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CORRIGENDUM

Laminar-film condensation/evaporation on a vertically fluted surface

By R. E. Johnson and A. T. Conlisk

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In our original article we stated that we believed that there was an error in the film profile calculations by Joos (1984) for film condensation on a fluted surface when the flute amplitude is large. This belief was based primarily on our inability to physically explain his results in the light of our own results. Our original claim was incorrect and we wish to set the record straight. In addition, the basic issue raises an interesting point about the problem which will be discussed below. Our error, which was brought to our attention by Joos, was due to our misinterpreting the fluted surface geometry that he considered.

The condensation film profile for a film having zero initial thickness on a cylinder with a surface curvature $\kappa_b(s)$ and uniform temperature is given in our original paper by

$$h^4(s) = -\frac{4}{3(\kappa_b'(s))^{\frac{4}{3}}}\int_{s_0}^{s} (\kappa_b'(s))^{\frac{1}{3}}\,\mathrm{d}s, \quad \text{on curves;} \quad z = -\int_{s_0}^{s} \frac{\mathrm{d}s}{\kappa_b'(s)}, \tag{1}$$

where s is arclength and $\kappa_b' = \mathrm{d}\kappa_b/\mathrm{d}s$.

In our original paper we considered a fluted surface given by $\kappa_b(s) = \kappa_1 + \kappa_0 \cos \pi s$. This surface is a circular cylindrical-like surface with waves (flutes) superimposed. Joos, on the other hand, considered surfaces having a surface displacement similar to $y = a \cos \pi x$. Since only the curvature gradient κ_b' affects the film profile, κ_1 is irrelevant and for all practical purposes these two fluted surfaces look very much alike to the naked eye, except for large flute amplitudes (figure 1). Although the surface displacement is often similar, the surface curvature κ_b' is very different for the two surfaces. In our original case κ_b' is a simple sine curve and κ_0 can in fact be scaled out of the problem, making the features of the film profile essentially independent of the flute amplitude. For the case considered by Joos, however, the surface curvature gradient changes dramatically as the flute amplitude a increases (figure 2). For very small flute amplitudes the two surfaces have a very similar surface curvature gradient, but for larger amplitudes the case considered by Joos begins to deviate significantly from the sinusoidal shape.

The calculations which we originally questioned corresponded to a case when the flute amplitude $a = 0.5$ and the curvature gradient has rather large values near the crest ($x = 0$) and trough ($x = 1$) (figure 2). In particular, we did not understand the origin of kinks in his film profile which propagated from the crest to the trough as the film progressed along the cylinder. We re-evaluated the film profile from (1) for the surface considered by Joos and have verified his original prediction that transverse waves are indeed present when κ_b' deviates from a simple sinusoid. In figure 3 we plot the film profile for a small and a large value of the amplitude ($a = 0.1$ and $a = 0.34$); these profiles resemble those published by Joos (1984). In the case that we considered originally ($\kappa_b(s) = \kappa_1 + \kappa_0 \cos \pi s$), the main features of the profile are always similar to

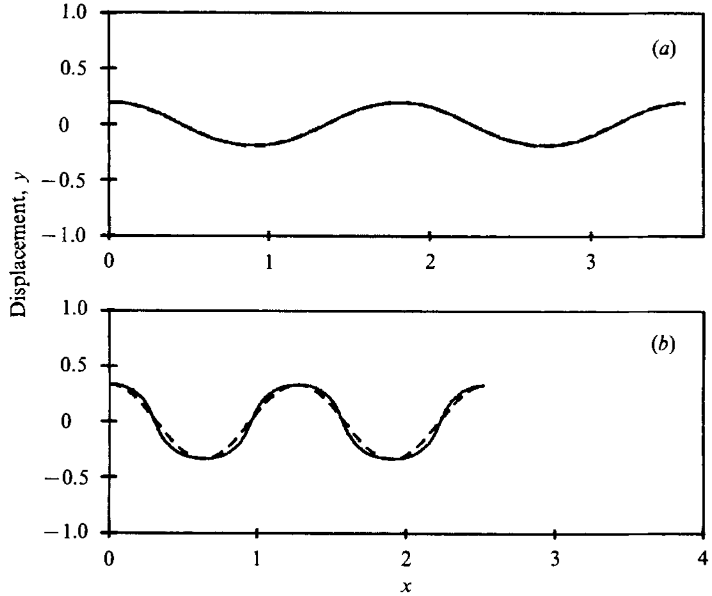

FIGURE 1. Comparison of the fluted surface displacement used by Johnson & Conlisk (——), and Joos (– – – –). (*a*) $a = 0.21$ (surfaces are indistinguishable); (*b*) $a = 0.34$. Note that lengths have been made dimensionless by the arclength from crest to trough.

