convention on Tonnage Measurement of Ship, TMS 1969", for ships with an overall length (LOA) less than equal to 24 meters (≤ 24 m). The gross tonnage (GT) of a ship shall be determined by the following formula [14]:

$$GT = K_1 \times V$$  \hspace{1cm} (1)$$

where $K_1 = K_1 = 0.2 + 0.02 \log_{10} V$ (or as tabulated in Appendix 2) = 0.24 and $V$ = Total volume of all enclosed spaces of the ship in cubic metres = 160.65 m³. So we get the value of GT = 39.22 m³. After going through the optimization process, we get the main dimension of catamaran hull fishing
vessels that meet the planned Gross Tonnage. The main dimension of fishing vessels obtained are as shown in Table 2:

**Table 2. Main Dimensions of Ship Optimization**

| Catamaran hull of Optimization |          |
|-------------------------------|----------|
| \( L_{OA} \)                  | 16.2 meters |
| \( L_{WL} \)                  | 15.665 meters |
| \( B \)                       | 6 meters   |
| \( H \)                       | 2 meters   |
| \( T \)                       | 1 meters   |
| \( B_1 \)                     | 1.25 meters |
| Operational of Distance       | 54 sea miles |
| \( V_s \)                     | 6.5 knots  |

### 3.2 Modeling Fishing Vessel of Catamaran Hull

After obtaining the definitive main dimension with the optimization method, a hull catamaran hull is modeled to determine the hull's shape and pattern. Modeling the hull of a fishing vessel using the Maxurf (Maxurf Modeler) software. The variables needed in modeling the hull of the fishing vessel in the maxurf software are \( L_{OA}, B, H, T, \) and \( L_{WL} \). The shape of the hull catamaran fishing vessel as shown in Figure 3.

*Figure 3. Catamaran hull of Fishing Vessel on Software Maxurf*

### 3.3 Ship Stability Analysis

Analysis of the stability of catamaran fish vessels is carried out to determine the characteristics of the ship when it is shaking because of the influence of the load. To calculate the stability of catamaran
fishing vessels, it is necessary to plan the scenario of the load (loadcase) when operating, so it can know the value of static stability in each condition. Loadcase is planned in 3 conditions, the first condition if the ship departs (loadcase 1), the seconds condition the ship is at fishing ground (loadcase 2), and the next condition when the ship returns from fishing ground (loadcase 3). While the stability requirements refer to the IMO A. 749 chapter 3 and HSC 2000 annex 7 Multihull standards. Before analyzing the stability of the ship, the first arrangement of the vessel consumable tank includes the fuel tank, fresh water tank and ballast tank. In detail the laying of the fishing vessel consumable tank is shown in Table 3. and Figure 4.

Table 3. Consumable tank of plan

| Name                  | Specific gravity | Fluid type     | Aft [m] | Fore [m] | F Port [m] | F Stb [m] | F Top [m] | F Bott. [m] |
|-----------------------|------------------|----------------|---------|----------|------------|-----------|-----------|-------------|
| Fuel Oil Tank SB      | 0.84             | Diesel oil     | 1       | 3.84     | -3         | -1.3      | 0.9       | 0           |
| Fuel Oil Tank PS      | 0.84             | Diesel oil     | 1       | 3.84     | 1.3        | 3         | 0.9       | 0           |
| Fresh Water Tank SB   | 1                | Fresh Water    | 4.5     | 4.67     | -3         | -1.3      | 0.9       | 0           |
| Fresh Water Tank PS   | 1                | Fresh Water    | 4.5     | 4.67     | 1.3        | 3         | 0.9       | 0           |
| Ballast tank SB       | 1.025            | Sea Water      | 12      | 14       | -3         | -1.3      | 0.9       | 0           |
| Ballast tank PS       | 1.025            | Sea Water      | 12      | 14       | 1.3        | 3         | 0.9       | 0           |

