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RESISTANCE REDUCTION ON TRIMARAN SHIP MODEL BY BIOPOLYMER OF EEL SLIME

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Abstract:

Resistance reduction in ship becomes an important issue to be investigated. Energy consumption and its efficiency are related toward drag reduction. Drag reduction in fluid flow can be obtained by providing polymer additives, coating, surfactants, fiber and special roughness on the surface hull. Fish skin surface coated with biopolymers viscous fluid (slime) is one method in frictional resistance reduction. The aim of this research is to understand the effect of drag reduction using eel slime biopolymer in unsymmetrical trimaran ship model. The investigation was conducted by towing tank test with variation of speed. The dimension of trimaran model are L = 2 m, B = 0.20 m and T = 0.065 m. The ship model resistance was precisely measured by a load cell transducer. The comparison of resistance on trimaran ship model coated and uncoated by eel slime are shown on the graph as a function of the total drag coefficient and Froude number. It is revealed that the trimaran ship model with eel slime has higher drag reduction compared to trimaran without eel slime at similar displacement. The result shows that the drag reduction is about 11 % at Fr 0.35.

Keywords: Resistance reduction, trimaran ship model, biopolymer eel slime.

1. Introduction

The population of multihull vessel achieves 40% from vessel statistics in the entire world (Papanikolau, 2005). Multihull vessel has many applications, such as: high speed ferry, hydrographic ships, and submarine rescue ships, mine countermeasure ships, environmental protection ships for oil spill recovery (Dubrovsky, 2005). The application of multihull vessel as transportation modes has been continuously developed and run into rapid growth in recent years (Moraes, 2007). Trimaran as an example for multihull vessel compared to catamarans and mono hull has more characteristics especially in few aspects, i.e., its efficiency (Degiuli et al., 2005) indicate that trimaran has peculiarity such as extended deck, lower draft and better transverse stability compared to monohull vessels. Meanwhile, trimaran with three hulls has more considerable attention because it's bigger deck area and shallower-draft (Utama, 2007). In the engineering process, multihulls vessel has many technical challenges compared to monohull ship design, characterized by a more complex configuration and operating at higher speeds. In the multihull vessel, the problem of drag reduction still widely discussed. Compared to monohull the complexity of trimaran affecting the component of resistance excessively, i.e., the interaction between viscous and wave resistance components in a multihull. The configuration of the trimaran with high length-to-breadth L/B ratio will reduce its wave making resistance. Also, the low length-to-draft L/T ratio of the trimaran enable to accessing the inaccessible area compared to monohulls with similar sizes.

Additive solution, e.g., biopolymer in one of method for reducing drag phenomena in ship. Biopolymers, as for example, high molecular weight polysaccharides produced by living organisms can provide effective drag reduction. Polysaccharides from several fresh water and marine algae, fish slimes, seawater slime and other fresh water biological growths have been found to be good drag reducers (Hoyt, 1975).

Hoyt (1975) have investigated the effect of additional hagfish slime and drag reduction until 14.5%. Ripken and Pilch (1964) reported that slime dogfish was able to reduce the flow resistance. Rosen and Neri (1970) also have examined the variety of slime produced by several species of river and sea fish. From the study concluded that a reduction in the flow resistance. Tests were conducted using a rheometer.

Yanuar et al. (2011) investigated experimentally the drag reduction effects due to the utilization of slime solution into a mono-hull ship at the basin. Yanuar et al. (2011) found that the slime effectiveness for drag reduction is up to 8%. Also, Yanuar et al. (2012) conducted an experimental investigation for the drag reduction effects due to the utilization of slime solution into a catamaran ship model at the basin. The test results indicate an effective drag reduction is up to 7% at Fr = 0.45. Yanuar et al. (2012) also investigated drag reduction on

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navy fast patrol boat (FPB) 57 m type model with the following main dimensions: L=2450 mm, B=400 mm, and T=190 mm using micro bubble. The injection of micro bubble behind the mid-ship is the optimal location to obtaining the most effective drag reduction, which can reach 6%–9%.

