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Theoretical analysis on new mechanism of purse seine net hauling vertical drum*

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Abstract: In order to improve the feature of net hauling implements, this study seeks after the engineering feasibility of utilizing a new mechanism of vertically moving belt type of net hauling drum in purse seine fishing operation, it is concluded as following.

1) Based on the construction of this new mechanism drum, the friction force to haul net can be greatly increased by increasing angle of contact.

2) As long as the motion of net on the drum, which is made up of vertical moving belts, conform to motion condition equation, it is possible for the drum to make net move in a space spiral and spoil for 3 or 4 turns on the drum.

3) By comparing the tension of the new mechanism with present used implements, the new mechanism is more reasonable and more effective in improving the feature of net hauling implements.

1. Introduction

In purse seine fishing operation, net hauling is one of the most severe labour. In order to save labour, many kinds of net hauling implements have been invented and much more researches have been done (SAHRHAGE, 1992), such as powered block, net hauler and side roller. The powered block is mainly used in bigger vessel fishing operation, the side roller and the net hauler are used in vessel or boat scales. With the development of purse seine fishing. The pull force of hauling net gets larger and larger, the speed of hauling net gets faster and faster. Because the mechanism of present used net hauling implements is that net is wound on the round body for only a little of contact angle, the friction force is limited, sometimes it is not large enough for single set of implements to haul the net (KRISTJONSSON, 1971). To meet the need of fishing operation, some auxiliary equipment is necessarily installed. Net hauler and side roller need autotension-press roller, powered block must be high suspended from the deck with derrick (KANEKO, 1988), or more than one kind of implements is used in same time (MATUBAYASHI, 1992). This not only increases the complex of implements, but also causes some other troubles, such as the decrease of stability, the net damage and the miscooperation among implements.

This study is to pursue a new mechanism of purse seine net hauling implements which can overcome the shortcomings of present used implements and can be suited for the development of purse seine fishing. Based on the designed experimental model of net hauling vertical drum, the structure and performance of new drum are theoretically analyzed as following.

2. The operation principle of new mechanism net hauling drum

At present, the tendency of purse seine fishing in the world is toward to single vessel operation from group vessel operation. To adapt to the change, the features of purse seine net hauling implements must be improved to meet the need of fishing operation in pull force,

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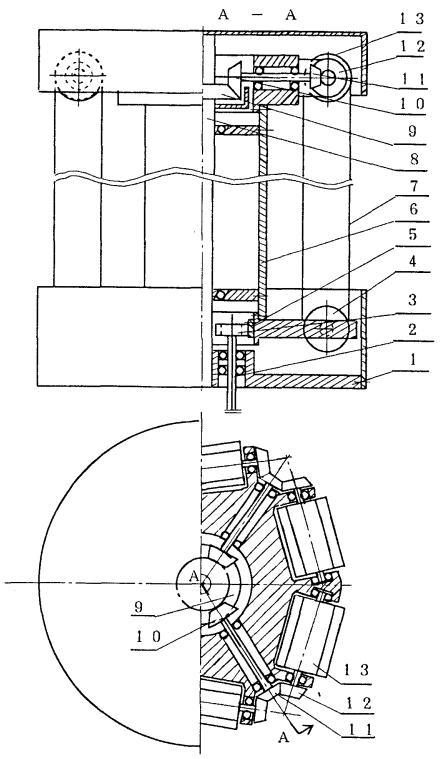


Fig. 1. Transmission draft of new mechanism net hauling drum. 1: Baseplate, 2: Driving shaft, 3: Driving gear, 4: Driven belt pulley, 5: Driven gear, 6: Supporting structure, 7: Synchronous belt, 8: Fixed main shaft, 9: Fixed gear, 10, 11, 12: Bevel gear, 13: Driving belt pulley.

speed and structure. For this special consideration, as a part of study on purse seine net hauling implements, the designed vertically moving belts type of new mechanism drum is adopted as the object of this study.

