Some Considerations in Energy Conservation of Fishing Boats

—Effect of Propeller Coating—

Kaname SATO*, Tadashi TAKAHASHI*, Hayao AKIZAWA*

Yujiro SAOTOME*, Kiyoshi INOUE* and Yoshio MIYAZAKI*

漁船の省エネルギーに関する一考察

—プロペラ塗装の効果について—

佐藤 要・高橋 正・秋沢 速夫

五月女 雄二郎・井上 清・宮崎 芳夫

抄 録

前報の研究⁽¹⁾においては、自己研磨型防汚塗料（SP 型塗料）の採用が、船底の長期間にわたる清浄性保持にきわめて有効で、省エネルギー効果の高いことを実験的に確認している。この実験の途中で、プロペラの汚損が船底の汚損と同程度に燃料消費量に影響することが判明した。本報においては、プロペラ表面の長期間にわたる清浄性保持のため、プロペラ表面に SP 型プロペラ塗料を塗布した場合の利点と欠点を、基礎実験と実船実験によって確かめ、船底に対する SP 型 A/F の塗装効果と合せ、その省エネルギー性について考察した。

実験は、1) 静的、動的な室内基礎実験、2) 実験船による海上実験にわけて行なわれ、次のような結論を得た。

- 1) SP 型プロペラ塗料はすぐれた密着性と研磨効果により、生物附着と金属腐蝕によるプロペラ表面の粗度増加が抑制され、ほぼ建造時のプロペラ効率を維持することができる。
- 2) プロペラ塗装のための粗度増加によるプロペラ効率の減少は無視してよい。
- 3) プロペラ塗装による船底鋼板の電蝕作用に対する悪影響は認められない。
- 4) SP 型船底塗料と同じく、繫船中の防汚効果も十分期待できる。
- 5) この SP 型プロペラ塗料は、SP 型船底塗料と併用すれば図 1 の G 点に示したようなプロペラ汚損による燃費係数 C の低下を防止することができ、漁船の燃料使用量の軽減、入渠回数の節減に寄与するものと考えられる。

1. Introduction

The problem how to economize propelling energy of ocean vessels has been studied, in general, from a viewpoint of fuel consumption. The same approachment has been applied also to the study of energy saving for fishing boats. As one of possible methods to solve this problem, a long-term maintenance of the ship's hull surface smooth and clean against corrosion, weathering or biological deterioration has been taken into consideration.

The authors conducted the experiments of a type of self-polishing antifouling paint applied to the bottom of the fishing boat hull, and the results were introduced in our previous report entitled "Adoption of Self-Polishing Antifouling Paint."⁽¹⁾ The basic properties of this type of paint were firstly examined through fundamental experiments in the laboratory, and then, a series of field tests were conducted on the

* Members : Tokyo University of Fisheries (4-5-7, Konan, Minato-ku, Tokyo, Japan)

hull coated with self-polishing antifouling paint (SP A/F paint), using the training boat of Tokyo University of Fisheries, M/V Umitaka-maru. The test data were processed by the following equation to find out the fuel consumption coefficient of the experimental boat so that it can be compared with the coefficient obtained from the ship of which hull was coated with conventional insoluble type A/F paint.

$$C = \frac{\Delta^{2/3} \cdot V^3}{Fc} \quad (2)(3)$$

Where, Δ : Displacement of the ship (ton)

V : Velocity of the ship (knot)

Fc : A daily fuel consumption (kilogram)