In the 2012, Yanuar et al. (2013) have investigated the effect of unsymmetrical trimaran ship model. Ship model configuration is varied by 5 configurations, there is: S/L = 0.1; 0.2; 0.3 with R/L = 0. The two other are: S/L = 0.3 with R/L = 0.1 and S/L = 0.3 with R/L = 0.2. The result indicate the effective drag reduction can be obtained up to 17% at Fr = 0.35 with configuration S/L = 0.1 .The study focused on the estimation of drag reduction in resistance of trimaran ship model by using eel slime biopolymer and conducted experimentally using towing tank test. The trimaran model with main hull L = 2 m, B = 0.20 m and T = 0.065 m, conducted at towing tank facilities with variation of speed and adjustment. The experiments were conducted in a range of Froude number 0.1 up to 0.7. The ship model resistance was precisely measured by a load cell transducer. The comparison of trimaran ship model resistance for each position where eel slime coated and uncoated is shown on Fig. 4 as a function of the total resistance coefficient and Froude number.

2. Experimental Set-up

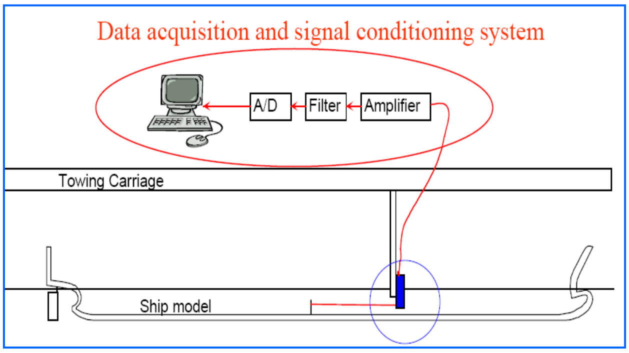

Fig. 1: Experimental set-up

Fig. 1 shows the experimental set-up in the towing tank. The towing tank with length of 50 m, width of 20 m, and water depth of 2 m is used for this research. The experimental set-up consists of load cell transducer, trimaran models, data interface and computer. Ship model conducted in a towing carriage with a constant speed. The comparison of the total resistance between trimaran ship models with coated slime and uncoated slime is analyzed. Total resistance was measured by a load cell transducer for each and carried out on the range of Froude numbers. The load cell transducer was connected to the trimaran model amidships and vertically above the base line, allowing the model to move freely in the vertical plane. Ship model run was kept stable by controlling of towing carriage. Testing is conducted by recording the results of the string tension on the load cell through the data acquisition in the computer. In this investigation, the total resistance is obtained through a load cell reading which is placed on the towing string. So the string tension is the total resistance of ship models. The results then processed using a string tension value to obtain the total drag coefficient as function of the Froude number. Model tests conducted on the trim condition of 2–3 degrees with range of Froude number between 0.05-0.65.

Fig. 2 shows the lines plan of trimaran (Unsymmetric outboard side hull configuration) for test model. Trimaran consists of a slender center hull also called the main hull and two slender outer hulls which much smaller size also called the side hulls or outriggers, Wang (2011). In addition, Fig. 3 shows positions of eel slime on trimaran’s main hull. There are three types slime position of configuration to compared and investigated the influence of slime positioning , such as position 1 (0-15% Lwl from the bow), position 2 (15%-30% Lwl from the bow) and position 3 (30%-45% Lwl from the bow). Eel slime positioning on the ship hull is conducted using special gum (Cyanoacrylates). Location of the eel skin varied in the three areas: in front, middle and backside of ship model. The aim of this study is to understanding the influence of eel skin location in the same size. Total area of eel skin used is the ratio of the length of the corresponding percentage seen in Fig. 3. Reynolds number used ranged from 1 x 106 to 6 x 106 and has entered the turbulent zone.

