Addendum to “Two-fluid confined flow in a cylinder driven by a rotating endwall”

P. T. Brady,¹ M. Herrmann,² and J. M. Lopez³,⁴

¹Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY 14850, USA
²School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, AZ 85287, USA
³School of Mathematical and Statistical Sciences, Arizona State University, Tempe, AZ 85287, USA
⁴Department of Mathematics, Kyungpook National University, Daegu 702-701, South Korea

(Received 18 April 2012; published 26 June 2012)

In a recent paper [Phys. Rev. E 85, 016308 (2012)], we reported on numerical simulations of swirling two-phase flows in which for cases where the viscosity of the upper fluid is sufficiently smaller than that of the lower fluid, a small region of reversed flow is present on the interface. In this Brief Report, we show that the reported reversed flow is grid converged and comment further on its physical origin.

DOI: 10.1103/PhysRevE.85.067301 PACS number(s): 47.55.—t, 47.15.—x

It has been pointed out to us that in our paper [1], for cases where the upper fluid viscosity is sufficiently smaller than that of the lower fluid, the reversed flow on the interface is not visible in the streamline plots presented in Fig. 4 of Ref. [1], whereas the interfacial tangential velocity profiles shown in Fig. 5(d) clearly indicate such a flow reversal.

We take this opportunity to confirm the presence of the reversed flow and to provide more quantitative information. We wish to begin by pointing out that the flow is solved using the velocity components in a region with an associated small recirculation zone below the interface (seen in the axial, u, and vertical, w, velocity contours as the region enclosed by the interface and the zero contour below the interface) is unchanged by the increased resolution. In particular, the small reversed interfacial region with an associated small recirculation zone below the interface is unchanged by the increased resolution.

To further quantify the grid convergence of the results, and in particular of the recirculation zone, we present in Fig. 2 meridional velocity profiles tangential to the interface.

FIG. 1. (Color online) Contours of the radial u, axial w, and azimuthal v components of velocity in a region with r ∈ [0,0.4] and z ∈ [0,0.4,0.6], for Re = 2000, Fr = 2.46, We = 114, and µs = 0.2 corresponding to Fig. 4(f) in Ref. [1]. The top row (a)–(c) is computed with ns = 300 and the bottom row (d)–(f) with ns = 600. There are 15 positive (black) and 15 negative (gray) contour levels, given by leveli = ±(i/15)² max, where max = 0.15 for u and max = 0.1 for w. For v, leveli = 0.5(i/15)² as v is non-negative and has a maximum value of 0.5.

FIG. 2. Tangential velocity profiles corresponding to the case in Fig. 5(d) of Ref. [1] computed with various grid resolutions ns as indicated.
FIG. 3. Meridional velocity tangent to the interface at the radial point of maximum $V_t$, as a function of the distance normal to the interface for various grid resolutions $n_x$, as indicated, from the case shown in Fig. 5(d) in Ref. [1].

$V_t$ computed with various grid resolutions. The profile with $n_x = 300$ corresponds to the profile shown in Fig. 5(d) of Ref. [1]. We see that the profile is essentially grid independent for the range of resolutions shown, as is the reversed flow region, which exists for $r$ values near 0.26 for which $V_t > 0$.

Another feature of Fig. 1 that warrants a mention is the thin wedge of positive axial velocity about the interface. Ideally, the point of the wedge should reach the axis so that the axial velocity would have a local maximum of $w = 0$ at the axis coinciding with the location of the interface at the axis. Contour plotting routines have a hard time with such fine details, so in Fig. 4 we plot the axial velocity on the axis near where the interface meets the axis, at steady state as computed on various grids. The figure clearly shows the above-mentioned scenario, and that the local maximum converges to $w = 0$ under grid refinement. Table I lists the numerical values of the local maximum in $w$ at the axis for the various grids.

Table I. Local maximum of $w$ on the axis for various grids.

<table>
<thead>
<tr>
<th>$n_x$</th>
<th>$\max (w(r = 0))$</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>$3.56 \times 10^{-5}$</td>
</tr>
<tr>
<td>300</td>
<td>$-2.64 \times 10^{-5}$</td>
</tr>
<tr>
<td>450</td>
<td>$-2.20 \times 10^{-5}$</td>
</tr>
<tr>
<td>600</td>
<td>$-1.87 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

This work was supported by the US National Science Foundation Grants No. DMS-0808045 and No. DMS-0922864, and Korea Science and Engineering Foundation WCU Grant No. R32-2009-000-20021-0.