Figure 4 shows the laying of the consumable and ballast tanks in accordance with the ship's planning and calculation. Ballast tank placement in front of the ship is used to balance the ship due to the addition or reduction of cargo and consumables. After planning the location of the consumable tank, the loadcase scenario planning is carried as show in Table 4:

Table 4. Loadcase of Fishing Vessels

| Type fluid of tank    | Loadcase 1 | Loadcase 2 | Loadcase 3 |
|-----------------------|------------|------------|------------|
| Fuel Oil Tank SB      | 100%       | 50%        | 10%        |
| Fuel Oil Tank PS      | 100%       | 50%        | 10%        |
| Fresh Water Tank SB   | 100%       | 50%        | 10%        |
| Fresh Water Tank PS   | 100%       | 50%        | 10%        |
| Ballast tank SB       | 0%         | 50%        | 100%       |
| Ballast tank PS       | 0%         | 50%        | 100%       |
| Payload               | 50%        | 70%        | 100%       |
Table 4 shows, in loadcase 1 the state of catamarans departing from the pier, so that the fuel load and clean water supply are 100% full. At loadcase 2 catamarans arrived at the fishing ground so that the load on the consumable tank decreased by 50%. At loadcase 3 the catamaran fishing vessel returns to the dock after the cargo fish is fully loaded or 100% with 10% consumable. Stability analysis is carried out with the help of Maxurft stability software. The results of the simulation of ship stability on each loadcase that is obtained each stability arm curve as shown in Figure 5, 6, and 7:

Loadcase 1 shown in Figure 5a is the scenario of a ship departing from the pier to a fishing ground with a 100% fuel tank load, 100% fresh water tank, 0% ballast tank and 50% payload. Then the following results are obtained:
- The area of GZ between 0°-30° of 49.24 m.deg meets IMO requirements.
- The area of GZ between 0°-40° of 68.63 m.deg meets IMO requirements.
- GZ area between 30°-40° of 19.38 m.deg has fulfilled IMO requirements.
- A maximum GZ value of 2.27 m at a heeling of 20 deg.
- GM value of 8.335 m must not be less than or equal to 0.15 m.

Loadcase 2 shown in Figure 5b is the scenario that the ship is in a fishing ground with 50% fuel tank load, 50% fresh water tank, 50% ballast tank and 70% payload. Then the following results are obtained:
- The area of GZ between 0°-30° of 48.75 m.deg meets IMO requirements.
- The area of GZ between 0°-40° of 67.93 m.deg meets IMO requirements.
- The GZ area between 30°-40° of 19.17 m.deg meets IMO requirements.
- The maximum GZ value is 2.261 m at a heeling of 20 deg.
- A GM value of 8.225 m must not be less than or equal to 0.15 m.

Loadcase 3 shown in Figure 5c is the scenario the ship has returned from fishing ground to the dock with a 10% fuel tank load, 10% fresh water tank, 100% ballast tank and 100% payload. Then the following results are obtained:
- The area of GZ between 0°-30° of 47.74 m.deg meets IMO requirements.
- The area of GZ between 0°-40° of 66.84 m.deg meets IMO requirements.
The GZ area between 30°-40° of 19.10 m.deg has fulfilled IMO requirements.

The maximum GZ value of 2.176 m at a heeling of 20 deg.

GM values of 7.73 m must not be less than or equal to 0.15 m.

In addition to analyzing the stability of the ship, the calculation period of the ship is also carried out (T). T value is used to determine the time needed when the ship experiences a shaky state until the ship returns to its original position. Calculation of the shaking period is carried out for each loadcase.