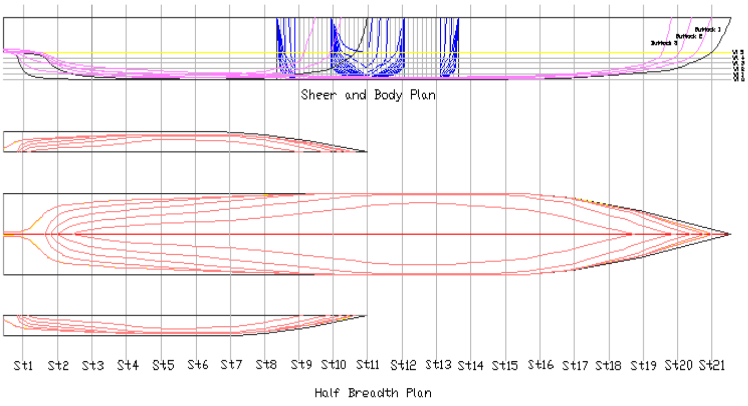

Fig. 2: Lines Plan of Unsymmetrical Trimaran

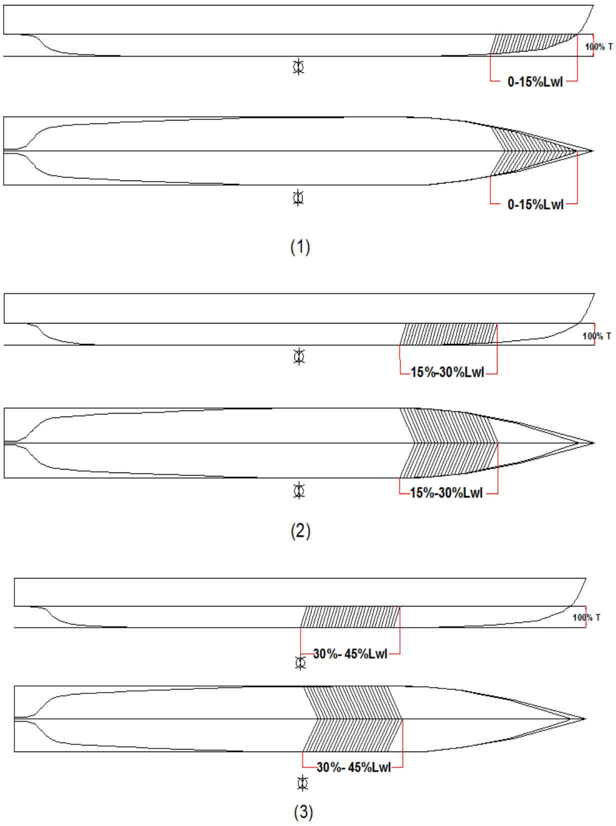

Fig. 3: Positioning of Eel Slime on Trimaran's Mainhull

Table 1: The main dimension of trimaran ship model

Parameter	Mainhull	Sidehull	Unit
L	2.00	1.00	M
B	0.20	0.10	M
T	0.065	0.065	M
Disp	12.5	5.5	Kg

Table 1 Show the main dimension of trimaran ship model which is used in the model test.

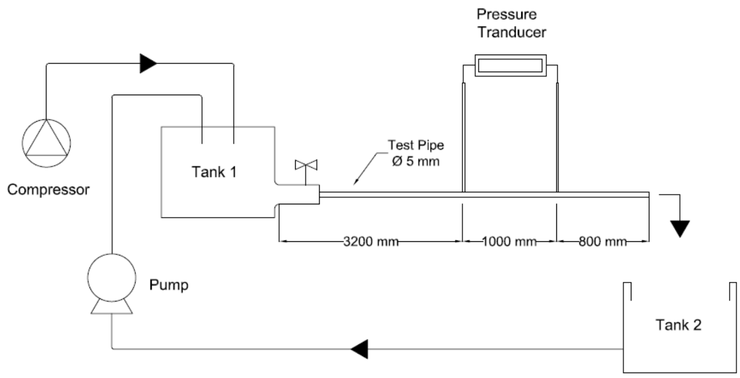

Fig. 4: Experimental set-up

Fig. 4 shows the rheological properties. The eel slime polymer solution in the tank is circulated by piston pump. The flow of polymer solution is conducted by compressor to test pipe. The pressure drop gradient is measured at 1000 mm length between each pressure tap by pressure transducer. The diameter of pressure tap is 2 mm. The inner diameter (d) of circular pipe is 5 mm. The shear stress and the shear rate can be obtained by measuring the pressure drop gradient and its velocity gradient, respectively. The concentration of eel slime polymer in aqueous solution is 250 ppm and 500 ppm. The temperature is kept at 27^{o}C. Eel slime polymer was used in this investigation. Slime is a viscous liquid on the skin of an eel. The data for testing the round pipe (rheology) is conducted in the same way as Yanuar (2011).

