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The present and the possible application of the mean effective velocity in Ship Hydromechanics

SUMMARY

The calculation results of the effective mean velocity from the old and proposed new definition are presented for comparison. All consequences from the state-of-art analysis and the proposed modifications were numerically verified. The results of the model propulsion test BN18 bis formed the base of the numerical procedures. The test was programmed with special care.

INTRODUCTION

The concept of the effective velocity field introduced to ship hydrodynamics is one of the most significant elements of input data in ship propeller design.

Below the definition is given to bring this concept closer to the reader. At first *the nominal velocity field* $\vec{V}_n$ is reminded to be the velocity field behind the towed ship hull without the propeller, *the total velocity field* $\vec{V}_c$ - that measured in the plane π just before the propeller and *the induced velocity field* $\vec{V}_i$ - that calculated in the plane π from the singularity system modelling the propeller in action.

The effective velocity field $\vec{V}_e$ is defined as the difference between $\vec{V}_c$ and $\vec{V}_i$:

$$\vec{V}_e = \vec{V}_c - \vec{V}_i \tag{1}$$

The effective velocity field $\vec{V}_e$ is then to be transformed from the plane π to the propeller plane with taking into account the propeller stream contraction. Only the $\vec{V}_c$ and $\vec{V}_n$ velocity fields are measurable. The $\vec{V}_n$ velocity field can be measured in practice in model conditions only due to the technical difficulties in towing of real ships. The $\vec{V}_i$ velocity field can be determined only by calculation. Thus the $\vec{V}_e$ velocity field can be determined from (1) in part by measuring $\vec{V}_c$ and in part by calculating $\vec{V}_i$. The $\vec{V}_e$ velocity field is not measurable.

The starting point in $\vec{V}_e$ determination can also be the nominal velocity field $\vec{V}_n$.

In the simplest case if the screw propeller could operate in the uniform stream $\vec{V}_0$, the total velocity field $\vec{V}_c$ in the propeller plane would be $\vec{V}_0 + \vec{V}_i$. In this case the effective velocity field would be $\vec{V}_e = \vec{V}_0$. This results from the definition (1) :

$$\vec{V}_e = \vec{V}_c - \vec{V}_i = \vec{V}_0 + \vec{V}_i - \vec{V}_i = \vec{V}_0 \tag{2}$$

In the case of the behind screw propeller the nominal velocity field $\vec{V}_n$ is deformed due to the $\vec{V}_i$ field and the additional $\Delta\vec{V}$ field, which gives the total field :

$$\vec{V}_c = \vec{V}_n + \vec{V}_i + \Delta\vec{V} \tag{3}$$

The effective velocity field $\vec{V}_E$ will be :

$$\vec{V}_e = \vec{V}_n + \vec{V}_i + \Delta\vec{V} - \vec{V}_i = \vec{V}_n + \Delta\vec{V} \tag{4}$$

It means that the behind screw propeller introduces two disturbances to the nominal velocity field $\vec{V}_n$: the induced velocity field $\vec{V}_i$ and the $\Delta\vec{V}$ field .

The additional $\Delta\vec{V}$ velocity field is not yet determined in practice.

In spite of the difficulties the nominal velocity field measured in model conditions is taken in the today practice as the starting point for effective velocity field determination. It is possible when the following simplifying assumption is taken into account :

$$V_e(x) = V_n(x)\frac{V_T}{(V_n)_V} \tag{5}$$

where :

V_T - the effective mean velocity from thrust identity.

The isolated effective velocity field and other isolated velocity fields (nominal, total, induced), can be averaged in specified regions according to different criteria such as output, momentum, or energy criterion. The corresponding mean velocities are V_V, V_M and V_E. The following relation between them is always valid :

$$V_V \leq V_M \leq V_E \tag{6}$$

A quite different mean quantity is known in ship hydrodynamics - the effective mean velocity which characterizes the hull-propeller-water system. The definition of this quantity, being in use to day, can be noted as follows :

$$SB \cdot FB \longleftrightarrow SB \cdot FO \tag{7}$$

$$\left.\begin{array}{l} \mathit{thrust} \\ \mathit{momentum} \\ \mathit{power} \end{array}\right\} \mathit{identity}$$

The screw propeller SB in behind condition FB is compared with the same screw SB in uniform stream FO. The velocity V_0 of the uniform stream will be chosen in such a way that either the thrust, torque or power is equal in both cases. The velocity V_0 is different in the three cases and equal to V_T, V_Q or V_P. Only two of the velocities are independent of each other (usually V_T and V_Q). The third one, (V_P), is in relation with V_T and V_Q. The approximate relation was proved :

$$V_P \cong \frac{1}{2}\left(V_T + V_Q\right) \tag{8}$$

If the screw propeller SB is an optimum one in behind conditions, another relation is also valid :

$$V_T < V_P < V_Q \tag{9}$$

In the case when an isolated velocity field and the averaging area are given the velocity mean value depends on the averaging criterion only.It is not possible to equalize the different mean values from different criteria. This inequality is inevitable.

