# 旋網用油圧ウインチの力学特性



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| 著者 | 町井, 紀之<br>能勢, 幸雄 |
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# Mechanical Properties of a Hydraulic Purse Winch

Tadanobu Machii*[1] and Yukio Nose*[2]

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Relationships of velocity ($V_w$; m/s) and of effective force ($F_w$; kgw) of a hydraulic purse winch during fishing operation were obtained by using only the engine revolution ($N_e$; rpm) and the effective output pressure of an oil pump ($P-P_0$; kgw/cm$^2$), respectively. Using the loaded (*i.e.* pulling the net) $P$ (kgw/cm$^2$) and the non-loaded (*i.e.* without pulling the net) $P_0$ (kgw/cm$^2$) pressure of the pump, $V_w$ and $F_w$ could be expressed respectively as

$$V_w = k_v\,(q_p/q_w)N_e \qquad \text{and} \qquad F_w = k_f q_w\,(P-P_0)\,,$$

where $k_v$ and $k_f$ are constants, $q_p$ ($l$/rev) and $q_w$ ($l$/rev) are the displacement of the pump and the winch, respectively. Without using special instruments, $V_w$ and $F_w$ of the purse winch can be calculated applying the equations obtained. This simplified method is useful for the Third World Countries where sufficient instruments could not be provided for research works mainly due to economic problems.

A purse seine operation requires a strict mechanical correlation between the winch, the fishing gear and the fishing boat. Therefore, mechanical properties such as velocity and force of hydraulic purse winch (henceforth shall be referred to as "winch") are fundamental factors in designing fishing gear and examining the safety of fishing boats during fishing operations.

Studies on purse winches with regard to fishing gear such as that of Torban[1] are very limited in the world.

One of the reasons for the scarcity of the study is the difficulty of practical measurements on mechanical properties at sea during fishing operation as well as the difficulty in installing instruments on board, and the obstruction of the fishing operation.

Accordingly, the purpose of this study is to derive the mechanical relationships on velocity and on effective force of winch by using only the revolution of an engine and the output pressure of an oil pump, respectively, *i.e.* without utilizing special instruments on board.

## Mechanical Properties

### *Velocity of Winch*

Fig. 1 shows a simple driving system of the oil pump to be examined here. The pump's revolutions ($N_p$; rpm) are written in terms of the revolution of the engine ($N_e$; rpm) as

$$N_p = (D_e/D_p)\eta_t N_e\,, \qquad (1)$$

where $\eta_t$ is the transmission's efficiency of the oil pump's driving system, and $D_e$ (m) and $D_p$ (m) are the diameters of the pulley of the driving system connected to the engine and the pump, respectively.

The pump's output flow rate ($Q$; $l$/min) is expressed in terms of the displacement of the pump ($q_p$; $l$/rev) as

$$Q = \eta_{vp} q_p N_p\,, \qquad (2)$$

where $\eta_{vp}$ is the volumetric efficiency of the pump.

From Eqs. (1) and (2), $Q$, of the pump, can be represented as

$$Q = k_q q_p N_e\,, \qquad (3)$$

where

$$k_q = (D_e/D_p)\eta_{vp}\eta_t\,.$$

$Q$, the input of the winch, is presented in terms of the displacement of the winch ($q_w$; $l$/rev) and the revolution of the winch ($N_w$; rpm) as

$$Q = (q_w/\eta_{vw})N_w\,, \qquad (4)$$

where $\eta_{vw}$ is the volumetric efficiency of the winch.

*[1] Department of Marine Science and Technology, Tokyo University of Fisheries, Konan, Minato, Tokyo 108, Japan (町井紀之：東京水産大学海洋生産学科).

*[2] University Museum, The Tokyo University, Hongo, Bunkyo, Tokyo 113, Japan (能勢幸雄：東京大学総合研究資料館).