In consequence, it was found that the fuel consumption coefficient 'C' of the M/V Umitaka-maru was remarkably improved and its value reached the level when she was built; that polishing effect, which is a characteristic performance or quality of SP A/F paint, was exerted in great deal. Thus, it seemed to be sufficient to send the M/V Umitaka-maru to the dockyard only once a year for the maintenance, though she had been, as a rule, sent twice a year. As a matter of fact, the M/V Umitaka-maru sent only once to the dockyard in 1981 which was the 2nd experimental year of this study, because her hull had been assumed smooth and clean due to the effect of applying SP A/F paint of the bottom surface of the hull. The fuel consumption coefficient, however, was considerably reduced in 1982, as seen at G point of the 25th voyage shown in Fig. 1*, due to barnacles attached and stacked on the propellers of which surface had not been treated by any coatings. This enlightens that, even if the bottom of hull is maintained smooth and clean by applying SP A/F paint, a reasonable value of fuel consumption coefficients can not be secured, unless otherwise the propeller surface is kept smooth and clean also. Such caution should be exercised particularly for fishing boats, because barnacles deposit more easily on the bottom and the propeller surface of fishing boats which, in general, come to anchor or moor for a long time in every off-fishing season.

Following to the preliminary experiments in respect of the propeller coating as introduced in our previous report⁽¹⁾, further laboratory experiments and field tests similar to previous ones have been conducted, and both effects of the propeller and the hull coated with SP A/F paint have been examined to find out how much contribution is made by the combined effects for saving of propelling energy of the ship. The results of examination are introduced in this report.

Fig. 1 Changes of fuel consumption coefficient 'C' of the Umitaka-maru

* The same diagram as Fig. 1 is shown also in Fig. 6 of Reference(1)

The presentation is made as a part of the Special Project Research on Energy by the Ministry of Education, Science and Culture, in Japan as same as the previous report⁽¹⁾.

2. Experimental Methods

It has not been virtually practiced to coat the ship's propeller with paint for following reasons.

- a) Mental reluctance against a coating of the propeller of which surface is polished very well like a mirror.
- b) Probable lowering of propeller efficiency due to additional friction caused by paint coated on the surface.
- c) Troublesome work to remove paint from the propeller surface before every periodical inspection.

As one of main subjects of this study, the following experiments were conducted to confirm what is the practical outcome of the propeller coated with paint.

- 1) Static and dynamic experiments were conducted by using a number of test pieces of an alloy with which the propeller was casted and the same kind of steel which the hull was constructed, and a model of the propeller of the experimental boat, M/V Seiyo-maru.
- 2) Field experiments by using experimental boats of which propellers were coated with SP type propeller paint.

The types of paint used for a series of experiments of this study were developed and manufactured by Nippon Paint Co., Ltd.

2.1 Fundamental experiments

2.1.1 Static experiment

Metals exposed to sea water are subject to corrosion⁽⁴⁾ because of electrochemical action that can occur in any salt solution. Such corrosive action is intensified between different metals—a steel with which the hull is constructed and an alloy with which the propeller is casted. As a preventive measure against such a corrosive action for the steel hull, a number of highly purified zinc straps are attached at places over the hull in such a fashion that many more zinc straps are distributed towards the stern. In order to examine the corrosive action in relation to the preventive measure, the metallic and glass-made test pieces with or without a coating were prepared as shown in Table 1, and they were immersed into artificial sea water for 6 months. The hydrogen ion exponents pH of the solution were maintained in the range from 8.0 to 8.2. An air circulation device was arranged so that the surface of each test piece can be always washed by clean solution which was replaced once every 5 days to prevent supersaturation of ions and other dissolved ingredients. Each test piece was taken out of solution at a certain date after immersing for

Table 1 Contents of the test pieces

Material of test pieces	Type of coating	Size (L x B x T) (mm)	Number of test pieces
Glass plate	uncoating	149 x 50 x 1.9	9
	SP type-1 coating		9
	SP type-2 coating		9
Steel plate	SP type-1 coating	149 x 50 x 1.9	9
ALBC-2 (for propeller)	uncoating	149 x 50 x 3.0	9
	SP type-2 coating		9

one, two, and six months, dried and placed into a thermostatic cabinet for weighing by means of an electronic balance.

As for the uncoated test piece of an propeller alloy, not only its weight but also roughness of its surface were measured at every checking date. On the assumption that glass exposed to sea water was not subject to any corrosion, the glass-made test pieces were used as a standard of comparison with which to measure a loss in weight of metallic test pieces.