Just as Fig. 1 shown, The whole body of the drum is installed on the deck with the baseplate 1. The driving shaft 2 makes the supporting structure 6 revolve with the whole drum through gear 3 and gear 5. As the drum revolves, the bevel gear 10 turns, which meshes with the fixed centre bevel gear 9. Power is transferred to the driving belt pulley 13 by bevel gears 12 and 13. So that it is possible for the belt 7 to move up while the drum revolves. When it is used in purse seine fishing operation, at first, the head parts of sinker line and cork line are connected to a guiding rope which have been wound around the drum for 3 or 4 turns, then, the implements start to run. During net hauling operation, the guiding rope leads net to pass through a net binding groove and the bound net bundle is guided to wind on the drum which is made up of several belts around. While the net rotates with drum it is carried up by the belts. In normal operation, the wound net is stationary on the belts of drum. After passed through 3 or 4 turns in space spiral, the net is transported to certain height to reach an net outgoing groove to be handled. Because the net is carried to move in space spiral and the pitch of spiral is a little larger than the width of net bundle, the net can be wound for 3 or 4 turns around the drum without any interference among the turns. In this way, the contact angle between net and drum is enlarged and the pull force for hauling net can be greatly increased. Based on this operation principle, the new mechanism net hauling drum has the advantages of considerable pull force, appropriate hauling velocity, convenient net handling and reasonable construction.

3. The theoretical analysis of the new mechanism net hauling drum

Refer to the construction and the principle of the net hauling drum, its motion conditions and advantages can be analyzed as following.

3.1 The kinematic analysis of net motion

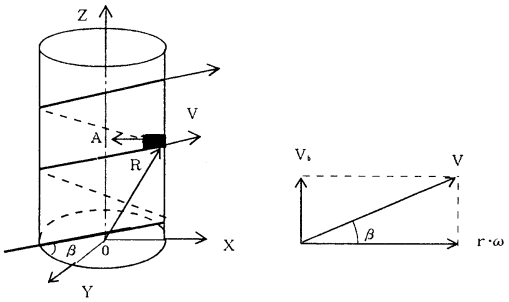
As a net hauling implements, in order to increase contact angle and pull force, in this study the space spiral is adopted as the locus of net motion on drum when the implements work. To realize the spiral motion of hauled net, it is necessary to analyze the motion condition and to determine motion calculation of mechanism just as following kinematic analysis.

As Fig. 2 shown, if taking a little length of net as moving particle, its motion vector equation is

$$R(x, y, z)=xi+yj+zk$$

The velocity vector equation is

$$v=x'i+y'j+z'k$$



(a) (b)

Fig. 2. The kinematic analysis chart. A: Centripetal acceleration of net motion, V: Speed of net motion, R: Radius vector of net motion, V_b: Speed of belt in vertical motion, $r \cdot \omega$: Tangent volfcity of net motion, a: The vector chart of net motion, b: The vector chart of velocity, X: X coordinate axis, Y: Y coordinate axis, Z: Z coordinate axis, β: spiral ange, ■: a little length of net.

The acceleration vector equation is

$$A = x''i + y''j + z''k$$

Suppose that both the rotaion of drum and the up motion of belt are uniform. The parametric equation is

$$x = r \cos \omega t$$
$$y = r \sin \omega t$$
$$z = v_b t$$

So that, the value of velocity can be calculated with following formula:

$$v = \sqrt{\chi'^2(t) + y'^2(t) + z'^2(t)} = \sqrt{r^2\omega^2 + V_b^2} \quad (1)$$

The value of acceleration can be calculated as following:

$$A = \sqrt{x''^2(t) + y''^2(t) + z''^2(t)} = r\omega^2 \quad (2)$$

In formula (1) and (2), r is the radius of drum, ω is the angular velocity of drum, t is the time, v_b is the velocity of belt in up motion, v is the velocity of net motion in space spiral and A is the centripetal acceleration of net motion.