Based on the data that has been obtained in the form of hydrostatic characteristics of catamaran fishing vessels, the calculation period is then carried out which refers to the International Code on Intact Stability, 2008 - Part A. The roll period (T) of a ship shall be determined by the following formula [15]:

\[ T = \frac{2x C x B}{\sqrt{GM}} \]  

(2)

where:

\[ C = 0.373 + 0.023 \left( \frac{B}{d} \right) - 0.043 \left( \frac{LWL}{100} \right) \]  

(3)

LWL = length of waterline [m], B = Breadth [m], d = Draught [m], GM = The height of metacenter [m]. The results of the calculation of the ship’s roll period with 3 loadcase scenarios can be as show in Table 5.

| Loadcase | GM    | B    | d    | LWL  | T    |
|----------|-------|------|------|------|------|
| Loadcase 1 | 8.36  | 6    | 0.85 | 15.85| 2.19 |
| Loadcase 2 | 8.22  | 6    | 0.88 | 15.85| 2.18 |
| Loadcase 3 | 7.73  | 6    | 0.99 | 15.85| 2.21 |

Table 5. Value of the roll period

Table 5. shows that the highest value of the battered period is 2.21 seconds contained in the loadcase 3. The results of the analysis show that the value of GM is inversely proportional to the value of the roll period (T) of the ship.

3.4 Design of Lines Plan & General Arrangement of Fishing vessel

Catamaran hull ship planning is designed using the superstructure, has consumable tanks and also cargo space. The basic pattern of the hull and the shape of the room is taken from the lines plan created in the maxsurf modeler and then exported to the AutoCAD software. General arrangements refer to lines plan drawings. The general arrangement and lines plan for catamaran hull fishing vessels are shown in Figures 8 and 9.
Figure 9 is a general description of the ship which includes, displacement of the ship, the coefficient of hull shape, resistance of the ship, powering the ship, fishing gear planning, cargo fishing, the number of crew et al. Displacement is the weight of water displaced by a hull in the water; in other words, the volume of displacement multiplied by the density of water. To calculate ship displacement, the formula is used as follows [16]:

$$\Delta = V_t \times \rho_{\text{water}} \text{ (ton)}$$  \hspace{1cm} (4)

Where $V_t$ = total displacement volume, $\rho_{\text{fresh water}}$ = Density of sea water = 1025 kg/m$^3$. So that the total displacement,
\[ \Delta = L \times B \times T \times CB \times \gamma \]  
\[ = 18.74 \text{ [tons]} \]  

Calculation of the coefficient of the ship shape is taken from calculations using the Maxurf software as shown in Table 6.

| Hull Form Coefficient | Value |
|-----------------------|-------|
| \( C_B \)             | 0.192 |
| \( C_M \)             | 0.305 |
| \( C_P \)             | 0.63  |
| \( C_{WL} \)          | 0.257 |

In an experiment to calculate the total resistance value of a catamaran, its hull is assumed to be a demihull ship added to the interference price due to the hull which is S distance from its center line. The value of the total resistance is multiplied by 2 considering the wet surface area (WSA) is in each hull [17]. The total resistance can be calculated with the following formula:

\[ R_T = 0.5 \times \rho \times 2 \times WSA \times V^2 \times C_{Tot} \]  

where \( \rho = \text{fluid density (kg/m}^3\), \( WSA = \text{wetted surface area of shipwreck immersed in water (m}^2\), \( V = \text{ship speed (m/s), C}_{Tot} = \text{coefficient of total catamaran resistance}. \) So we get the \( R_T \) value as follows:

\[ R_T = 8684.606 \text{ [N]} \]

\[ = 8,684 \text{ [kN]} \]

\[ R_T = R_T + 15\% \text{ margin} \]

\[ = 9,987 \text{ [kN]} \]