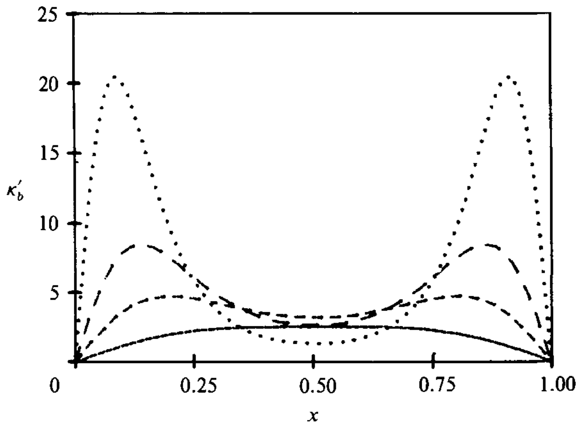

FIGURE 2. Surface curvature gradient $d\kappa_b/ds$ versus transverse position x for a surface $y = a \cos \pi x$: ——, $a = 0.1$; - - - - -, $a = 0.2$; – – – –, $a = 0.3$; ·········, $a = 0.5$.

the film profile shown in figure 3(*a*) (for all κ_0). The change in the nature of the film profile as the amplitude a increases is readily apparent in figure 3(*b*) and is due to the change in the character of κ_b'. The transverse wave in figure 3(*b*) is induced by the relatively large value of κ_b' near the crest and propagates towards the trough leaving a hump of fluid behind where the curvature gradient is small. Naturally, higher order contributions to the surface tension effect would tend to smooth this wave. If the amplitude is increased further the crest of the transverse wave becomes more pointed (see the example given by Joos). Lastly, the reader must be cautioned that the validity of the theory begins to break down as the amplitude a increases because κ_b', which was assumed to be of order unity, becomes large (e.g. when $a = 0.5$, $\max(\kappa_b') \approx 20$).

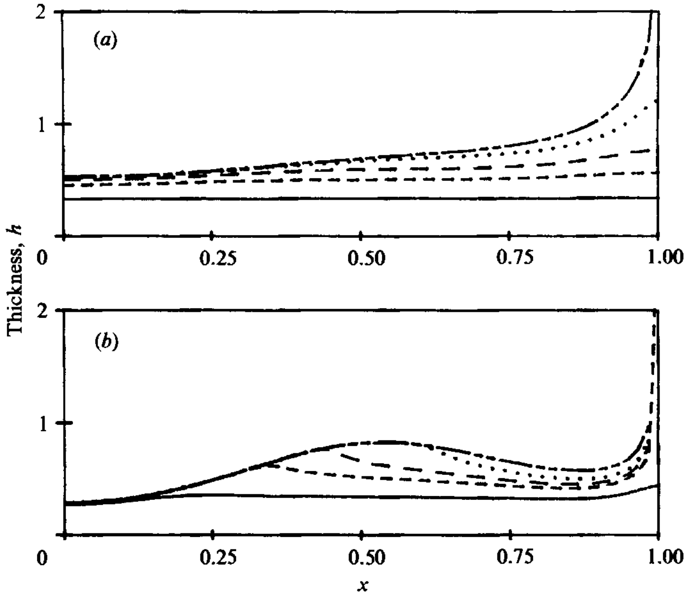

FIGURE 3. A sequence of condensation film profiles versus transverse position for five stations along the length of the cylinder (surface: $y = a \cos \pi x$: (*a*) $a = 0.1$; (*b*) $a = 0.34$): ——, $z = 0.01$; - - - -, $z = 0.05$; — — —, $z = 0.1$; ········, $z = 0.2$; —–—, $z = 0.4$.

The interesting observation connected with this issue is as follows. Since the film profile depends on the gradient of the surface curvature and, therefore, essentially on the third derivative of the surface displacement, two surfaces which appear quite similar can have very different condensation film profiles. This dependence on κ_b' may have important ramifications regarding the practical matter of manufacturing surfaces to obtain specific condensation film characteristics.

REFERENCE

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