TABLE-continued

Heat transfer coefficient enhancement and pressure drop increase in surface feature channel over smooth wall channel

Reynolds number	HTC Enhancement	DP Increase
5935	1.66	1.74
8247	1.62	11.79

Where HTC = Estimated heat transfer coefficient, $W/m^2/K$
DP = Experimental pressure drop, kPa

[0383] FIG. 14 shows the variation of ratio of heat transfer enhancement to pressure drop increase as a function of Reynolds number. The ratio greater than 1 implies more heat transfer enhancement than pressure drop increase.

Example

The Effects of Reynolds Number on the Effectiveness of Using Surface Features for Mixing of Large Channel Gaps

[0384] A 0.119 cm (0.047") tall gap channel had SFG-0-Cis-A design with 60° angle chevron surface features was examined using the computational fluid dynamics code Fluent Version 6.2.16. The dimensions of the channel are as follows: Gap of 0.119 cm, width of 0.406 cm (0.160") and length of 6.35 cm (2.5"). The chevrons were 0.051 cm (0.020") deep into the wall and 0.038 cm (0.015") in width, with normal-to-normal chevron separation of 0.038 cm (0.015"). The pattern is cis-A, with the same features on both sides of the channel's gap. The chevrons were centered in the middle of the channel width, with the chevrons extending from the center to the wall 0.203 cm (0.080") on either side at 60° angle between the centerline of the channel width to wall in the direction opposite the direction of flow. In other words the point at the symmetry line of the chevron aligns in the direction of flow. There were 33 total surface features in series, with an upstream development length of 0.406 cm (0.160") prior to the start of the features and a downstream length of 0.584 cm (0.230") from the end of the last chevron's point. The model used the symmetry planes that this geometry afforded: The horizontal width symmetry plane that halves the channel at the center of the channel gap created by the cis alignment, and a vertical gap symmetry plane that halves the channel at the center of the channel's width, created by the centered chevrons. These symmetry lines allow for a quarter symmetric model of the channel.

[0385] The conditions of the Fluent Version 6.2.16 models are listed in this paragraph. A total of 127,000 nodes were used in this quarter-symmetry model. The outlet static pressure of the channel was 125.42 kPa (18.19 psia). The design point flow rate was 4.975E-05 kg/s, with the following inlet stream mass fractions: Oxygen at 0.03240, carbon dioxide at 0.31482, methane at 0.00263, steam at 0.09184, and the balance nitrogen, and the species are assumed well mixed at the inlet. The flow rates for the three cases we looked at were 100%, 50% and 10% of the design point flow. The inlet stream and all wall temperatures are held fixed at 870° C. (1598° F.). The system used the laminar viscous flow model, ideal gas law for density and heat capacity, mass-weighted average mixing laws for thermal conductivity and viscosity, and kinetic theory binary diffusivities coupled with full multi-component diffusion equations. The reactor used a surface rate reaction for methane combustion, but the rates aren't germane to the analysis as the fluid mixing as the total methane flow rate for combustion is small and shouldn't greatly change the temperature or composition of the stream for flow path lines, as the inlet and outlet mass-weighted dynamic viscosities are 4.44E-05 kg/m/s and 4.43E-05 kg/m/s, respectively.

[0386] The model results are tabulated in Table ZZ, and it shows the inlet flow parameters for the channel and the results for mixing when the percent of the full flow ranging from 100% to 50% to 10%. The Gap based Peclet number is based upon the inlet velocity, the channel gap instead of the main channel (gap and height are the only dimensions used) hydraulic diameter, and the methane diffusivity at the inlet composition and temperature with pressure set at 141.2 kPa. The Reynolds number calculations are based upon four times the model input mass flow rate, the main channel hydraulic diameter and the inlet dynamic viscosity of 4.44E-05 kg/m/s. The percentage of path lines making at least one pass through a surface feature calculation was based upon CFD particle path line analysis with weightless particles released from line made by the inlet plane and the vertical gap symmetry plane (6 path lines) or the horizontal width symmetry plane (23 path lines).

TABLE ZZ

The tabulated model results for the CSF-0-Cis-A 60° surface features with decreasing mass flow rate. For the 10% and 50% flow cases, full mixing was not observed over the 33 feature placed in series.

Percent of full flow	100%	50%	10%
Inlet bulk velocity [m/s]	94	50.4	10.34
Diffusivity of Methane at 870° C., 141.2 kPa [cm^2/s]	2.22	2.22	2.22
Gap-based Peclet number [—]	505	271	56
Inlet Reynolds number [—]	1705	852	170
% of path lines making at least one pass through surface features			
From vertical gap symmetry plane (6 total path lines)	100.0%	50.0%	0.0%
From horizontal width symmetry plane (23 total path lines)	100.0%	69.5%	17.4%
Number of features to onset of mixing	6	8	10
Number of features to full mixing (33 total)	25	Not applicable	Not applicable

[0387] The results in Table ZZ indicate that the design point flow rate for the CSF-0-Cis-A surface feature with a 60° chevron was very effective in mixing the stream and forcing all of the inlet streams path lines to pass through at least one surface feature. The use of lower flow rates and the same surface feature and channel geometry saw substantially fewer path lines traveling through the features. The 10% and 50% of full flow rates cases had less driving force to travel through these relatively obliquely angled surface features than the higher flow rate. The cis A orientation allowed the full flow rate to take advantage of the lower velocities in the corner, caused by the adjoining solid wall, to allow these corner sections to pass into the additional area given by the surface features. The 60° angle then allowed the exiting flow from the surface feature to leave the surface feature and enter the main channel flow with its momentum more aligned with the direction of flow than if the angle was 45°, for example. When the stream leaves the surface feature