dicular to the flow. However, the effectiveness of a surface feature design depends upon channel geometry and flow rate.

Calculations/Analysis

[0308] The one sided geometry was run with two flow orientations: A and B, where in A flow feeds along the angled legs toward the apex, where in B flow hits the apex and then flows outward past the angled legs.

[0309] Comparison of the pressure drop in the channel for one-sided and two-sided surface features in cis A and Cis B orientations is shown in the table below.

TABLE

Pressure drop comparison

	Pressure drop (psi)	
	Cis A	Cis B
One-sided feature	1.00	1.04
Two-sided features	N/A	1.13

The higher pressure drop in the two-sided features is because of features on both sides of the channel. For the "B" flow orientation, the one-sided feature geometry has the lowest pressure drop and provides better mixing than the two sided case. It should be noted that this comparison was done for a relatively small open flow gap of 0.381 mm and a surface feature depth to microchannel open gap ratio of 0.67. It has been shown elsewhere that when the open microchannel gap increases and or the surface feature depth to microchannel open gap ratio decreases below 0.3 then the use of dual sided surface features is particularly advantageous. It is particularly advantageous to move to larger microchannel open gaps to increase the productivity of a unit operation and reduce the total amount of metal contained within a unit operation. In some embodiments, the "A" flow orientation is less likely to form infinite recirculation zones (or dead zones) than the "B" flow orientation. For other patterns, a reverse trend is observed.

Example

Surface Feature Geometry

[0310] A number of surface feature geometries were investigated for mixing efficiency and induction of flow rotation, the conditions of which are shown in Tables X1-X2. For the geometry and conditions of case 1 in Table X1, some pathlines of flow appear to become trapped in dead zones at the apex or point of angle change of the surface features at the center of the channel width. In part, the potential dead zones at the apex are formed because the leg length of the two legs of the surface feature is the same and the angle of each leg is changed by 180 degrees thus creating a perfect symmetry point at the apex where the force for flow in the feature is identical down either leg. Patterns that do not create this symmetry point are less prone to the formation of dead zones.

TABLE X1

CFD model geometry and conditions for simulations of cases 1–3.

	Case number		
	1	2	3
Surface feature geometry type	SFG-0-45°-cis-B	SFG-6-45°-trans	SFG-6-45°-cis
Flow direction	Cis-B	N/A	N/A
Surface feature width (mm)	0.381	0.381	0.381
Surface feature depth (mm)	0.254	0.254	0.254
Surface feature pitch or tangent to tangent spacing (mm)	0.381	0.381	0.381
Surface feature angle (degrees relative to width direction, or orthogonal to bulk flow)	45°	45°	45°
Channel gap modeled (mm)	0.159	0.457	0.2285
Full channel gap (mm)	0.318	0.457	0.457
Channel width modeled (mm)	2.032	4.064	4.064
Full channel width (mm)	4.064	4.064	4.064
Channel length upstream of features (cm)	0.381	0.381	0.381
Channel length with surface features (cm)	5.588	5.588	5.588
Channel length downstream of features (cm)	0.381	0.381	0.381
Total number of surface features per surface feature containing wall	50	51	51
Total number of walls containing surface features	2	2	2
Number of cells	157,800	284,160	142,080
Model symmetry	Quarter	Full geometry	Half
Wall boundary condition	No-slip	No-slip	No-slip
Inlet fluid temperature (° C.)	N/A	N/A	N/A
Inlet velocity (m/sec)	12.13	12.13	12.13
Inlet velocity profile	Uniform	Uniform	Uniform
Outlet pressure (bar)	25.3	25.3	25.3
Reaction enabled?	No	No	No
Fluid properties			
Density (kg/m3)	5.067	5.067	5.067
Viscosity (kg/m-sec)	3.62e−5	3.62e−5	3.62e−5