After knowing the value of total resistance (RT) then move with the calculation of the power to move the ship. To calculate the power of the ship can be determined by the following formula [18] :

\[ P_E = R \times V \]  
\[ = 48.41 \text{ [kW]} \text{ with; } 1 \text{ [Hp]} = 0.7355 \text{ [kW]} \]

\[ = 64.92 \text{ [Hp]} \]

where \( P_E = \text{Effective Horse Power (Hp)} \). From the above calculation, the effective horse power \( (P_E) \) value is 64.92 Hp. From this \( P_E \) can then be calculated to get the \( P_B \) value that will be used to determine the selection of the main engine. That formula to determine \( P_B \) as follows is :

\[ P_B = P_D + (x\% \times P_D) \]  

where \( x\% = \text{Machinery of correction [10\%-15\%]. To used 15 \%} \)
\[ R_D = \frac{P_E}{P_C} \]  
\[ P_C = \eta_R \times \eta_P \times \eta_H \]  

where, \( \eta_P \) = efficiency of the propeller mounted on the back of the ship, \( \eta_R \) = relative rotative efficiency, \( \eta_H \) = efficiency of the hull. To determine the efficiency value, Lagrange interpolation is carried out as follows:

\[ \eta_P, \eta_R, f(x) = \frac{(x-x_1)}{(x_0-x_1)} \times f(x_0) + \frac{(x-x_0)}{(x_1-x_0)} \times f(x_1) \]  
\[ \eta_P = f(x_0) = 0.66 \]
\[ \eta_R = f(x_0) = 1.025 \]

The value of \( \eta_H \) determine to used formula as follows [16]:

\[ \eta_H = \frac{(1-t)}{(1-w)} \]  
\[ = 0.9 \]

So that the value of \( P_C \) (Propulsion efficiency) = 0.609, \( P_D \) (Delivery Horse Power) = 116.95 [Hp], and \( P_B \) (Break Horse Power) = 134,498 [Hp] (98.92 kW). The value of \( P_B \) are used as a reference to determine the specifications of the driving machine. In engine planning is based on the power needed when the ship is at maximum speed with considerations including weight and dimensions of the engine, engine speed and vibration. The driving force to be used by this catamaran is an outboard engine. Outboard motors are generally a type of 2 stroke motor. Outboard motor characteristics are easy to install and disassemble and are easy to operate [19]. Based on previous calculations that this catamaran fishing boat requires a power of 134,498 [HP], so it takes 2 (two) Yamaha outboard 70 [HP] outboard engines with a weight of 217 [kg]. The specifications of the engine to be used on catamaran fishing vessels as shown in Figure 10 and Table 7 as follows:

![Figure 10. Engine of outboard 70 [Hp], Yamaha branded](image)
The weight components of Dead Weight Ton (DWT) in fishing vessel planning are crew weight and luggage, fuel weight, weight of clean water requirements, payload weight and variable ballast requirements. Payload is the capacity of cargo fish that can be transported. Payload weight is fish plus ice cooler. The payload itself is obtained from the weight of the DWT minus the weight of the consumable. The weight components of DWT fishing vessels are shown in Table 8:

| No | Item                            | Value  | Unit |
|----|---------------------------------|--------|------|
| 1  | weight crew & provision        | 0.85   | Tons |
| 2  | weight of Fresh Water          | 0.125  | Tons |
| 3  | weight of Fuel Oil             | 1.6091 | Tons |
| 4  | weight of fish                 | 2.8    | Tons |
| 5  | weight of cooling ice          | 2.8    | Tons |
|    | **Total**                      | **8.22**| Tons |

Light Weight Ton (LWT) is the weight of an empty ship and consists of the weight of the ship's fiber, the weight of the hull's construction, the weight of the machinery, the weight of the fishing gear, and the weight of the equipment used. The weight components of fishing boat LWT are shown in Table 9 as follows.
Table 9. Breakdown weight of LWT Fishing vessel

| No | Item LWT       | value | unit |
|----|---------------|-------|------|
| 1  | Hull weight   | 0.93  | tons |
| 2  | deck weight   | 0.819 | tons |
| 3  | construction  | 0.35  | tons |
| 4  | wall of weight| 3.24  | tons |
| 5  | roof of weight| 0.0704| tons |
| 6  | polycarbonated glass | 0.0086 | tons |
| 7  | machinery outboard | 0.434  | tons |
| 8  | equipment and supplies | 4.536 | tons |
| 9  | bathroom weight | 0.065  | tons |
| 10 | passanger room weight | 0.015  | tons |
| 11 | navigation room weight | 0.06   | tons |

