# DESTRUCTION OF THE FREE LIQUID FILMS BY SOLID PARTICLES

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In chemical engineering processes associated with the application of protective envelopes to granulated materials, free liquid film devices are used. The references, Sagomonyan (1), Tate (2) and Zukas (3) discuss the mechanisms and describe the analytic design methods of hte penetration processes of solids into the half--bounded liquid space and into liquid substrates, as well as the processes of thin target punching. However, a determination of the film free surface shape on the side where solid particle leaves the film is lacking in these accounts.

In order to solve these problems we apply a procedure (1) to predict solids impact entrance into liquid substrates. In the case considered the potential of the liquid disturbed motion within the film fits the Laplace equation

$$\Delta\varphi = 0 \qquad (1)$$

with boundary conditions $(\partial\varphi/\partial n)_{r=R} = V_n$ on the particle surface and $\varphi = 0$ on the film free surface. The prediction diagram is shown in Figure 1.

Consideration of free surfaces permits to search for a solution of the Laplace equation (1) as a sum of flow potentials over the balls arranged at points along the axis $z = \pm 2mh$, m = 0, 1, 2, ...; this corresponds to the problem of unseparated flow of intinite liquid stream over a ball chain. The potential fulfilling the boundary conditions can be described as

$$\varphi = k\sum_{m=-\infty}^{\infty} \frac{z-2mh}{[x^2+y^2+(z-2mh)^2]^{3/2}} , \qquad (2)$$

where h is film thickness.

It must be noted that eqn. (2) is valid in the coordinate system linked with a moving particle. To determine the parameter k the boundary condition on particle surface is used

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$$\left.\frac{\partial \varphi}{\partial n}\right|_{r=R} = \frac{k}{R^3}\left[-2\cos\theta + \sum_{\substack{m=-\infty \\ m\neq 0}}^{\infty} \alpha_m^3 \frac{\alpha_m(3+\cos^2\theta)-2\cos\theta-2\alpha_m^2\cos\theta}{(\alpha_m^2-2\alpha_m\cos\theta+1)^{5/2}}\right.=V_0\cos\theta,$$

where $\alpha_m = -R/2mh \leq 1/2$, $\sum_{\substack{m=-\infty \\ m\neq 0}}^{\infty} \alpha_m^3 = 0$, $V_0$ — particle velocity inside the film.

Therefrom, we find $k = -V_0R^3/2$, with a high accuracy.

In going over to the coordinate system linked with the film $z' = z - V_0t$ the dimensionless paramters $\zeta = z/R$, $\zeta' = \zeta - \tau$, $\tau = V_0t/R$, $\eta = \sqrt{x^2+y^2}/R$ are introduced. Then, the outer free surface shape of splash is determined by a set of ordinary differential equations

$$\frac{d\zeta}{d\tau} = \frac{1}{2}\sum_{m=-\infty}^{\infty} \frac{2(\zeta-\tau-\alpha_m^{-1})^2 - \eta^2}{[\eta+(\zeta-\tau-\alpha_m^{-1})^2]^{5/2}},$$

$$\frac{d\eta}{d\tau} = \frac{3}{2}\sum_{m=-\infty}^{\infty} \frac{\eta(\zeta-\tau-\alpha_m^{-1})}{[\eta^2+(\zeta-\tau-\alpha_m^{-1})^2]^{5/2}} \tag{3}$$

with initial conditions $\zeta(0) = h/R$, $\eta(0) = 1$.

The theoretical prediction of free surface shape is compared to high-rate cinematography results, and this enables us to consider the proposed model as corresponding to the actual process. Figure 2 gives the numerical realization of equations at different instants $\tau$.

By representing the splash as a hollow jet one can examine the process of its destruction on the side where a particle leaves the film as well as size spectrum of drops or fragments forming, within the framework of the statistical theory of liquid jet disintegration /4/.

## REFERENCES

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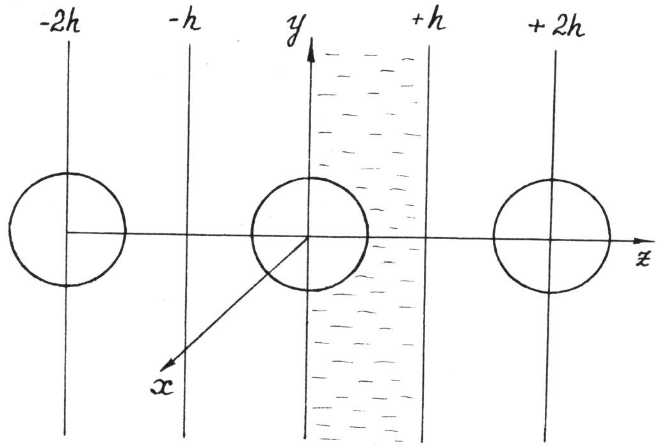


Figure 1: Solid particle and liquid film.

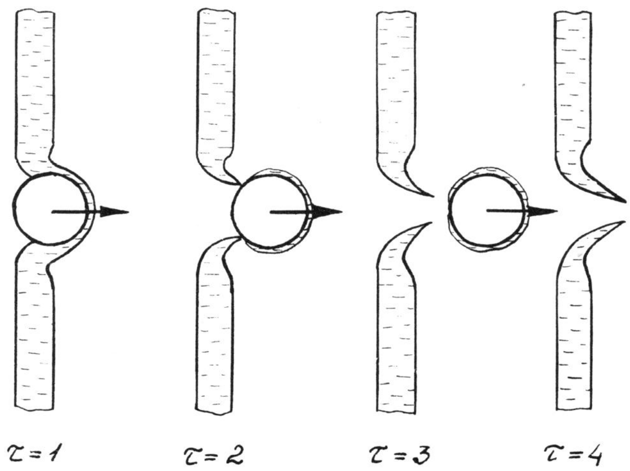


Figure 2: Shape of liquid film punched by a solid particle.