The effective mean velocity, EMV, from thrust, torque, or power identity depends on the averaging criterion and adjustment degree of the behind propeller SB to the uniform velocity field FO, the second element of the definition formula (7). The two variables can be neuralized when a new definition of the EMV is formulated accordingly. nstead of comparing the same behind screw propeller SB operating n FB and FO velocity fields, two different screw propellers SB_{opt} and SO_{opt} are compared, which are best adapted to the velocity fields of operating FB and FO. The velocity $\vec{V}_0$ of the uniform stream FO is to be determined by using the step-by-step method. The new definition can be expressed as follows :

$$SB_{opt} \cdot FB \leftrightarrow SO_{opt\,j} \cdot FO_j \tag{10}$$

In the j-th step the velocity V_{0j} of the uniform stream FO_j is selected, the $SO_{opt\,j}$ screw propeller is designed and the effective mean velocities V_{Tj} and V_{Qj} are determined from the thrust and torque identity criterion. The velocity $V_{0\,(j+1)}$ in the (j+1) -th step is selected to atisfy the condition :

$$\left|V_T - V_Q\right|_{j+1} \langle \left|V_T - V_Q\right|_j \tag{11}$$

The limit values of V_T and V_Q are equal : $V_T = V_Q = V_{TQ}$.

Values of the mean velocities $(V_e)_V$, $(V_e)_M$, $(V_e)_E$ of the isolated effective velocity field from output, momentum, and energy identity are different when compared with the effective mean velocities V_T, V_Q, V_P from the thrust, torque and power identity independently of the used EMV definition.

The question is what are the purposes of using the EMV in Ship Hydrodynamics.

➊ The EMV is used today to determine the propulsive efficiency of the ship :

$$\eta_D = \eta_0\,(V_{me}) \cdot \eta_H\,(V_{me}) \cdot \eta_R\,(V_{me}) \tag{12}$$

where:

V_{me} – the effective mean velocity V_T, V_Q or V_P

η_D does not depend upon V_{me}

If : $(K_{TB})_{exp}$, $(K_{QB})_{exp}$, V, n, D, t and $K_{TO} = f(J)$, $K_{QO} = f(J)$

are received from experiment and treated as a set of given data, then it will be possible to determine η_D from (12) for each freely chosen value of V_{me} after the functions η_O, η_H and η_R are calculated by using very simple and easy procedures. The last statement can be found in the author's investigation results [5,4,8]. The conclusion is that the effective mean velocity should be considered unnecessary in propulsive efficiency determination. In the special case when V_T, V_Q or V_P are used the same value of η_D must be received.

$$\eta_{DT} = \eta_{DQ} = \eta_{DP} \tag{13}$$

➋ The EMV is used today to determine the effective velocity field, according to the hypothesis (5) when the nominal velocity field is given. Contrary to the propulsive efficiency, different results of $V_e(x)$ are received from different EMV values and the same nominal velocity field $V_n(x)$.

At first, different but taken as equivalent EMV values (V_T, V_Q or V_P) can be used. Secondly, different mean values of nominal velocity can be used from output, momentum and energy identity, $(V_n)_V$, $(V_n)_M$ and $(V_n)_E$, accordingly.

Even when the author's definition of EMV and the only one value of EMV, V_{TQ}, were used the different mean values of the nominal velocity field will remain unchanged and the effective velocity field $V_e(x)$ will not attain its univocal character.

$$V_e(x) = V_n(x)\,\frac{V_{TQ}}{(V_n)_l} \tag{14}$$

where :

$$(V_n)_l \rightarrow (V_n)_V,\ (V_n)_M,\ (V_n)_E$$

In [4] the author presents a new method of determination of the effective velocity field in the following form :

$$V_e(x) = V_n(x) \cdot C \tag{15}$$

where: C does not depend upon any velocity mean value.

Because the formula (14) can not be accepted, and the new definition of C is proposed, the EMV is not necessary in $V_e(x)$ determination.

➌ The EMV could be useful when behind propeller efficiency is to be determined from the following definition :

$$\eta_B^A = \frac{K_{TB}}{K_{QB}} \cdot \frac{J_A}{2\pi} \qquad J_A = \frac{V_A}{nD} \tag{16}$$

where:

V_A - effective mean velocity.

Unfortunately the definition (16) cannot give univocal results due to the fact that the effective mean velocity is not univocal and therefore η_B^A is not in use in today practice.

The new definition of EMV [6] introduces a quite new situation. The so defined EMV is univocal and the behind propeller efficiency results in one and only one value.

❹ When the today procedure is taken into account in determination of EMV then the resulting V_T and V_Q (suposing the behind propeller SB to be optimum in FB) are to fulfil the condition formulated by the author in [6,8] :

$$V_T < V_Q \tag{17}$$

If another relation, namely :

$$V_T > V_Q \tag{18}$$

results from model propulsion test one can be convinced that the procedure or the stock propeller selection is to be checked.