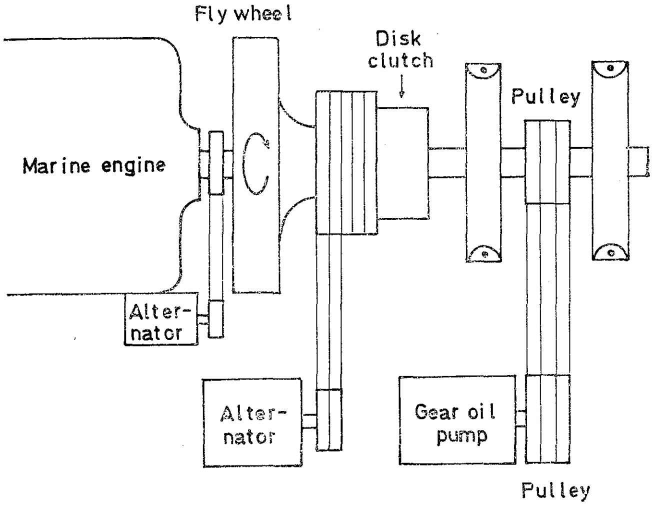


**Fig. 1.** Driving system of oil pump.

Equalizing Eq. (3) to Eq. (4), $N_w$ is represented as

$$N_w = k_n(q_p/q_w)N_e \, , \qquad (5)$$

where

$$k_n = k_q \eta_{vw} \, .$$

On the other hand, the velocity of the winch ($V_w$; m/s) is written as

$$V_w = (\pi/60)D_w N_w \, , \qquad (6)$$

where $D_w$ (m) is the diameter of the warping drum of the winch.

Consequently, substituting Eq. (5) into Eq. (6), $V_w$ is expressed in terms of $N_e$ as

$$V_w = k_v(q_p/q_w)N_e \, , \qquad (7)$$

where

$$k_v = k_n(\pi/60)D_w \, .$$

*Effective Force of Winch*

Fig. 2 shows a simple hydraulic circuit. Since the connection of the circuit is done with short oil tubes in the case of a small purse seiner, reduction in pressure of the circuit is assumed to be negligible in this study.

Input horse power of the winch ($HP_i$; ps) is presented in terms of the input pressure of the winch ($P$; kgw/cm$^2$) at loaded condition during pulling of the fishing gear as

$$HP_i = (PQ)/450 \qquad (8)$$

and the output horse power of the winch ($HP_w$; ps) is expressed by the output torque of the winch

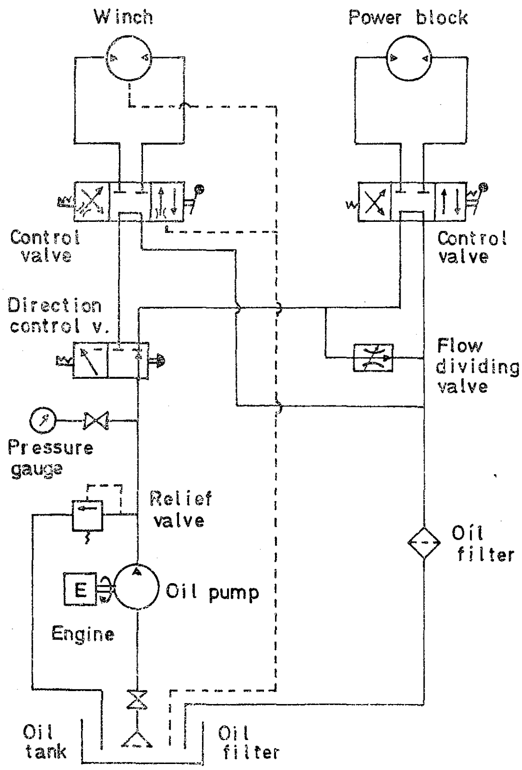


**Fig. 2.** Hydraulic circuit.

($T_w$; kgw·m) as

$$HP_w = (2\pi N_w T_w)/4{,}500 \, . \qquad (9)$$

Expressing the total efficiency of the winch as $\eta_w$, then $HP_w$ is

$$HP_w = \eta_w HP_i \, . \qquad (10)$$

Substituting Eqs. (8) and (9) into Eq. (10), $T_w$ is is represented as

$$T_w = (5/\pi)\{(PQ)/N_w\}\eta_w . \quad (11)$$

The effective oil pressure ($P_r$; kgw/cm$^2$) is written, using the output pressure of the pump ($P_0$; kgw/cm$^2$) at non-loaded condition when the fishing gear is not being pulled, as