2.1.2 Dynamic experiment

A series of experiments on how much the influence was exerted by different treatments on the propeller surface were conducted. For the experiment, a model of one thirtieth of the propeller used for the training boat of Tokyo University of Fisheries, M/V Seiyō-maru was made and each of treatments shown in Table 2 was provided, one by one, on the surface of the model propeller. The model propeller with each treatment was operated in a water tank and the thrust and torque of the propeller were measured. A potentiometer and a torque meter were used as the measuring instruments. Efficiency of the propeller was calculated in accordance with each of the different treatments.

Table 2 Conditions of the model propeller surface and surface roughness

Surface treatments of propeller	Surface roughness R max. (μm)
uncoating	1.6
SP type-2	6.5
SP type-2 + sand 1	67.0
SP type-2 + sand 2	185.0

Since the controllable pitch-propeller was used for the M/V Seiyō-maru, a pitch of 16 degrees in angle was applied to the propeller model, because it was one of typical pitches⁽⁵⁾ for the propeller of the M/V Seiyō-maru.

2.2 Field experiments

2.2.1 Preliminary experiment

Many types of paint had been applied to the propeller surface of the small training boat of Tokyo University of Fisheries, Hiyodori, and examined which type of paint was the most suitable one since 1981.

As a result, SP type propeller paint developed in 1981 was the best because of its very adhesive performance with the surface of metals and protective quality against the deposition on the propeller of marine organisms. This type of paint produced as a trial, however, had to be applied on the under-coating of anti-corrosive paint like ordinary bottom paint for the steel hull. Besides, it took much labour to coat or re-coat this type of paint on the propeller surface or remove paint from propeller for periodical inspection, notwithstanding its excellent adhesive performance with metal surface. Different types of SP propeller paint from the previous one were used for the experiments of this study. They were new products in which considerable improvements were embodied to prevent the abovementioned disadvantages.

2.2.2 Experiments by boats

The improved type of SP propeller paint was applied to each propeller of the M/V Shinyō-maru and M/V Seiyō-maru, training boats of Tokyo University of Fisheries, and the changes in main engine horse powers, velocity of the boat, the number of propeller revolution were measured over the period of one year to investigate on how much the influence of propeller coating was exerted on performances of the boat. Besides, roughness on the propeller surface, conditions of coated paint, sizes of area in which paint was peeled away, depositing conditions of marine organisms, corrosion affected on the hull were examined, while each boat was stayed in the dockyard for maintenance twice at every year. The major specifications of the M/V Shinyō-maru, Seiyō-maru, and Hiyodori are shown in table 3.

Table 3 Details of the actual experimental ships

Experimental Boat	Gross tonnage (ton)	L x B x D (m)	Type of propeller	Diameter x pitch (m)
SHINYO-MARU	382.07	42.0 x 7.8 x 4.0	fixed propeller	2.40 x 1.852
SEIYO-MARU	216.98	29.7 x 7.0 x 3.6	controllable-pitch propeller	1.70 x 1.072
HIYODORI	17.85	14.0 x 3.8 x 1.5		1.05 x 1.000

3. Results and Discussions

3.1 Static experiment

The changes in weight of the test pieces were checked after immersing for one, two and six months into artificial sea water. The results are plotted into graphs shown in Fig. 2.

The changes in weight of uncoated glass plates $\blacksquare$ lie within the limits of instrumental errors $+0.008 \sim -0.001 \text{ g/m}^2$. This means that no corrosion had not occurred on the glass plates exposed to the salt solution, and instrumental accuracy of the weighing balance had been maintained throughout the experimental period of 6 months. The changes in weight of the glass plates with SP type-1 coating, of which paint is generally used for coating of the bottom of hull, and SP type-2 coating, of which paint is particularly used for coating of the propeller, are plotted into the graphs shown by such symbols as $\bullet$ and $\blacktriangle$, respectively. Rather intensive decreases in weight, which seem to be caused by hydrolyzing of paint, are seen both in the graphs of $\bullet$ and $\blacktriangle$.

