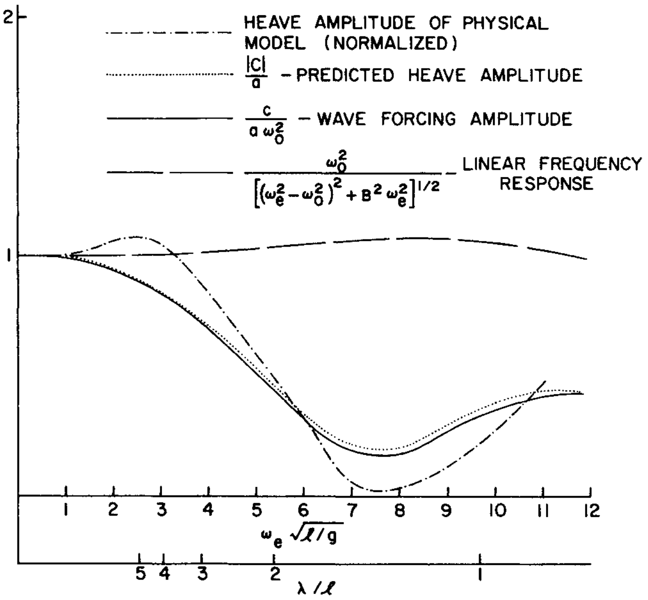

Fig. 1 Craft response at $U/\sqrt{\ell g}=1.15$.

The analytical solution has been applied to 7/100 scale model of the JEFF(A) with the results shown in Fig. 1. The predicted value of the normalized amplitude of the solution ($=|C|/a$) is plotted vs encounter frequency and wavelength for a Froude number of 1.15. The magnitude of the wave forcing term and the linear frequency response are also shown separately since these are the factors which generate the heave response. It may be seen that the heave response of the vehicle is controlled by the form of the wave forcing curve, while the predicted linear frequency response is quite flat at this speed for wavelengths greater than the craft length.

For comparison, an experimentally determined heave response obtained from towing tank tests as presented in Ref. 3 is included. The experimental curve behaves roughly in the same manner as the theoretical prediction. This suggests that the model may be relied upon to explain physical mechanisms and the influence of design particulars, though not in precise quantitative terms.

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Technical Comments

Comments on "Controlling the Separation of Laminar Boundary Layers in Water: Heating and Suction"

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THESE comments on Ref. 1 by Aroesty and Berger are aimed at indicating that Aroesty and Berger: 1) solved incorrect describing equations; 2) made unacceptable assumptions regarding the variation of the fluid properties; and 3) performed a series of mathematical approximations which led to entirely erroneous results.

With the notation of Ref. 1, the variable fluid properties Falkner-Skan equations are

$$(Nf'')'+ff''+\beta(R-f'^2)=0 \tag{1}$$

$$(Ng'/Pr)'+fg'=0 \tag{2}$$

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For heated water boundary layers, the density ratio R may be taken as unity. Aroesty and Berger write the energy equation as

$$g''+Pr_\infty fg'=0 \tag{3}$$

While this is very convenient for the approximations which Aroesty and Berger later make, it is unacceptable in problems dominated by fluid properties variations.

Further violation of the physics of the problem results from the assumption of the constant N. The extensive parametric study of Ref. 2 showed that variation of fluid properties plays a critical role in boundary-layer separation. In view of this conclusion, the assumption of $N=$ const renders the paper of Aroesty and Berger invalid.

After a questionable reduction of the differential equations and crude mathematical approximations, Aroesty and Berger conclude that the increment of surface temperature necessary to prevent separation may be expressed as

$$\Delta T_{\min}=-1000(\beta+0.1988) \tag{4}$$

The computer program used in Ref. 2 was exercised some time ago in a parametric study of separating heated water boundary layers. This program solved the inverse Falkner-Skan problem ($f''(0)=0$, β to be found) exactly for a complete variation of fluid properties and the results for $T_\infty=60°$F may be expressed as

$$\Delta T_{\min}=2.55(1000^*|\beta+0.1988|)^{1.075} \tag{5}$$

These results agree with the data taken by Aroesty and Berger from their Ref. 15 and exhibited in their Fig. 3. Thus, rather than a ΔT of 40°F for a β of -0.24 indicated by Aroesty and Berger, it is in fact a ΔT of about 140°F. Predictably, the errors just listed result in a totally incorrect result.

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Reply by Authors to A. Wortman

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THE intent of our paper was to explore the potential impact of surface heating on the separation of the laminar boundary layer in water. Since our approach was analytic, it was necessary to simplify the appropriate equations of motion while still retaining the dominant phenomena. It is well known that for water the temperature variation of viscosity is much greater than the corresponding variations of thermal conductivity. (For example, kinematic viscosity increases by 77% between 68°F and 32°F, while the thermal diffusivity decreases by only 8.5%). Thus, the essential phenomena are due to viscosity variation and large Prandtl number, but not the temperature dependence of thermal conductivity. For purposes of developing simple estimates and closed form solutions, it is then appropriate to approximate the thermal conductivity by a constant value, but to retain the temperature variation of the viscosity. Contrary to Dr. Wortman's assertion, this is exactly the procedure described in our paper.

The boundary layer energy equation can then be simplified to

$$g'' + Pr_\infty f g' = 0$$

but the viscosity variation with temperature has in fact been included, using the form $1/N = (a+bT)/(a+bT_\infty)$. (See our Eq. 11).

Our asymptotic analysis, valid for large Prandtl number, overestimates the impact of heating on separation for the case of water where the magnitude of $(Pr)^{1/3}$ is only two. This was recognized at the time of publication, and therefore we included a revised relationship between surface overheat and pressure gradient parameter, shown in our Fig. 3. This relationship is essentially the one which Wortman recommends. We do not challenge him on this. We merely point out that it was already included in our paper.

The conclusion that heating has little potential for maintaining attached laminar flow in water was based on our analytic approach. The later availability of numerical solutions served to strengthen this conclusion even further.

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