3. Test Analyses

The shear stress is proportional to the velocity gradient (shear rate), can be described by power law model:

$$\tau = K(\gamma)^n \tag{1}$$

K and n are constant for the particular fluid. The higher value of K, the more viscous the fluid. For n=1 is for Newtonian behavior K=μ corresponds to the Newtonian viscosity. For pseudo-plastics model is obtain if n<1 and if n>1 for dilatants model. The Newtonian viscosity depends on the temperature and the pressure and independent to the shear rate. The viscosity is defined as the ratio of shear stress to shear rate. Several rheological models or rheological equations of state have been proposed to describe the nonlinear flow curves of non-Newtonian fluids. Bingham, pseudo-plastics, and dilatants are the non-Newtonian fluids which the flow curve is non-linear. The viscosity of a non-Newtonian fluid is not constant at a given temperature and pressure, but depends on other factors such as shear rate in the fluids. Thus, the connection between shear stress and shear rate is described by measuring the pressure drop gradient and the volumetric flow rate in circular pipe flow is given by:

$$\frac{D\Delta P}{4L} = K\left(\frac{8u}{D}\right)^n \tag{2}$$

Where: D is the inner pipe diameter, ΔP is pressure drop, L is the length of pipe (test section), K is consistency of the fluid, n is power Law index, u is the average velocity.

Power Law Index (n), can be obtained from equation:

$$n = \frac{d\ln(D\Delta P/4L)}{d\ln(8u/D)} \tag{3}$$

The coefficient of n is the determinable from the slope of a log-log plot of DΔP/4L versus 8u/D where ΔP/L is the pressure gradient at a flow velocity, in a pipe of diameter D. The characteristics of eel slime used a power-law index values, the connection between shear stress and velocity gradient (flow curve) determines the power-law index (n). N value determines the type of non-Newtonian fluids such as pseudoplastis. For chemical and physical properties was not be investigated.

The apparent viscosity can be obtained from equation:

$$\eta = K(\gamma)^{n-1} \tag{4}$$

The total resistance of a ship in the water medium is divided into two principal components: frictional resistance and residual resistance. Total resistance coefficient can be defined as:

$$R_T = R_R + R_F \tag{5}$$

Where:

R_T is total resistance, R_R is residual resistance and R_F is frictional resistance.

The total resistance is directly found from the measured load cell during the test.

The total resistance coefficient C_T has been calculated as:

$$C_T = \frac{R_T}{0.5\rho S V^2} \tag{6}$$

Where ρ is water density and S is the wetted area of the ship hull.

The Froude number is defined as:

$$Fr = \frac{V}{\sqrt{gL}} \tag{7}$$

Where V is the speed of the ship, L is the length of the ship, g is acceleration of gravity.

Reynolds number is obtained by:

$$\mathrm{Re} = \frac{\rho V L}{\mu} \tag{8}$$

Drag reduction is obtained by:

$$DR(\%) = \left| \frac{C_T - C_{TO}}{C_{TO}} \right| \times 100\% \tag{9}$$

where C_{TO} is the total coefficient resistance of trimaran uncoated by eel slime and C_T is the total coefficient resistance of trimaran model coated by eel slime.

4. Results and Discussion

Fig. 5 shows the flow curve of the slime solution measured by a horizontal circular pipe. The temperature is maintained at T = 27o C during the experiments as the rheology is temperature dependent. Using standard tangent-drawing procedures, tangents are drawn to the curve at various 8V/D, to obtain correspondence value of n from the tangent slop and K from the tangent intercept at 8V/D equal to unity. The flow curve shear Stress τ is plotted against shear rate, du/dy for slime solution at 250 ppm and 500 ppm. The plot data for slime solution is not parallel, indicating the material is a Power Law fluid over the range of shear stress. Since the value from all there particle volume of solution on the same single curve, the value of power law index for slime solution are n = 0.78-0.85