The loss in weight of each glass plate with SP type-1 coating $\bullet$ is slightly larger than that of SP type-2 coating $\blacktriangle$. Because, SP type-1 coating is dissolved more easier in sea water than the SP type-2 coating but also the adhesive performance of the former is inferior to that of the latter. The changing trends of losses in weight both of the coated propeller alloy test pieces $\triangle$ and bottom steel test pieces $\circ$ are similar to those of coated glass test pieces $\bullet$ and $\blacktriangle$ as seen in the graphs in Fig. 2. This indicates that no corrosion had not arisen both on propeller alloy and bottom steel test pieces coated with SP type paint during the experimental period of 6 months. As a matter of fact, the authors tried to remove paint from all the test pieces after completion of all the experiments and weighed the steel and propeller alloy test pieces once again. Consequently, there were no changes at all between the weight of each metallic test piece before the experiment and that after the experiment. But, the slight changes in weight for uncoated propeller alloy ALBC-2 test pieces $\square$ were observed. An average loss in weight of 9 test pieces for 6 months is calculated to be 7.774 g/m^2 . It is considered that a loss in weight of uncoated ALBC-2 seems to be resulted from de-aluminumization of alluminum bronze due to occurrence of selective corrosion.⁽⁶⁾

The value of roughness measured on the surface of every test piece are plotted into a graph shown in

Fig. 2 Weight changes of the test pieces as shown in Table 1

Fig. 3. The graph indicates an increase in roughness with the immersed time proceeds. When compared the trend of this graph with those of the graphs shown in Fig. 2, it is understood that the values in roughness increase in proportion to losses in weight of each test piece. SONE⁽⁷⁾ has reported that the propeller blade of a ship lost its weight approximately 5% and its thickness more or less 18% for 10 years after launching.

The majority of such a loss in weight might be attributed to the abrasion of the propeller on every opportunity of periodical dry docking. Judging from data in metallic corrosion obtained by this study, the loss in weight because of corrosion over a period of 10 years is estimated to be 1.45% of original weight of the propeller. (Refer to Fig. 2)

3.2 Dynamic experiment

If the propeller is coated with paint, roughness of its surface might be increased, and if marine organisms such as barnacles deposit on the propeller, roughness of its surface would be also increased. Under such circumstances, original efficiency of the propeller would be somewhat reduced. To examine how much influence were exerted on efficiency, a series of experiments were conducted by using a one-thirtieth (1/30) model of the propeller mounted to the training boat of Tokyo University of Fisheries, M/V Seiyo-maru.

Four (4) different kinds of roughness, as shown in Table 2, were used for the experiments, and the model propeller provided with one of them at a time was operated in the water tank. The lowering rates in propeller efficiency were calculated from the values of thrust and torque by means of the following equation*:

$$\Delta\eta_p = \eta_{pr} - \eta_p$$

Where, $\Delta\eta_p$: change in propeller efficiency which varies with blade friction drag coefficients,

η_{pr} : efficiency of the propeller of which surface is provided with roughness,

η_p : original efficiency of the propeller, of which surface corresponds to uncoated one in Table 2.

The lowering rate in propeller efficiency is;

$$\Delta\eta_p/\eta_p = \eta_{pr}/\eta_p - 1$$

The ratio of $\Delta\eta_p/\eta_p$ is given as follows;

$$\Delta\eta_p/\eta_p = - (A_e/A_o) \left\{ \frac{(1+\phi_o)}{(V/nP+\phi_o)} \right\} \left\{ \frac{(C_{fr}-C_{fro})}{C_{fro}} \right\}$$

Therefore,

$$l_m = A_e / \{Z(R-r)\}, K_s = H_{max}$$

$$C_{fr} = \{1.89 + 1.62 \log (l_m/K_s)\}^{-2.5}$$

Where, C_{fro} : profile friction drag coefficient of the clean surface for a new propeller blade,

C_{fr} : profile friction drag coefficient of a surface roughened by marine organisms and others, of average diameter K_s ,

Fig. 3 Changes of the surface roughness of the propeller alloy

* Refer to Reference(8).