From the velocity vector figure (Fig. 2), the relation equation of v, $r\omega$ and v_b can be showed as following:

$$v_b = v \sin \beta \quad (3)$$
$$r\omega = v \cos \beta \quad (4)$$

The β is the spiral angle of space spiral for net motion on drum. Its value can be selected by changing radius r or pitch h which is the height of net moving for the each turn or rotation.

$$\beta = \tan^{-1} \frac{h}{2\pi r}$$

As mathematical analysis equation above, when the drum works, in order to make the hauled net move in space spiral on the drum, the motion velocity must conform to the motion condition equation (1), (3) and (4). From the acceleration equation (2), $r\omega^2$ is the normal acceleration and the tangential acceleration is zero. On the condition that both the rotation of drum and the motion of belt are uniform, the space spiral motion of hauled net dose not cause any impulse.

3.2 The mechanical analysis of net hauling drum

According to Euler's equation for the tension of winding soft thing on the round body, the mechanism of net hauling drum can be analyzed as following (The Japanese Society of Fisheries, 1956):

$$s_1 = s_2 e^{\mu \alpha} \quad (5)$$

In this equation, s_1 is determined by the load of net operation. It can not be changed by implements itself. s_2 is acting force for hauling net by fishermen or other external force. The smaller is its value, the better. To reduce the value of s_2 the $\mu\alpha$ has to be increased. μ is corresponded with the material of bothe round body and net. It is difficult to increase its value. So that, the technical critical point to improve the performance of net hauling implements is to increase the angle of contact α.

In the situation of this drum, the angle of contact is divided into many parts by the belts, as showed in Fig. 3.

If taking one of those as α, the pull force can be calculated with following formula:

$$s_1 = s_2 e^{\mu \alpha},\ s_2 = s_3 e^{\mu \alpha},\ s_3 = s_4 e^{\mu \alpha} \cdots,$$
$$s_1 = s_3 e^{2\mu \alpha} = s_4 e^{3\mu \alpha} = \cdots = s_n e^{(n-1)\mu \alpha}$$

The condition equation of preventing net to slip on the drum is

$$s_1 \leqq s_n e^{(n-1)\mu \alpha} \quad (6)$$

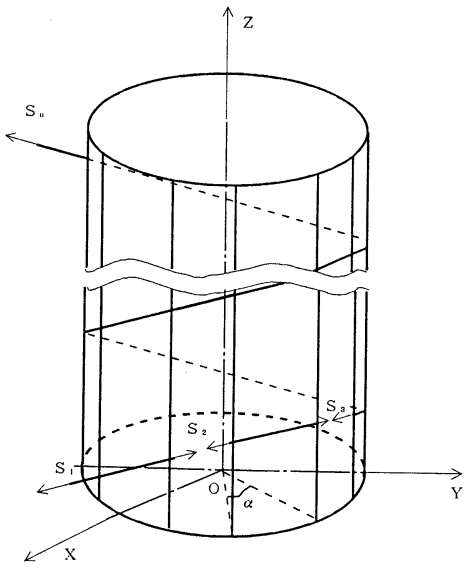


Fig. 3. The tension chart of new mechanism net hauling drum. S_1: Tension on the incoming end of net, S_2: Tension on the outgoing end of first passing belt, S_3: Tension on the outgoing end of seond passing belt, S_n: External force in the outgoing end of net, α: Contact angle of each belt, X: X coordinate axis, Y: Y coordinate axis, Z: Z coordinate axis.