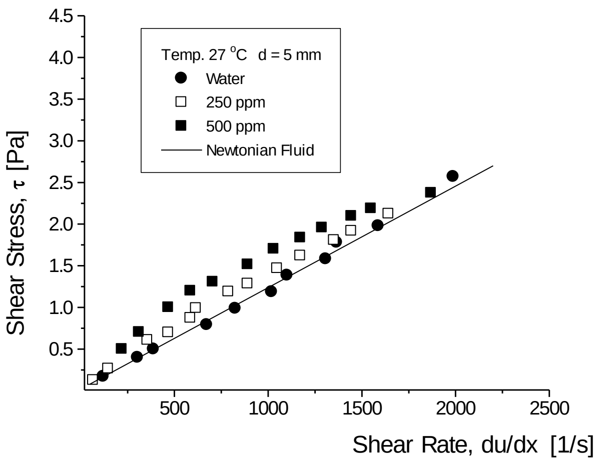

Fig. 5: Rheological behavior of eel slime solution

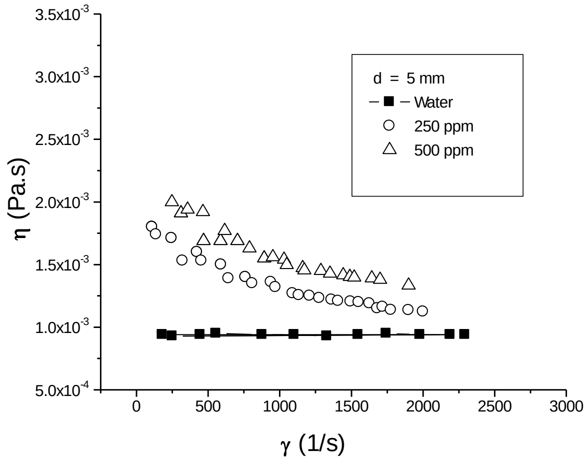

Fig. 6: Apparent Viscosity of eel slime solution

In Fig. 6, measurement of the viscosity of eel slime solution is conducted by horizontal pipe viscometer and the data of slime solution at 250 ppm and 500 ppm, the solution are presented apparent viscosity versus shear rate in Fig. 6. It was shown that the viscosity decreases with an increasing of gradient velocity. Measurements of viscosity depend on the type of viscometer and the hysteresis of the shear stress or shear rate, because the viscosity of slime solution depends on many parameters and the generalized Reynolds numbers, Re', is calculated using the apparent viscosity of slime solution.

Fig. 7 shows the relationship between total resistance coefficient (C_T) and Froude number (Fr) for trimaran ship model coated by slime, trimaran model uncoated by slime and monohull model. The coating of eel slime on trimaran ship model was located in 3 different areas. Results show that the total drag coefficient of the ship model has the same trend. The value of total resistance coefficient (C_T) for all trimaran ship models with coated eel slime has positive effects. As indicated by the value of total drag coefficient is lower than the trimaran uncoated by eel slime. The value of total resistance coefficient (C_T) trimaran ship model coated or uncoated by eel slime is lower than monohull ship model. It is influenced by the interference that occurs between the main hull and side hull in trimaran model.

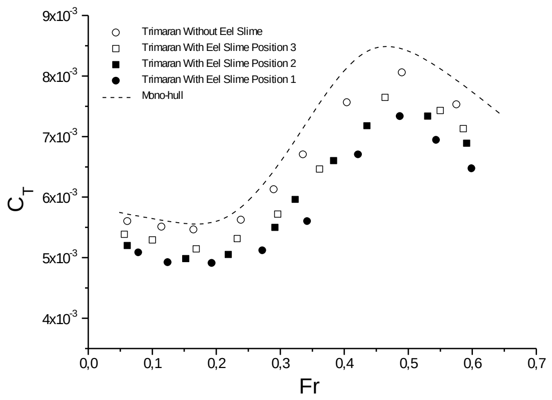

Fig. 7: Total resistance coefficients (C_T) of monohull and trimaran model with and without slime

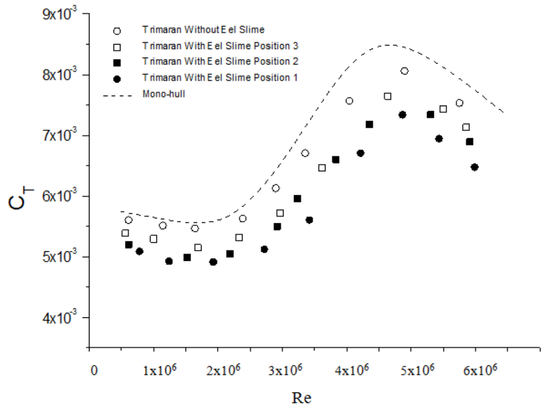

Fig. 8: Relation between total resistance coefficients (C_T) of monohull and trimaran model with and without slime and Reynolds number