- Z : number of blades,
 R : tip radius (m),
 A_o : disc area (m²),
 K_s : average diameter of sand grains glued to the surface of the flat plate,
 H_{max} : maximum roughness on propeller surface,
 V : ship's velocity (m/sec),
 n : propeller revolution (rps),
 ϕ_o : value of the constant for six model propellers in Gutsche's research ($= -1.10$)
- r : radius of boss (m),
 A_e : expanded blade area (m²),
 P : nominal mean pitch (m),

As shown in Fig. 4, each $\Delta\eta_p/\eta_p$ calculated by the formula mentioned above is plotted as the ordinate versus each advance coefficient as the abscissa.

Experimental values are indicated by dotted lines, and the values calculated are expressed formula by solid lines for roughness of $67\ \mu\text{m}$ 'Y' and $185\ \mu\text{m}$ 'X'. No significant difference in efficiency was observed between the model propeller blades coated with SP type propeller paint, of which roughness indicated as $6.5\ \mu\text{m}$ in Table 2, and the uncoated model propeller blades in these experiments. Furthermore, the advance coefficient 'J' is calculated by,

$$J = V_o / Dn$$

Where, D : propeller diameter (m),

n : number of propeller revolutions(rps),

V_o : advanced propeller speed(m/sec).

Both experimental values for roughness of $67\ \mu\text{m}$ and $185\ \mu\text{m}$ obtained by using the model propeller, which are expressed by the dotted lines, show larger decreases than the calculated values according to the abovementioned equations, which expressed by the solid lines. This is likely resulted from such aspects that the propeller used in this experiment was roughened by spraying the propeller paint uniformly with sand grains over the whole surface of the blade, while the formula⁽⁸⁾ G. Broersma et al was established for a practical ship based on such a condition that the depositing area of marine organisms would be confined to more or less $0.7 R$. It is not correct to apply the result of their study to our research by the Seiyō-maru. It can be said, however, the lowering rate in propeller efficiency is so small that it may be negligible.

4. Results of Field Experiment and Discussion

The Table 4 shows the values of roughness on each propeller surface for the Shinyō-maru and Seiyō-maru, which were measured before and soon after coating, and six months after coating. It is understood

Table 4 Changes of the surface roughness of the actual ship's propellers

Experimental Boat	Before coating (μm)	After coating (μm)	Six months after coating (μm)
SHINYO-MARU	98.0	45.0	24.0
SEIYO-MARU	66.0	43.0	21.0

Fig. 4 Lowering ratios of propeller efficiency;
 —Y— : the case of $67\ \mu\text{m}$, ...X... : the case of $185\ \mu\text{m}$

that the values soon after coating...45 μm for the Shinyo-maru and 43 μm for the Seiyō-maru...were reduced to almost half ...24 μm and 21 μm , respectively. The adhesive performance of paint films proved to be excellent for both the ships. Peeling-off of paint films were limited to only leading edges of the blades and some physically damaged spots. It was already introduced in the previous report⁽¹⁾ that SP type A/F paint had been very useful to protect the coated surface from the deposition of marine organisms. This was also proved in the experiments of the study, though all of three experimental boats were moored for a few months during the experimental period. Any galvanic actions between the propeller with SP type-2 coating and the steel bottom of hull with SP type-1 coating could not virtually observed. Fig. 5 shows, as for the Shinyo-maru, the relationship between the horse-power (BHP) of the main engine and ship speed (knot) measured for a period between a time just after coating and a time just before sending her to the dry dock is plotted into the graphs. The solid line with a symbol X indicates the data obtained just after coating (just after coming out of the dock); the other solid line with a symbol Z, just before coating (just before sending the ship to the dry dock). The dotted lines with a symbol Y show the data obtained in a period between a time after coating and a time before coating. As seen from the results shown in Table 4, the smoothness and clearness of the propeller were maintained sufficiently throughout the experimental period of this study. It is understood, therefore, that the values of BHP are increased in inverse proportion to lowering rates in ship speed due to deterioration on the bottom surface. The relation between BHP and rpm is shown Fig. 6. As seen in the graph, the changes in revolutions according to the changes in BHP are very slight and may be considered almost constant, indicating that the propeller surface was maintained smooth and clean for the experimental period. This enlightens that the values of BHP shown in Fig. 5 were increased due to deterioration of the ship's bottom. This trend is also seen in Figs. 7 & 8, in which the relation between BHP and ship's speed (knot) for the Seiyō maru is exhibited.