❺ Parallel to the EMV determination, designation of the effective mean pitch EMP is always possible from the third procedure. The EMP is defined as follows. The behind optimum propeller SB_{opt} with pitch radial distribution and the propeller SB_{mod} with a constant pitch can be compared. The constant pitch value is to satisfy two following equations :

$$(K_{TB})_{SBopt} = (K_{TB})_{SBmod} \tag{19}$$

$$(K_{QB})_{SBopt} = (K_{QB})_{SBmod} \tag{20}$$

and at the same time the condition :

$$V_T = V_Q = V_P \tag{21}$$

is to be satisfied.

The third procedure is based on the modification of the new definition of EMV. Thus the EMP could be defined on the basis of the new definition of EMV given by the author in [6,7,8].

In the light of the above given answers the reader can form his own opinion about the necessity of changing the definition of the effective mean velocity EMV. This paper presents four procedures, including the present one, for determining some propulsive parameters and gives some numerical relations between them.

The special model propulsion tests, BN18 bis, were carried out. Their results were processed by using the four procedures and subprocedures.

THE PROCEDURES FOR DETERMINATION OF THE EFFECTIVE MEAN VELOCITY EMV

The effective mean velocities were determined from four different procedures.

Procedure 1 (Tab.1, Fig.1) is adapted to the present EMV definition according to the notation :

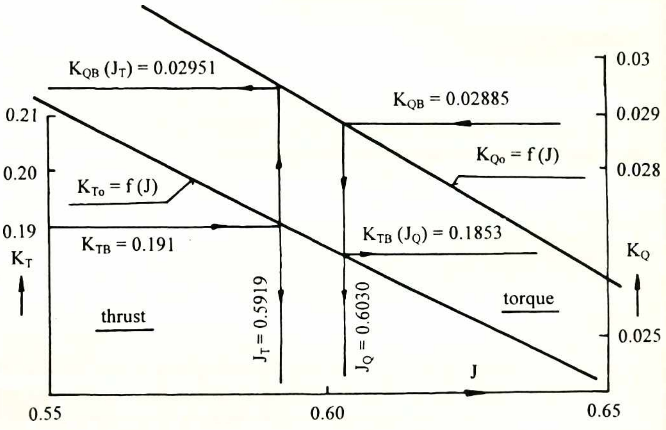
$$SB \cdot FB \leftrightarrow SB \cdot FO \tag{7}$$

The essence of this definition is that the screw propeller SB operating in the behind condition FB is compared with the SB in the uniform stream FO. Thrust (or torque) in both situations is equalized. The thrust (or torque) values can be obtained from experiment or calculation. This fact is noted in Column 2 of Tab.1 for the situation SB · FB and in Column 3 for the situation SB · FO. Each line of Tab.1 gives information on the source of SB · FB and SB · FO characteristics for the specified subprocedure. In Column 4,5 and 6 the EMV from thrust, torque and power identity for each subprocedure are given.

Tab.1. *Procedure 1*

Sub-procedure	Procedure 1		Averaging criterion		
	SB · FB	SB · FO	thrust	torque	power
1	2	3	4	5	6
1.1	Experiment	Experiment	$V_{T11} <$	V_{Q11}	$V_{P11} = \cong \frac{1}{2}(V_{T11}+V_{Q11})$
1.2	Experiment	Calc. Given geom. of SB	$V_{T12} <$	V_{Q12}	$V_{P12} = \cong \frac{1}{2}(V_{T12}+V_{Q12})$
1.3	Experiment	Calc. Design of SB	$V_{T13} <$	V_{Q13}	$V_{P13} = \cong \frac{1}{2}(V_{T13}+V_{Q13})$
1.4	Calc. Design of SB	Calc. Design of SB	$V_{T14} <$	V_{Q14}	$V_{P14} = \cong \frac{1}{2}(V_{T14}+V_{Q14})$

An additional information is to be given on the way of using the power identity in EMV determination because it is a new author's criterion [5,9]. The criterion is based on equalizing the power of thrust and torque of the behind propeller SB in FB field and of the same propeller in FO uniform stream.



$n = 8.42\ [s^{-1}]$ $V_m = 2.222\ [ms^{-1}]$
$D = 0.278\ [m]$ $t = 0.217$

	J	0.55	0.60	0.65	0.70
	K_{TO}	0.2121	0.1869	0.1613	0.1353
K_I	K_{QO}	0.03194	0.02903	0.02603	0.02298
	K_I	- 0.02110	0.00410	0.02970	0.05570
K_{II}	$- K_{II}$	0.03530	0.00188	- 0.02707	- 0.05269

