Analysis of Electro-osmotic Flow of Power-law Fluids in a Micro channel(1D)

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***Introduction**: A fundamental understanding of the liquid flow characteristics in micro-channels is essential to optimum design and precise control of microfluidic devices. In general, liquid motion can be generated by either applying a pressure gradient or imposing an electric field, leading to respective pressure-driven flow or electro kinetically driven flow. Electroosmotic flow enjoys numerous advantages, specifically, a plug-like velocity profile in electro-osmotic flow can result in reduced dispersion making capillary electrophoresis one of more successful technologies for chemical and biomedical analyses.*

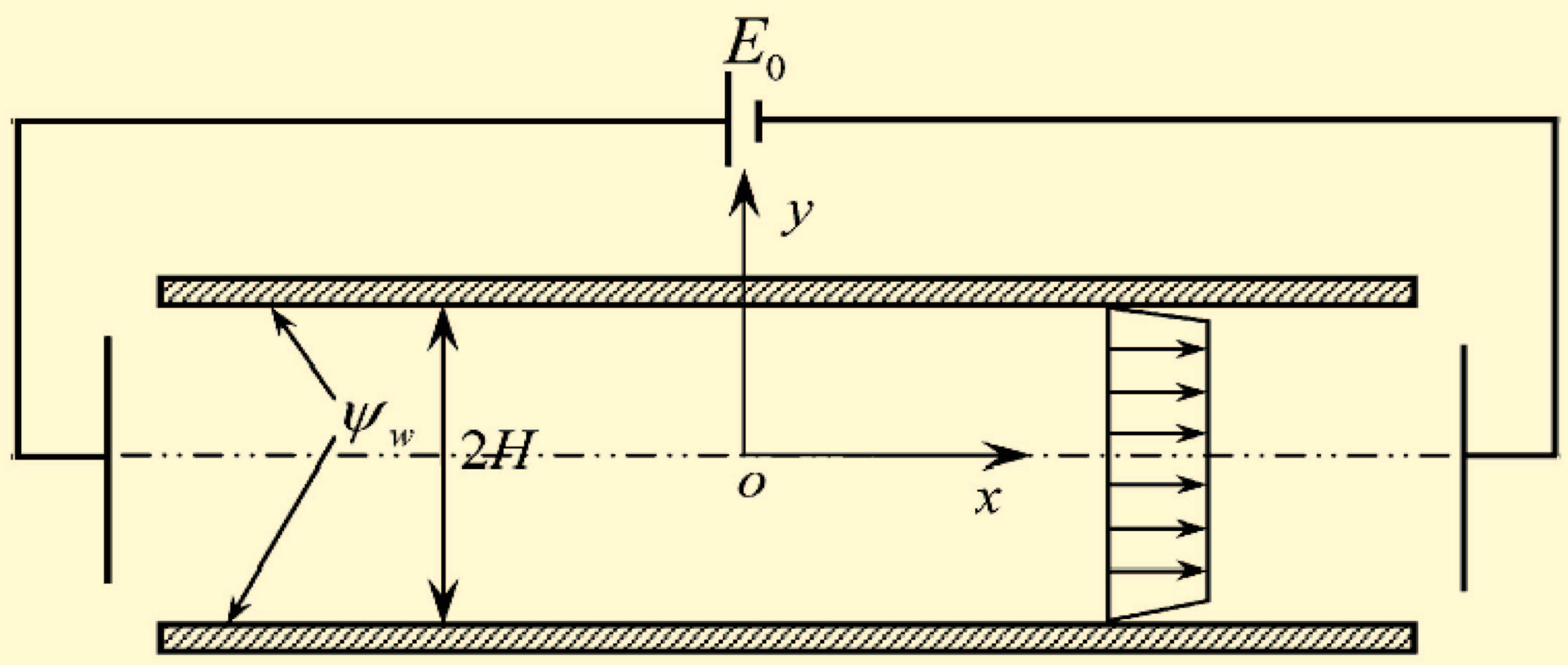

Figure 1. *The sketch of a two-dimensional slit channel.*

***Computational Methods**: The velocity variations are in the direction normal to the axial direction only because the length of the micro channel is very large compared to the width of the channel. Therefore we reduced the 2-D slit to 1-D micro channel. The governing equations including the linearized Poisson–Boltzmann equation, the Cauchy momentum equation, and the continuity equation are solved to seek electric potential and velocity distribution as follows:*