In Fig. 7, the solid line with a symbols X indicates the data obtained just after coming out from the dock and another solid line with a symbol Y, shows the data just before entering the dry dock. The values of BHP are plotted as the ordinate versus ship speed as the abscissa. The dotted line with a symbol Z represent the data obtained for the Seiyō-maru when she was sent to the dockyard in October 1981. The bottom of her hull was coated but no polishing and coating were provided for her propeller at

Fig. 5 Comparison between BHP (ps) and ship's speed (knot) of the Shinyo-maru

Fig. 6 Comparison between BHP (ps) and number of revolutions (rpm) of the Shinyo-maru

Fig. 7 Comparison between BHP (ps) and ship's speed (knot) of the Seiyō-maru

that time, because her experimental data could be compared those of the Shinyō-maru of which propeller was coated with SP type paint. Thus, the rate of roughness on her propeller surface reached even a maximum of $200\ \mu\text{m}$ due to deterioration by marine organisms and others.

Fig. 8, for which the same symbols as in Fig. 7 are used, shows the relationship between BHP and the number of propeller revolutions for the Seiyō-maru. The relationship between Fig. 7 and Fig. 8 is entirely different from that between Fig. 5 and Fig. 6. The revolutions are reduced by 6 to 8 rpm when the propeller was not polished (See Figs. 7 & 8), comparing with the data when the propeller was coated with the paint. This means that the increase of BHP for the Seiyō-maru attributes to fouling on the bottom and the propeller surface, resulting in lowering the ship speed (knot).

Fig. 9 shows the results for the Seiyō-maru in view of the fuel consumption coefficient 'C' obtained by the above-mentioned equation. The fuel consumption coefficient is plotted as the ordinates versus the data as the abscissa, corresponding to the respective lines in Fig. 8.

The segment from A to C indicated with a solid line represents the data of the uncoated propeller, while the segment from C to F of dotted line indicates the data of the propeller coated with SP type propeller paint. The fuel consumption coefficients at C and F point, show the higher values than that at A point. Those values at C and F point were obtained from the ship when she was just come out from the dockyard, where her hull had been coated with conventional insoluble type paint and propeller with SP type paint, while the value at A point was obtained from the ship when she was just returned from the dockyard, where her hull had been coated by conventional insoluble type paint, but no coating had been

Fig. 8 Comparison between BHP (ps) and number of revolutions (rpm) of the Seiyō-maru

Fig. 9 Changes of fuel consumption coefficient 'C' of the Seiyō-maru

provided for the propeller. This suggests that the coated propeller could be more efficient for the energy conservation of the ship. The fuel consumption coefficients are reduced at D and E point due to deterioration of the ship.