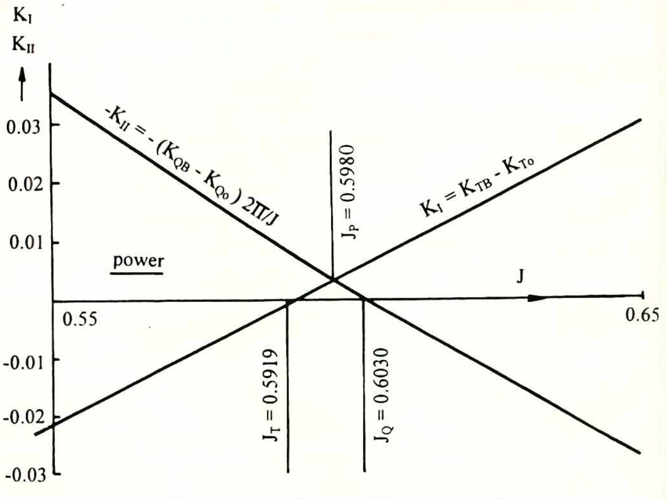


Fig.1. *Procedure 1.1. Thrust, torque and power identity*

$$T_B \cdot V_P + Q_B \cdot \omega_B = T_0 \cdot V_P + Q_O \cdot \omega_B \tag{22}$$

$$(T_B - T_0)V_P + (Q_B - Q_O)\omega_B = 0 \tag{23}$$

$$(T_B - T_0)\,D_B + (Q_B - Q_0)\cdot \frac{2\pi\, n_B \cdot D_B}{V_P} = 0 \qquad (24)$$

$$(K_{TB} - K_{TO}) + (K_{QB} - K_{QO})\,\frac{2\pi}{J_P} = 0 \qquad (25)$$

or

$$K_I + (-K_{II}) = 0 \qquad (26)$$

where :

$$K_I = K_{TB} - K_{TO} = f(J) \qquad (27)$$

$$-K_{II} = -(K_{QB} - K_{QO})\cdot\frac{2\pi}{J} = f(J) \qquad (28)$$

The EMV from power identity, V_P, satisfies the equations (24, 25,26). Fig.1 presents the graphical solution of the equation (26) in the case when the subprocedure 1.1 is applied.

Both curves $K_I = f(J)$ and $(-K_{II}) = f(J)$ have a common point of intersection, at $J_P = 0.5980$. Two other characteristic points can be found in Fig.1. The first one corresponds to the thrust identity criterion $(K_I = 0;\ J_T = 0.5919)$, the second to the torque identity $(-K_{II} = 0;\ J_Q = 0.6030)$. The curves can be drawn with the help of the table in Fig.1 where the results of BN18 bis propulsion tests and the experimental relations $K_{TBO} = f(J)$ and $K_{QBO} = f(J)$ are presented.

Procedure 2 (Tab.2, Fig.2) was built on the basis of the new definition of EMV introduced by the author [6,7,8]. This definition can be noted as :

$$SB_{opt}\cdot FB \leftrightarrow SO_{opt}\cdot FO \qquad (29)$$

Tab.2. Procedure 2

Sub-procedure	Procedure 2		Averaging criterion		
	$SB_{opt}\cdot FB$	$SO_{opt}\cdot FO$	thrust	torque	power
1	2	3	4	5	6
2.3	Experiment	Calc. Design of $(SO_{opt})_{lim}$	$V_{T2.3} =$	$V_{Q2.3}$	$V_{P2.3}$
2.4	Calc. Design of SB	Calc. Design of $(SO_{opt})_{lim}$	$V_{T2.4} =$	$V_{Q2.4}$	$V_{P2.4}$

The optimum behind propeller is compared with other screw propeller SO_{opt} which is optimal in FO uniform stream of unknown velocity V_0 being the wanted EMV. The task of finding the velocity V_0 can be solved by using the step-by-step method. In the j-th step the velocities V_{Tj} and V_{Qj}, and $(SO_{opt})_j$ propeller will be found under the supposition that $V_0 = V_{0j}$. In the (j+1)-th step the velocity $V_{0(j+1)}$ will be chosen under the condition :

$$\left|V_T - V_Q\right|_{j+1} \langle \left|V_T - V_Q\right|_j \qquad (30)$$

and the $(SO_{opt})_{j+1}$ screw propeller will be designed. The sequence $(SO_{opt})_j$ tends towards the limit screw propeller $(SO_{opt})_{lim}$. The EMV limit value is the same for the thrust and torque criterion :

$$V_T = V_Q = V_{TQ} \qquad (31)$$

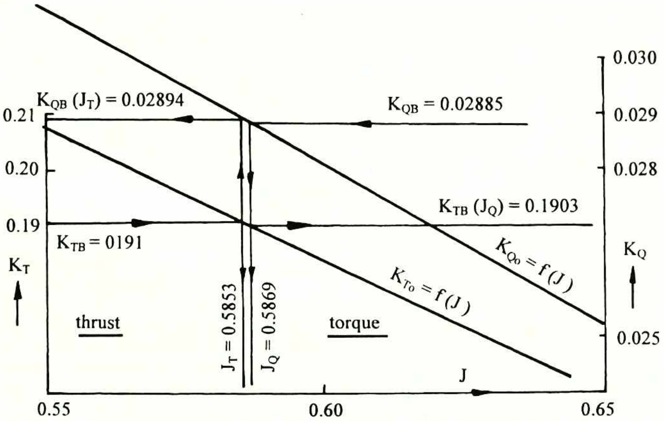
$$V_P = V_{TQ} \qquad (32)$$

The hydrodynamic characteristics of the $(SO_{opt})_{lim}$ propeller in FO :

$$K_{TO} = f(J) \qquad K_{QO} = f(J) \qquad (33)$$

and the subprocedure 2.3 of determining J_T and J_Q $(J_T = J_Q)$ according to the thrust and torque identity are presented in Fig.2. The same figure presents the power criterion and the J_p determination. The intersection point of the curves K_I and $(-K_{II})$ is situated on the J-axis. It means that $J_P = J_T = J_Q$. Hence it is obtained :

$$V_T = V_Q = V_P = 0.5862 \qquad (34)$$



$K_{TB} = 0.1898 \quad n = 8.42\ [s^{-1}] \quad V_m = 2.222\ [ms^{-1}]$
$K_{QB} = 0.02885 \quad D = 0.278\ [m] \quad t = 0.217$