Total  10.506 tons

In principle, the capacity of the ship is designed to be sufficient to accommodate fish, fuel, water, engine room, accommodation space, etc [20, 21]. Fish hatch is a room under the deck that is used for storing catches [22]. In the planning of loading capacity of the fish cargo system that is using a standard system that is assumed to transport catches to a state of death and use a cooling system in the form of ice, where the ratio of fish and ice is 1 ton for fish: 1 ton for blocks of ice. Planning of fish hold capacity and ice requirements as shown in Table 10 as follows:

Table 10. Arragement cargo space for fish & ice

| Weight & Space volume of fish | Fishing Storage system | bulk ice | tons/m\(^3\) (fresh fish on bulk) |
|------------------------------|------------------------|----------|----------------------------------|
| Est. amount of fish yield per day | 507                    | pcs/day  |
| Est. total fish weight       | 5                      | kg/pcs   |
| total weight of fish         | 2535                   | kg/day (2.54 tons) |
| space volume for fish        | 1.27                   | m\(^3\) (exclude ice) |

| Weight & Space volume of ice | ice requirement per tonne of fish | 1         | tons/tons fish |
|------------------------------|----------------------------------|-----------|----------------|
| total ice demand             | 2.54                             | Tons      |
| ice of stowage factor        | 1.5                              | m\(^3\)/tons |
| space volume for ice         | 1.69                             | m\(^3\)   |

Total space requirement 2.96 m\(^3\)

\(W_{\text{tot}}\) (payload) 5.08 tons

Table 10 shows that the bulk storage method is by stacking fish in layers and alternating with a layer of ice in the hold which is essentially coated in ice ± 15 cm thick [23]. The technique of cooling fish with a mixture of ice and sea water has advantages, namely, the rate of fish cooling takes place faster, the pressure on the body of the fish is reduced and the process of unloading is faster [24]. Lack of fish cooling techniques with a mixture of ice and sea water that is the temperature in the hold is not evenly distributed if the circulation is not good, so the temperature of the fish is not uniform and the process of salt penetration into the body of the fish [25].

This study plans fishing equipment that is not destructive and disturbing in accordance with government regulations [26]. This fishing boat uses a gillnet fishing gear consisting of nylon reels knitted to the length desired by the fishermen who then in the net are given lead as ballast to sink the
net. Where the minimum total weight of lead that is usually used is 12 kg. Gillnet fishing gear as shown in Figure 11 as follows [27]:

![Figure 11. Gillnet of Fishing Gear](image)

This catamaran hull fishing boat is designed to transport 5 crew members, so safety planning must be carried out taking into account the number of people on board and the accommodation space on board. In designing the Safety Plan, it is necessary to look at life saving appliances and fire control equipment that refers to SOLAS (Safety of Life at Sea) [28]. Every ship that sails must have safety equipment to support the factors of life in the middle of the sea. In this catamaran planning, safety equipment consists of: a) life jacket; b) life buoy; c) first aid kit and medicines; d) fire fighting equipment consisting of CO₂ and foam.

4. Conclusions
Research assisted with this computational software has obtained technical information of catamaran hull vessels and the main dimensions are Length of overall (LOA) = 16.2 [m], beam (B) = 6 [m], beam of each hull (B1) = 1 [m], height (H) = 2 [m], draught (T) = 1 [m], Crew of number = 5 person, speed (Vs) = 6.5 [Knots], and vessel capacity ± 40 [GT]. The required of Catamaran is a power of 134,498 [HP] consist of two engine 70 [HP]. For stability analysis based on International Maritime Organization (IMO) section A.749 and High Speed Craft 2000 annex 7 Multihull criteria, it can be concluded that all Loadcase scenarios planned on catamarans meet the stability criteria. Further research will analyze the stability of the ship with 0 ~ 100% payload and consumable conditions added variable wave properties.

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