5. Conclusion

The results of a series of experiments conducted in the laboratory and field can be concluded as follows,

- (1) SP type propeller paint provides excellent adhesive and polishing performance. The rate in roughness on the propeller surface can be largely reduced by this type of paint so that the propeller can maintain its original efficiency when she is built.
- (2) It has been generally assumed that if the propeller is coated with paint, roughness of its surface might be increased and the propeller efficiency would be somewhat reduced. The experiments of this study have proven that the lowering rate in efficiency of the coated propeller is so minor that it can be negligible.
- (3) Any galvanic actions between the propeller coated with SP type paint could not virtually observed. It can be said that coating of propeller might be useful to economize the number of zinc straps used to protect the hull from electrochemical action in sea water, though relevant details should be confirmed by the further study.
- (4) Similar SP type propeller paint to SP type bottom paint also has a sufficient antifouling effect to protect the propeller from deposition of marine organisms on its surface.
- (5) In view of the results mentioned above, the lowering of the fuel consumption coefficient 'C' as indicated at G point in Fig. 1 can be prevented effectively by use of SP type propeller paint together with SP type bottom paint. Thus the rate of fuel consumption can be reduced and the number of times for dry dock can be also economize.

In closing of this manuscript, we wish to express our sincere thanks to Mr. Kenichi SHIMADA, Tokyo Technical Section, Marine Coating Department, Nippon Paint Co., Ltd. for his constant cooperation in the course of this research.

Reference

- (1) Kaname SATO, Hayao AKIZAWA, Yujiro SAOTOME, Isao KASUGA, Yuji MINE and Yoshio MIYAZAKI: Some Considerations in Energy Conservation of Fishing Boats—Adoption of Self-polishing Anti-fouling Paint—, Japan Institute of Navigation, Vol. 68, January, 1983.
- (2) Hull surface maintenance, its role in operating economics, The Motor Ship, April, 1978.
- (3) (Hiromitsu ORITO and Masaru KAKINUMA: Hull Roughness and Decline in Ship's Speed, Bulletin of the Society of Naval Architects of Japan, No. 616, October, 1980.)
- (4) (Shintei Kokaikateiyo: the third, p 57, KAIBUNDO, March, 1973.)
- (5) (Funeno Kagaku: p 84, Vol. 31, October, 1978.)
- (6) (Zosensekkeibinran: the third, p 903, the Kansai Society of Naval Architects, Japan, June, 1981.)
- (7) (Masao SONE: Influence of the Fouled Ship Bottom on the Propulsion Horse-power of the Seikan Ferry-boats, Journal of the M. E. S. J., Vol. 16, No. 2, February, 1981.)
- (8) Prof. Ir. G. BROERSMA and K. TASSERON: Propeller Maintenance—Propeller Efficiency and Blade Roughness, International Shipbuilding Progress, Vol. 14, No. 156, August, 1967.
(parenthesized reports are written in Japanese)

質 疑 応 答

久々宮久（東京商船大学）：回流水槽を利用した、表面粗度の差のあるプロペラ模型実験の結果が鮮やかに図示されていて、感謝しました。推力、トルクの計測に困難はありませんでしたか。

佐藤 要：推力測定には、この回流水槽に常備されている揚抗力測定装置を使用して行いましたが、この計器の性能がこの回流水槽によく適しているらしく余り問題はありませんでした。ただトルクの方はモーターの発熱が電流値に影響するらしく、夏期の実験では測定値の変動が大きく可成り困りましたが、しかし冬期になってからは気温の関係で測定値が安定しましたのでどうやら図のような結果を得ることができました。

及川 清：（東京商船大学）漁船の省エネルギー対策の一環としての船底塗装に関する一連のご研究に深く敬意を表します。

ご報告によれば、S P型プロペラ塗料の塗装が有効であるとのことですが、翼端部に塗料の剝離が若干認められるようです。この原因と対策はどのようにお考えでしょうか。

佐藤 要：この種の塗料は、海水流の摩擦によって研摩が促進され、表面を平滑に保つことを目的に製作されています。したがって、プロペラ先端附近における空洞現象による塗料の剝離を完全に防止することは塗料の密着力からいってもかなり無理があるようです。ただ A/C 塗装後に A/F を上塗りすれば幾分は防止できるものと思われます。