	J	0.55	0.60	0.65	0.70
	K_{TO}	0.2072	0.1840	0.1598	0.1345
K_I	K_{QO}	0.03090	0.02810	0.02520	0.02217
	K_I	- 0.01638	0.00698	0.03125	0.05648
K_{II}	$-K_{II}$	0.02342	- 0.00785	- 0.03528	- 0.06000

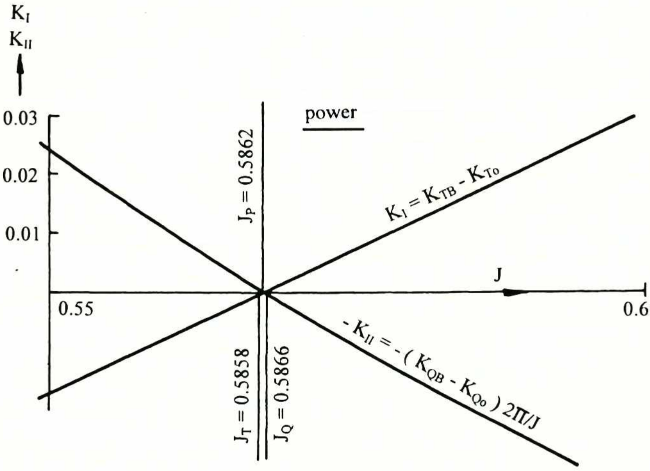


Fig.2. *Procedure 2.3. Thrust, torque and power identity*

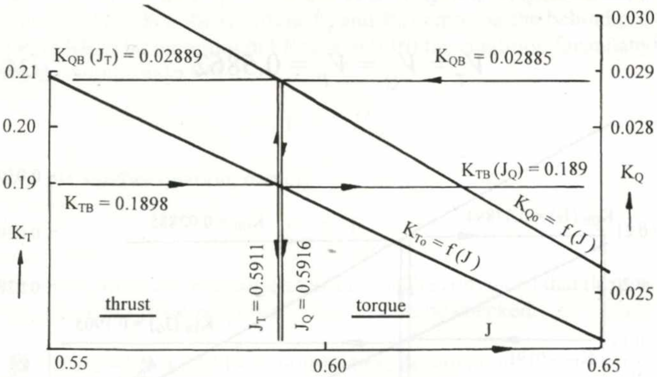
The subprocedure 2.4 is presented in Fig.3 with K_{TB} and K_{QB} from calculation (Tab.2)

Procedure 3 (Tab.3) is based on the idea of an itentional departure from the new definition of EMV. The essence of the departure is that the behind screw SB_{opt} will not be compared with the SO_{opt} screw in FO but with the SB_{mod} screw in FO. The pitch radial distribution of SB_{opt} is modified to a constant pitch of the SB_{mod}. Application of the step-by-step method is only possible. In the j-th step the pitch $(P/D)_j$ was chosen and the V_{Tj} and V_{Qj} mean velocities were found with the help of thrust and torque identities. The pitch $(P/D)_{j+1}$ is selected to satisfy the condition :

$$\left|V_T - V_Q\right|_{j+1} \langle \left|V_T - V_Q\right|_j \qquad (35)$$

***Tab.3.** Procedure 3*

Sub-procedure	Procedure 3		Averaging criterion		
	$SB_{opt} \cdot FB$	$SB_{mod} \cdot FO$	thrust	torque	power
1	2	3	4	5	6
3.3	Experiment	Calc. Design of SB_{mod}	$V_{T3.3} =$	$V_{Q3.3}$	$V_{P3.3}$
3.4	Calc. Design of SB	Calc. Design of SB_{mod}	$V_{T3.4} =$	$V_{Q3.4}$	$V_{P3.4}$



$n = 8.42\ [s^{-1}]$ $V_m = 2.222\ [ms^{-1}]$
$D = 0.278\ [m]$ $t = 0.217$

	J	0.55	0.60	0.65	0.70
	K_{TO}	0.2090	0.1857	0.16142	0.13623
K_I	K_{QO}	0.03118	0.02838	0.02547	0.02244
	K_I	- 0.01918	0.00414	0.02837	0.05356
K_{II}	$- K_{II}$	0.02662	-0.00492	- 0.03267	- 0.05753