***For Potential**:*

$\nabla^2 \psi = k^2 \psi$

Where, $k=(2z^2e^2n_\infty/\varepsilon K_b T)^{1/2}$

Boundary conditions:

Inlet : x= 0, $(\partial\Psi/\partial x)=0$

Outlet : x =L, $(\partial\Psi/\partial x)=0$

Wall: $\Psi=\varsigma$

For Velocity:

$m\nabla^n u= k^2 E_0 \varepsilon\psi$

Boundary conditions:

Inlet : x= 0, $\partial u/\partial x=0$

Outlet: x=L, $\partial u/\partial x=0$

Wall: $\Psi=\varsigma$

***Results**: The simulation is done in 1-D, diffusion model from COMSOL MULTIPHYSICS. Two models:*

1. Potential with dependent variable- shi and

2. Velocity with dependent variable- vel are used in,

$$\nabla(-D\nabla c)=R$$

Where c is dependent variable, D and R are the quantities to be specified that fit our equation.

Unit length micro channel is drawn and meshed, with more nodes at the exit end, since flow behaviour is analyzed with more emphasis at the exit end.

Figure 2. Geometry and Meshing of 1-D micro channel

CONSTANTS	EXPRESSIONS	VALUE
n	Flow index behavior	0.5, 0.8, 1, 1.2, 1.5
k	Electro-kinetic parameter	1
E_0	External Electric field	$2e^5$ V/m
m	Flow Consistency Index	$9e^{-4}$ Pa. s^n
ε_r (e_r)	Relative Permittivity	80
ε_0 (e_0)	Vacuum Permittivity	$8.85e^{-12}$F/m
ε (epsi)	$e_r e_0$	$708e^{-12}$F/m
z	Wall Zeta Potential	1
Ψ_w (shiw)	Wall electric potential	$-50e^{-3}$ V
T	Absolute Temperature	300 k
vs	(shiw*E_0*epsi)/m	-0.007867
vbar	Average velocity (By generalization vbar=vs)	-0.007867