$$P_r = P - P_0 .$$

Replacing $T_w$, $P$ and $Q/N_w$ by $T_r$, $P_r$ in Eq. (11) and $q_w/\eta_{vw}$ in Eq. (4), the effective output torque of the winch ($T_r$; kgw·m) is expressed as

$$T_r = k_t q_w (P - P_0) , \quad (12)$$

where

$$k_t = (5/\pi)(\eta_w/\eta_{vw}) .$$

The effective horse power ($HP_r$; ps) can be expressed in the same form as Eq. (9) by replacing $HP_w$ and $T_w$ by $HP_r$ and $T_r$ respectively. Hence,

$$HP_r = (2\pi N_w T_r)/4{,}500 . \quad (13)$$

Substituting Eqs. (5) and (12) into Eq. (13), $HP_r$ is obtained as

$$HP_r = k_h q_p (P - P_0) N_e , \quad (14)$$

where

$$k_h = (k_q \eta_w)/450 .$$

Generally, the force of the winch ($F_r$; kgw) is written as

$$F_r = (75/V_w) HP_r . \quad (15)$$

Consequently, the effective force of the winch ($F_w$; kgw), considering the kinetic friction ($\mu$) between the warping drum of the winch and the purse line, is given as

$$F_w = (1 - e^{-\mu\theta}) F_r , \quad (16)$$

where

$$\theta = 2\pi n .$$

Also, $n$ is the winding number of the purse line for the warping drum and $\theta$ is the contact angle of the purse line for the warping drum.

Therefore, substituting Eqs. (7), (14) and (15) into Eq. (16), $F_w$ is expressed in terms of $P - P_0$ as

$$F_w = k_f (1 - e^{-\mu\theta}) q_w (P - P_0) , \quad (17)$$

where

$$k_f = \{(10/\pi)(\eta_w/\eta_{vw})\}/D_w .$$

## Discussion

Since the value of $\mu$ in wet condition is close to $\mu = 0.17$ to 0.24 for polyamide (nylon) and $\mu = 0.50$ to 0.67 for polyvinylalcohol (cremona), which is in accordance with the result of the study of Hirayama and Honda,[2] and the value of $n$ is generally $n \geqq 3$ during fishing operation. Since $e^{\mu\theta} \gg 1$ in Eq. (17), Eq. (17) can be represented practically as

$$F_w = k_f q_w (P - P_0) . \quad (18)$$

Known values are given as follows: The values of $D_p$ and $D_e$, and $D_w$ are given from the specification of the driving system of the pump, and of the winch used. The values of $q_p$ and $q_w$ are always given in the specification of the pump and the winch used. Also, the values of $\eta_{vp}$, $\eta_w$ and $\eta_{vw}$ can be obtained respectively reading each characteristic curves of the pump and the winch used. Figs. (3), (4) and (5) show these curves as examples.

The unknown values are $\eta_t$ and $P_0$. From Eqs. (1), (2), (4) and (6), applying the following equation, $\eta_t$ can be calculated by using measured values $V_w$ and $N_e$ obtained from the experiments as

$$\eta_t = \{(D_p/D_e)/D_w\}(60/\pi)(q_w/q_p) \times \{1/(\eta_{vp}\eta_{vw})\}(V_w/N_e) . \quad (19)$$

The calculated value should be compared with the range $0 < \eta_t < 1$. Generally, the value of $\eta_t$ is from the range of 0.90 to 0.98 in the case of mechanical driving using a $V$-belt. The other unknown value $P_0$ should be measured directly from the condition when the fishing gear is not being pulled.

The equations to determine the velocity (Eq. (7)) and the effective force of the purse winch (Eq. (18)) were derived using only the revolution of an engine and the effective output pressure of an oil pump, respectively. Even small purse seiners using oil hydraulic system are usually equipped with an engine tachometer and an oil pump pressure gauge as essential instruments. Therefore, the methods derived are useful particularly in the Third World Countries, where precise instruments can not be provided mainly due to economic problems.

Though this paper's focus is directed on the derivation of the mechanical relationships of a hydraulic purse winch, the practical application for a Peruvian purse winch during fishing operation can be undertaken in the future study, using the results obtained.