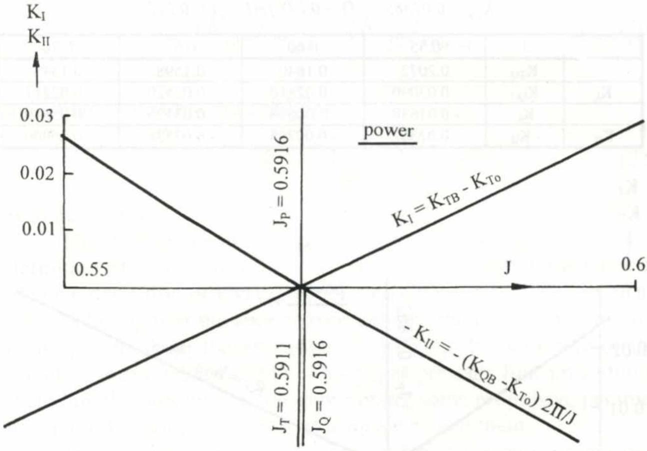


Fig.3. Procedure 2.4. Thrust, torque and power identity

The limit value P/D is the effective mean pitch (EMP). Simultaneously the effective mean velocities from thrust and torque identities become equal : $V_T = V_Q = V_{TQ}$.

The procedure 3 can be treated as a tool to find the EMP for a SB screw propeller with pitch radial distribution, i.e. to obtain a SB_{mod} screw propeller.

It means that the propeller SB_{mod} and the optimum behind propeller SB_{opt} have the same thrust and torque coefficients when the advance coefficient J is the same :

$$
\begin{aligned}
(K_{TB})_{SBopt} &= (K_{TB})_{SBmod} \\
(K_{QB})_{SBopt} &= (K_{QB})_{SBmod} \\
J_T = J_Q &= J_P = J \\
V_T = V_Q &= V_P = J \cdot n \cdot D
\end{aligned}
\tag{36}
$$

At present the radial pitch distribution is replaced by the pitch at $x = r/R = 0.7$ to give the effective mean pitch. Such procedure has no rational justification.

Procedure 4 (Tab.4) is related to the other idea of modification of the new definition of EMV. The essence of this modification is to replace the SO_{opt} screw with pitch radial distribution, used in the new definition (10), by the $(SO_{opt})_{mod}$ screw with a constant pitch. The constant pitch value is to be determined by using the step-by-step method, similarly to the procedure 3.

***Tab.4.** Procedure 4*

Sub-procedure	Procedure 4		Averaging criterion		
	$SB_{opt} \cdot FB$	$SO_{mod} \cdot FO$	thrust	torque	power
1	2	3	4	5	6
4.3	Experiment	Calc. Design of SO_{mod}	$V_{T4.3} =$	$V_{Q4.3}$	$V_{P4.3}$
4.4	Calc. Design of SB	Calc. Design of SO_{mod}	$V_{T4.4} =$	$V_{Q4.4}$	$V_{P4.4}$

CALCULATION RESULTS

CONCLUSIONS

The results of the effective mean velocity calculation with taking into account all four presented procedures were gathered in Tab.5.

The present definition of EMV was used in procedure 1, the new proposed definition in procedure 2. Moreover two ways of departing from definition 2 were used in procedures 3 and 4. Each procedure was divided into subprocedures. In each subprocedure three averaging criteria were applied: thrust, torque, and power identity.

The EMV values were gathered in Col.3, Tab.5. The propulsive efficiency η_{DOO} calculated in compliance with the definition formula :

$$\eta_{DOO} = \frac{K_{TB}}{K_{QB}} \cdot \frac{J}{2\pi}(1-t) \tag{37}$$

was given in Col.4, Tab.5.

The value $\eta_{DOO} = 0.78357$ is obtained when K_{TB} and K_{QB} are based on model propulsion tests, and $\eta_{DOO} = 0.77860$ results from calculated K_{TB} and K_{QB} parameters.

The difference of about 0.5 % is meaningless in practice. One can state that η_{DOO} values from all four procedures are the same.

The factors η_O, η_H, η_R are given in Col.5,6 and 7, Tab.5, respectively. The propulsive efficiency can be calculated by using the well known formula :

$$\eta_D = \eta_O \cdot \eta_H \cdot \eta_R \tag{38}$$

It is easy to prove that η_{DOO} from (37) and η_D from (38) should always be equal.

Each of the factors η_O, η_H, η_R depends upon the EMV. Their product η_D does not depend upon the EMV because $\eta_{DOO} = \eta_D$ is independent of the EMV.

It is evident from Tab.5 that the EMV determination in order to calculate η_D from (38) is unnecessary, which confirms the author's earlier statement. Any EMV value fulfils the task if only the functions $\eta_O\ (EMV)$, $\eta_H\ (EMV)$, $\eta_R\ (EMV)$ will be determined from the propulsion test results .

In Col.8, Tab.5 the behind screw efficiency :

$$\eta_B^A = \frac{K_{TB}}{K_{QB}} \cdot \frac{V_A}{nD} \cdot \frac{1}{2\pi} = \frac{K_{TB}}{K_{QB}} \cdot \frac{J_A}{2\pi} \tag{39}$$

is given where : V_A - effective mean velocity.

