SUMMARY

In the operation of a packed column with cocurrent downflow of gas and liquid (trickle bed) several flowpatterns can be observed depending on the degree of interaction between gas and liquid. At low liquid and gas flow rates - low interaction - gascontinuous flow occurs. In this flowregime the liquid mainly flows in the form of a film covering the packing particles and the gas fills the voids. At higher liquid and gas flow rates pulsing flow can develop due to local obstruction of the gas path by liquid. The liquid plug is subsequently blown away and moves with relatively high speed (~ 1 m/s) downward through the bed. This process repeats itself with a frequency of 1 - 10 Hz depending on gas and liquid flow rates.

Industrial application of the trickle bed is especially found in the petrochemical industry in processes like desulfurization and hydrogenation. Generally the gascontinuous flow regime is the preferred operating flow regime but often very near to the transition to pulsing flow or even in pulsing flow.

The hydrodynamical behaviour of a trickle bed during gascontinuous flow is fairly well known due to the strong resemblance with similar flow in countercurrent operation. About pulsing flow, however, relatively little is known. This thesis tries to gain fundamental insight in the characteristics of the pulsing flow regime in order to explain liquid phase mixing and gas-liquid mass transfer. The experimental work is mainly carried out with the system water/air.

First attention is given to the conditions determining whether pulsing flow will occur. For a particular packing the transition from gascontinuous to pulsing flow appeared to occur when a certain critical liquid velocity is exceeded. Generally the Froude number using the real liquid velocity and the particle diameter is the determining dimensionless number. Starting from this critical Froude number a relation is presented between the gas and liquid flow rates together with the packing characteristics at the pulsing onset.

From the moment on that pulsing flow occurs the behaviour of the system is strongly determined by the pulses. Increasing the liquid

flow rate above the critical value hardly increases the liquid holdup any more but does increase the pulse frequency. In the pulsing flow regime liquid holdup can therefore be correlated to the gas flow rate and packing characteristics only. Pressure drop is also strongly controlled by the pulse frequency. A linear relation is shown to exist between the pulse frequency and the pressure drop at constant gas flow rate. Because of this strong domination of the pulses, investigations were carried out to reveal the properties of pulses in a trickle bed. The results showed the pulse frequency to be linearly dependent on the amount by which the liquid flow exceeds the critical value. Moreover the liquid holdup of a pulse does not seem to depend on the liquid flow rate, which leads to the conclusion that in the pulsing flow regime all liquid flow exceeding the liquid flow at pulsing onset has to be transported by pulses. Only for low gas velocities (< 1 m/s) the pulse velocity is determined by the gas velocity and for higher gas velocities the pulse velocity becomes constant. The pulse must thus be porous in this situation. In larger diameter columns the pulse velocity tends to be somewhat lower than in smaller ones.

Tracer response experiments have shown that the cross-flow model representation best describes the mixing in the liquid phase. This model views the liquid phase as being divided in a stagnant and a dynamic part. The action of the pulses is to diminish the stagnant part thus decreasing the total axial mixing. This is further enhanced by the increase of the rate of mass exchange between the two parts, occurring during pulsing flow. Additional axial mixing due to the forward transport of material by the pulses is observed only at very high pulse frequencies.

Finally the mass transfer from the gas phase to the liquid phase is studied. A system is investigated with the controlling resistance to mass transfer located in the liquid phase as will often be the case with trickle bed reactors. Here also a very beneficial effect occurs due to the pulses. The increase in the mass transfer rate appeared to be linearly correlated to the pulse frequency.

SAMENVATTING

Bij operatie van
met gas en vloeistof -
patronen optreden afha
gas en de vloeistof. B
actie - vinden we "gas
film over de pakking c
Bij hogere vloeistof-
ontstaan door locale v
vloeistofprop wordt ve
heid (~ 1 m/s) naar be
een frequentie van 1 -
Bij hoge vloeistof- m
"bubble" stromingsgebi
continue vloeistoffase
ontstaat het "mist" st
operatie vinden we voo
als ontzwaveling en hy
dan plaats in "gas-cor
naar pulsing flow aan.

Het hydrodynamisc
flow" is vrij goed bek
gelijke stroming in ge
fasen bedreven worden.
stroom systeem in het
bekend. Deze dissertat
verschaffen in de aard
met name de menging in
dracht in een kolom be

Als eerste is daa
pulsing flow zal optre
continuous' naar "puls
zodra een bepaalde kri
meer algemene zin blij