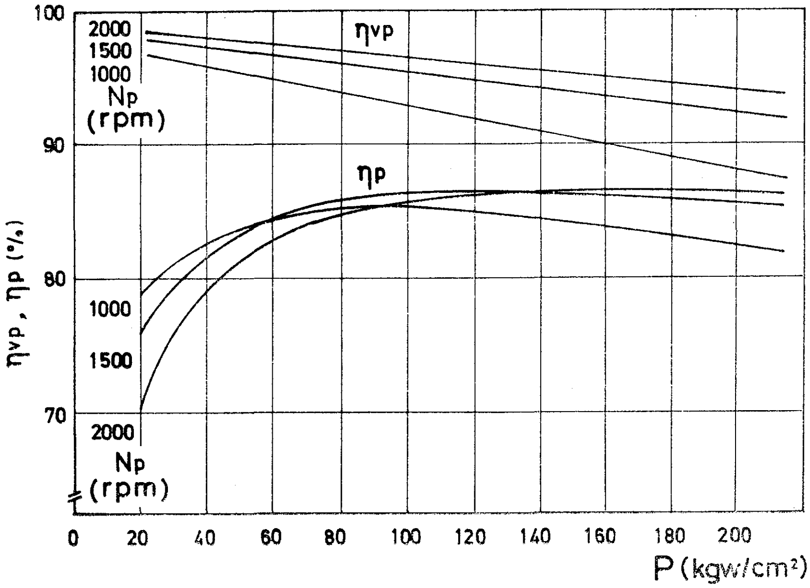


**Fig. 3.** Characteristic curve of volumetric efficiency ($\eta_{vp}$) and total efficiency ($\eta_p$) of oil pump (Simazu SP-40-66-R). $P$; output pressure of oil pump and $N_w$; revolution of oil pump.

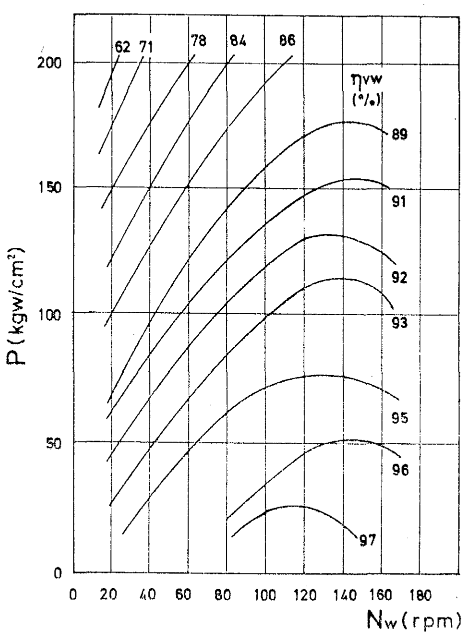


**Fig. 4.** Characteristic curve of volumetric efficiency ($\eta_{vw}$) of hydraulic winch (Ebara OEM-1FW).

$N_w$; revolution of hydraulic winch and $P$; input pressure of hydraulic winch.

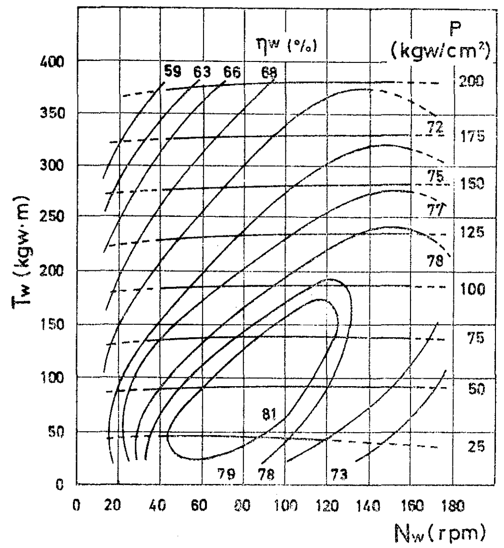


**Fig. 5.** Characteristic curve of total efficiency ($\eta_w$) of hydraulic winch (Ebara OEM-1FW).

$T_w$; output torque of hydraulic winch, $P$; input pressure of hydraulic winch and $N_w$; revolution of hydraulic winch.

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