One can find the relation between η_B^A and η_D :

$$\eta_D = \frac{K_{TB}}{K_{QB}} \cdot \frac{J}{2\pi}(1-t) = \frac{K_{TB}}{K_{QB}} \cdot \frac{J_A}{2\pi} \cdot \frac{1-t}{\frac{J_A}{J}} = \eta_B^A \eta_H \tag{40}$$

Tab.5. Effective Mean Velocities (EMV) and propulsive parameters from different definitions of EMV

Sub proc.	Effective velocity		η_{DOO}	η_O	η_H	η_R	η_B^A
1	2	3	4	5	6	7	8
Procedure 1							
1.1	$(V_T/V_m)_{1.1}$	0.6235	0.78357	0.60990	1.25582	1.02304	0.624
	$(V_Q/V_m)_{1.1}$	0.6352	0.78357	0.617	1.23259	1.03033	0.636
	$(V_P/V_m)_{1.1}$	0.6300	0.78357	0.6140	1.2426	1.0270	0.6307
1.2	$(V_T/V_m)_{1.2}$	0.6227	0.78357	0.60686	1.25733	1.02692	0.6232
	$(V_Q/V_m)_{1.2}$	0.6360	0.78357	0.61619	1.23115	1.03288	0.6364
	$(V_P/V_m)_{1.2}$	0.6303	0.78357	0.61205	1.2422	1.03012	0.6308
1.3	$(V_T/V_m)_{1.3}$	0.6379	0.78357	0.60941	1.22738	1.04759	0.638
	$(V_Q/V_m)_{1.3}$	0.6612	0.78357	0.62289	1.18421	1.06226	0.6617
	$(V_P/V_m)_{1.3}$	0.6511	0.78357	0.61705	1.20253	1.05548	0.6516
1.4	$(V_T/V_m)_{1.4}$	0.6405	0.77860	0.61093	1.22256	1.04245	0.637
	$(V_Q/V_m)_{1.4}$	0.6612	0.77860	0.62289	1.18421	1.05553	0.6575
	$(V_P/V_m)_{1.4}$	0.6522	0.77860	0.6177	1.20048	1.04949	0.6486
Procedure 2							
2.3	$(V_T/V_m)_{2.3}$	0.6171	0.78357	0.61493	1.27042	1.00300	0.617
	$(V_Q/V_m)_{2.3}$	0.618	0.78357	0.61607	1.26707	1.00380	0.618
	$(V_P/V_m)_{2.3}$	0.6175	0.78357	0.61552	1.26805	1.00343	0.617
2.4	$(V_T/V_m)_{2.4}$	0.6227	0.77860	0.61864	1.25739	1.00094	0.6192
	$(V_Q/V_m)_{2.4}$	0.6232	0.77860	0.61899	1.25636	1.00119	0.6192
	$(V_P/V_m)_{2.4}$	0.6232	0.77860	0.6187	1.25647	1.00109	0.6196
Procedure 3							
3.3	$(V_T/V_m)_{3.3}$	0.6028	0.78357	0.60249	1.29896	1.00122	0.6032
	$(V_Q/V_m)_{3.3}$	0.6035	0.78357	0.60296	1.29752	1.00156	0.604
	$(V_P/V_m)_{3.3}$	0.6035	0.78319	0.60276	1.29743	1.00147	0.604
3.4	$(V_T/V_m)_{3.4}$	0.6103	0.77860	0.60635	1.28292	1.00092	0.6069
	$(V_Q/V_m)_{3.4}$	0.6108	0.77860	0.60669	1.28190	1.00114	0.6074
	$(V_P/V_m)_{3.4}$	0.6104	0.77823	0.60656	1.28170	1.00104	0.6072
Procedure 4							
4.3	$(V_T/V_m)_{4.3}$	0.6183	0.78357	0.6186	1.26630	1.00029	0.619
	$(V_Q/V_m)_{4.3}$	0.6185	0.78357	0.61871	1.26599	1.00036	0.619
	$(V_P/V_m)_{4.3}$	0.6187	0.78319	0.61861	1.26565	1.00032	0.619
4.4	$(V_T/V_m)_{4.4}$	0.6264	0.77860	0.62258	1.24990	1.00056	0.623
	$(V_Q/V_m)_{4.4}$	0.6267	0.77860	0.62278	1.24931	1.00071	0.623
	$(V_P/V_m)_{4.4}$	0.6267	0.77823	0.62250	1.24934	1.00066	0.623

On the other side one has the relation (38). Supposing that $\eta_R \equiv 1$ the relation :

$$\eta_D = \eta_0 \cdot \eta_H \cdot 1 \qquad (39)$$

is obtained. Comparing (40) and (41) one can draw the following conclusion :

In the case when $\eta_R \equiv 1$ the efficiency of the behind screw and the open screw are equal. This conclusion is well confirmed by the procedures based upon the new EMV definition and upon both its modifications (see Tab.5). In these cases the value of η_R is very close to 1 [10] and

$$\eta_0 = \eta_B^A \qquad (42)$$

The general, earlier given statements found full confirmation in the calculation results.