In addition, the smaller the value of the total resistance coefficient trimaran ship model coated by eel slime compared with trimaran ship model uncoated by eel slime shows that eel slime affected the total resistance coefficient. Eel slime may affect the velocity distribution in the buffer layer region on the boundary layer. Low shear stress will result in lower resistance anyway. Addition of eel slime or non-Newton liquids except shear stress, there are other parameters affecting the resistance. The mechanism of the reduction of resistance using eel slime still can not be explained properly, further research needs to be investigated in more specialized. The test done repeatedly and get the best data with uncertainty values of about 5%.

Fig. 8 shows the Relationship between total resistance coefficient (C_T) and Reynolds number (Re) for trimaran ship model coated by slime, trimaran model uncoated by slime and monohull model. This graph is shown that the data is in turbulent regime. The value of Reynolds number is about from $1x10^6$ up to $6x10^6$.

Fig. 9 shows the total resistance coefficient ratio between trimaran model coated by eel slime and coated by eel slime as a function of Froude number. The value of total resistance coefficient ratio indicates that drag reduction occurred. If the ratio value is equal to or higher than 1 it indicated no drag reduction. If the ratio value is lower than 1, the resistance coefficient of the trimaran model coated by eel slime is lower than trimaran uncoated by eel slime. The best configuration is position 1 because have smaller resistance ratio than position 2 and 3.

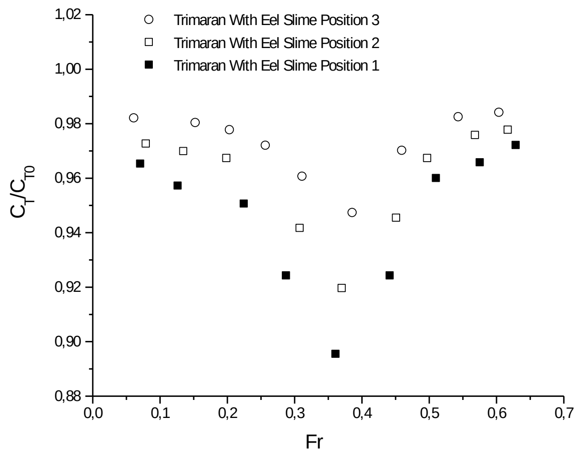

Fig. 9: Total resistance coefficient ratio between trimaran with and without eel slime

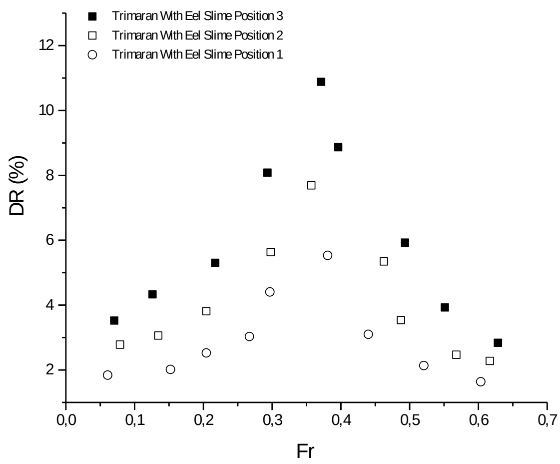

Fig. 10: Relationship between drag reduction (DR%) and Froude number (Fr)

Fig. 10 shows the relationship between drag reduction and Froude number. It shows that the drag reduction for position 1 is greater than 2 and 3 position. The maximum drag reduction is 11% at Fr 0.35. Meanwhile, the values of drag reduction at 2 and 3 positions are 8% and 5% respectively. The high viscous fluid in eel slime was effectively reduced resistance in ship model for this configuration.

5. Conclusions

This paper experimentally investigates the influence of eel slime on the wall of trimaran ship model. The result shows that the trimaran ship model coated by slime provide less total resistance coefficient than trimaran ship model uncoated by slime at the same displacement. The drag reduction in the position 1 has the greatest value compared to the other positions. The maximum drag reduction for this research is 11 % at Fr 0.35. The eel slime solution behaves as the shear thinning fluid. The power law model describes approximately the behavior of slime solution. The range of the power law fluid index (n) is of 0.78-0.85.

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