Table 1. Constants

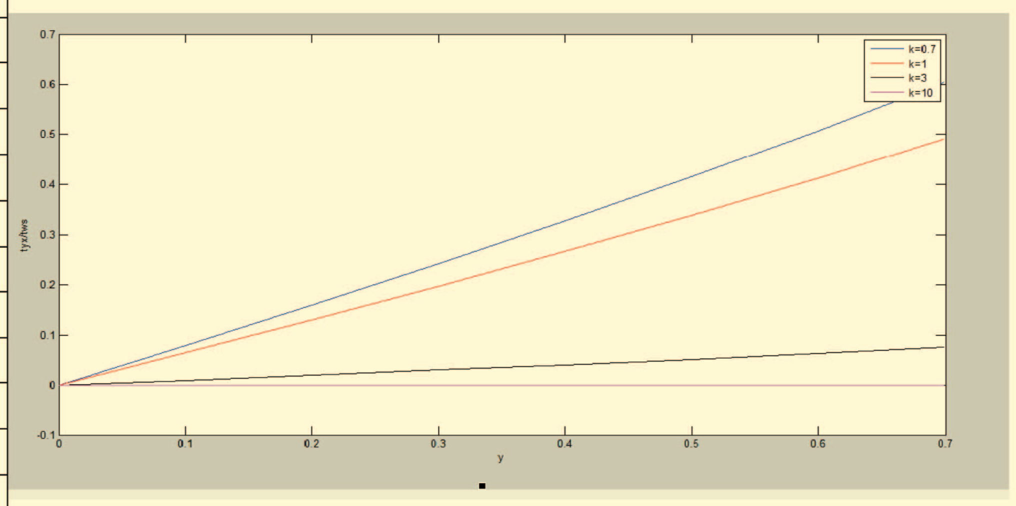

Figure 3. Tyx/Tws vs kY

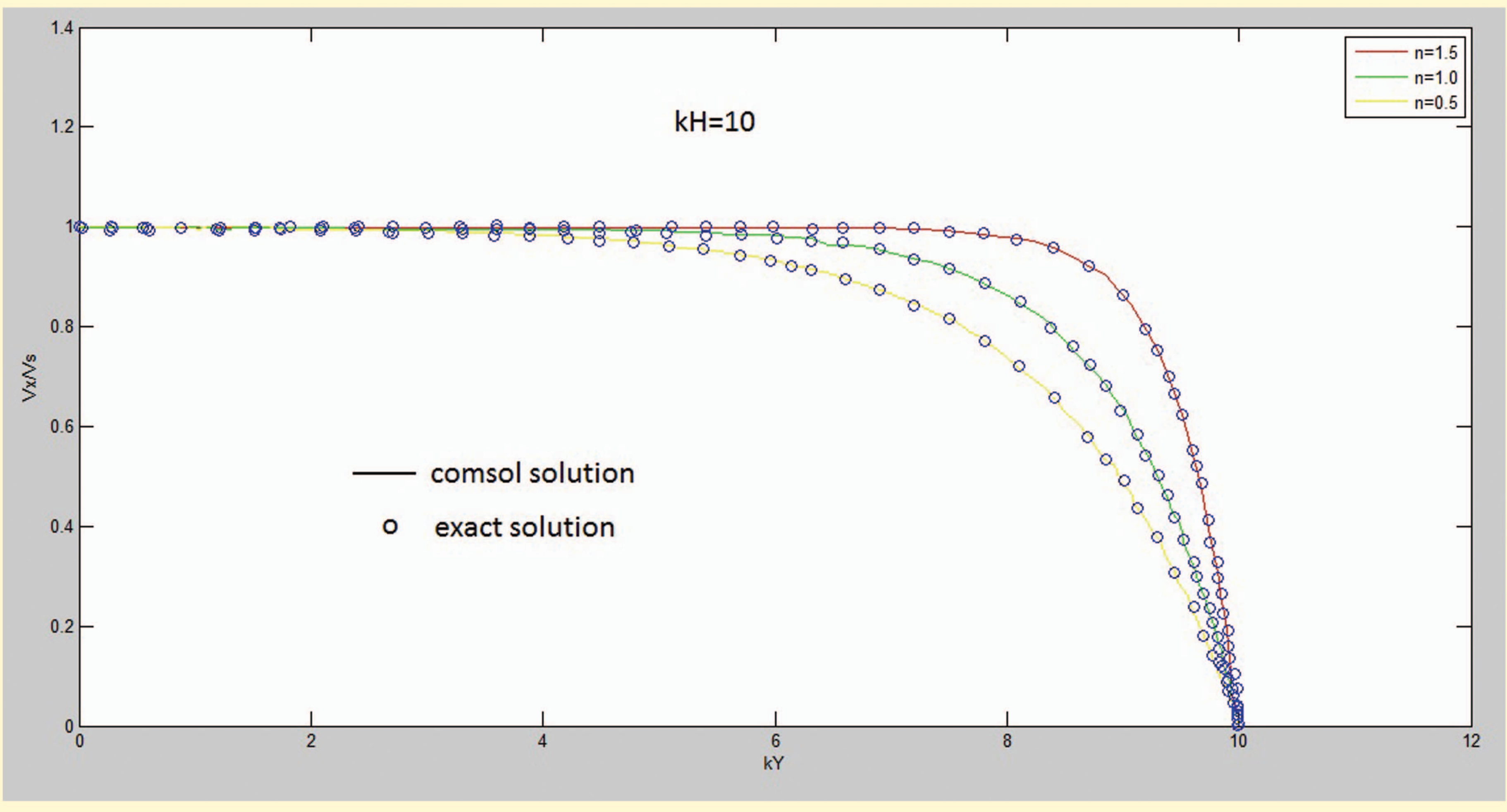

Figure 4. Vx/Vs vs kY

***Conclusions**: A generalized Smoluchowski velocity is taken into account due to the finite EDL thickness and the flow behavior index of power-law fluids. The calculations show that the shear stress is independent of the fluid behavior index and simulation results are well in accordance with analytical solutions by using approximations.*

References:

1. *Cunlu Zhaoa, Emilijk Zholkovskijb, Jacob H. Masliyahc, Chun Yanga, Analysis of electroosmotic flow of power-law fluids in a slit microchannel, Journal of Colloid and Interface Science, Volume 326, Issue 2, Pages 503–510, 15 October 2008.*
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