Let the EMV be applied to the effective velocity field determination [12] :

$$V_e(x) = V_n(x) \cdot \frac{V_k}{(V_n)_l} \qquad (43)$$

where:

V_k - one of the possible EMV according to the present definition : $V_k \rightarrow V_T, V_Q, V_P$

$(V_n)_l$ - one of the possible mean values of the nominal velocity field : $(V_n)_l \rightarrow (V_n)_V, (V_n)_M, (V_n)_E$ according to output, momentum and energy identity.

Thus nine different solutions are possible. If the new EMV definition which gives only one value of V_k is accepted then three solutions remain out of the nine possible ones because $(V_n)_l$ are not to be equalized.

A new original method is given by the author [3,12] to determine the constant factor C from the relation :

$$V_e(x) = V_n(x)\, C \qquad (44)$$

independent of any mean values.

All calculations were carried out on the basis of the results of BN18 bis model propulsion tests with the hull K1 and the screw propeller SB 102 designed for the effective velocity field characterized with the constant factor $C = 1.059$. This value was confirmed by using the above mentioned method of C determination [3].

NOMENCLATURE

C	-	constant factor
D	-	crew propeller diameter
EMP	-	Effective Mean Pitch
EMV	-	Effective Mean Velocity
FB	-	the behind velocity field
FO	-	the uniform velocity field
$J=\frac{V}{nD}$	-	advance coefficient
$K_Q=\frac{Q}{\rho n^2 D^5}$	-	torque coefficient
$K_T=\frac{T}{\rho n^2 D^4}$	-	thrust coefficient
n	-	screw propeller revolutions per second
P	-	screw propeller pitch
$\frac{P}{D}=f(x)$	-	pitch radial distribution
Q	-	torque
r	-	radial coordinate
SB	-	the behind screw propeller
SB_{mod}	-	the pitch radial distribution of SB, transformed to the constant pitch
$SB \cdot FB$	-	the propeller SB in FB velocity field
$SB \cdot FO$	-	the propeller SB in FO velocity field
$SB_{mod} \cdot FO$	-	the propeller SB_{mod} in FO velocity field
SO	-	the screw propeller in uniform velocity field
SO_{mod}	-	the pitch radial distribution of SO transformed to the constant pitch
$SO \cdot FO$	-	the propeller SO in FO velocity field
$SO_{mod} \cdot FO$	-	the propeller SO_{mod} in FO velocity field
t	-	suction coeficient
T	-	thrust
V	-	velocity
V_A	-	effective mean velocity
V_c	-	total velocity
V_e	-	effective velocity
V_i	-	induced velocity
V_n	-	nominal velocity
V_T, V_Q, V_P	-	effective mean velocity from thrust, torque and power identity, accordingly
V_V, V_M, V_E	-	mean velocity of an isolated velocity field from output, momentum and energy identity, accordingly
$x=\frac{r}{R}$	-	non-dimensional radial coordinate
η_D	-	propulsive efficiency (formula 38)
η_{DOO}	-	propulsive efficiency (formula 37)
$\eta_H=\frac{1-t}{\frac{V_A}{V_m}}$	-	hull „efficiency"
η_O	-	open screw efficiency
$\eta_R=\frac{\frac{K_{TB}}{K_{TO}}}{\frac{K_{QB}}{K_{QO}}}$	-	relative rotating efficiency
ρ	-	water density
ω	-	angular velocity

Indices :

A	-	related to V_A
B	-	behind conditions
E	-	related to energy
exp	-	related to experiment
j	-	step number in iterative process
lim	-	limit
m	-	related to ship model
mod	-	modified version
M	-	related to ship model
$opt.$	-	optimum version
O	-	open water conditions
P	-	related to power
Q	-	related to torque
T	-	related to thrust
V	-	related to output
$\rightarrow$	-	vector notation

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Current report

MARITIME UNIVERSITY OF SZCZECIN
MECHANICAL FACULTY
INSTITUTE OF SHIP ELECTROTECHNICS
AND AUTOMATION

TESTING OF PRODUCT RESISTANCE TO SALT MIST EFFECTS

Many industrial products are required to be tested in corrosive atmosphere. The tests are specially important for products of shipbuilding, automotive and electric - electronic engineering industries.

The Ship Automation Department of the Institute, having at its disposal a laboratory recognized by Polish Register of Shipping (PRS), has carried out technical climatic tests for many years and now it specializes in testing of product resistance to inactive-salt-mist effects. Many research investigations were performed in that area, in which exposure parameters were in compliance, at the request of a client, either with PRS requirements, or Polish and foreign standards.

The experience gained shows that appropriate assessment of test results is a vital question in this respect. J. Brzózka, D.Sc. and A.Stefanowski, D.Sc. of the Department elaborated the computerized assessment method of corrosion hazard effects, which can find applications in :

- ➢ shipbuilding industry
- ➢ automotive industry (e.g. paint coating adhesion tests)
- ➢ rubber material industry (e.g. assessment of changing rubber hardness)
- ➢ chemical industry (e.g. assessment of changing elastomer properties)
- ➢ electric-electronic engineering industry (e.g. microprocessor system tests).