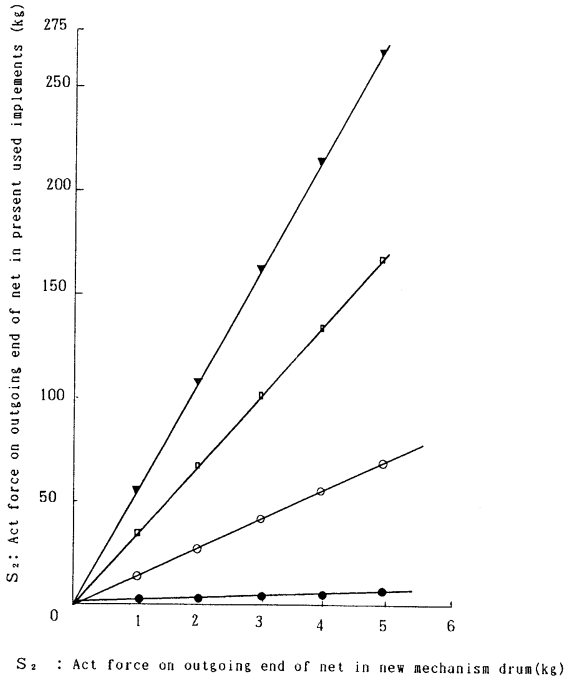


Fig. 4. The acting force cmparison chart. N: Number of net winding around the drum, ● : N=1, ○ : N=2, □ : N=3, ▼ : N=4.

In this formula, s_1 is the load force for net hauling in the incoming end. s_n is the external force in the outgoing end of net. n is the number of belts which the hauled net passes through on the drum. Its value can be determined by the number of net winding around the drum and the number of belts.

For the present used purse seine net hauling implements, the calculation of pull force is based on the formula (5). As single set of implements, the angle of contact always conforms equation

$$\alpha \leqq \pi$$

The maximum pull force is

$$s_1 = s_2 e^{\pi\mu}$$

In the situation of this drum, the calculation of pull force is based on the formula (6). By reasonably distributing position of belts, the angle of contact α' for each turn of net winding is always

$$\alpha' \geqq \pi$$

If the number of net winding is N, the minimum pull force is

$$s_1' = s_2' e^{N\pi\mu}$$

Comparing the present used implements with the improved designed drum, the pull force relation equation of net outgoing end becomes as following:

$$\ln\frac{s_1'}{s_2'} = \frac{1}{N}\ln\frac{s_1'}{s_2'} \text{ that is } \frac{s_1^N}{s_2^N} = \frac{s_1'}{s_2'} \qquad (7)$$

In the purse seine fishing operation, the load force is always a given value, suppose that it is $s_1 = s_1' = 1000$ kgf, in the situation of drum, if the number of net winding is $N=3$, the minimum angle of contact is 3π, the act force which is need for hauling net in outgoing end is $s_2' = 5$ kgf. While in the situation of powered block or side roller or net hauler, the maximum contact angle is π and the value of act force shoule be $s_2 = 170$ kgf. It is as more than 30 times much as in drum. The act force relation is shown in Fig. 4. From the formula (7) and

the Fig. 4, we can know that when the load force is ensured, the comparison function of s_2 and s_2' is linear. It would be changed with the change of the value of N, just as shown in Fig. 4. The larger is the N, the more obvious is the change of s_2 corresponding with the s_2'.

4. Discussion

The purpose of studying the mechanism of drum is to improve the feature of purse seine net hauling implements by increasing the angle of contact. From the analysis of construction, kinematics and mechanics, it is possible and feasible. The method to improve the performance of present used net hauling implements by changing its construction to increase contact angle up to 3 or 4 turns is more reasonable, more significant and more effective than to increase number of implements or to combine one type of implements with others in purse seine net hauling operation. As conclusion, if this drum is suitably installed on fishing vessel, it can adapt to the need of changing group vessel operation into single vessel operation in purse seine fishing and can reduce the number of fishermen and save labour. Compared with the present used net hauling implements, it has following specifics:

1) To increase contact angle, the net can be wound up to 3 or 4 turns around the drum. The pull force can be greatly increased. The acting force in the outgoing end can be reduced.
2) The hauled net can be carried to proper height for handling net and stowing it easily.
3) According to the need of hauling force, the acting force can be adjusted by changing the number of net winding around the drum.
4) Because net is carried up by the belts. The wear and tear of fishing gear can be prevented.
5) It not only can be used in purse seine fishing operation, but also can be used in other types of net fishing operation.

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巻網揚網用の新縦型ドラム機構の理論的解析

曹　　広斌・矢田貞美

要旨　揚網用の新縦型ドラムの揚網機構について，従来機構と理論的に比較解析した。本縦型ドラム機構は，ドラムに3，4周巻かれて螺旋運動しながら揚網するので摩擦力が増大し，揚網力も従来機構より大きいものと推定される。