Microscale Transport Processes

Prof. SGanguly

Department of Chemical Engineering

Indian Institute of technology, Kharagpur

Lecture No.# 33

Immiscible Flow in Microchannel (Contd.)

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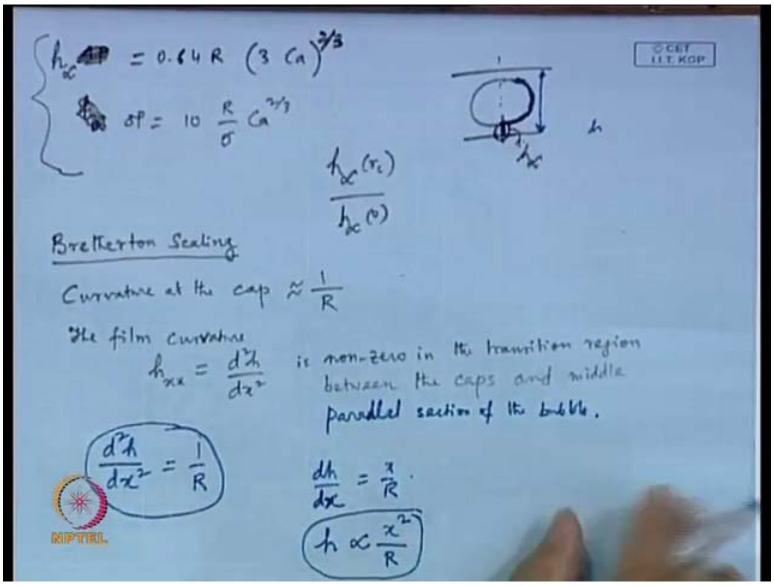

Welcome to this lecture of microscaletransport process what we have been discussing in the last class is flow oftwo phases flow of two immiscible phases through a microchannel.That means, flow of droplets or bubbles.And what we talked about isa relationship, which is referred asbrethertonsmodel or brethertons equationto find out, what would be the pressure dropif a if series of droplets or bubbles flow through the microchannel.

The resultsthat we got if we if we try to summarize the results it would be something like this.Thepressure drop that we talked about is delta p is equal to 0.64rinto three capillary number to the power two third and we said thatthis isthere is a theoreticalbasis to say that this would be the dependence. So, if somebody wants to find out what would be the pressure dropalongin a microchannel.This would be the pressure drop and the thickness of the annular liquid layer at the mid plane; that means, if the bubble if this is one x symmetric bubble placed.

In the microchannel then the thickness at the at mid position of bubble this thickness of liquid annular liquid layer that isreferred as.I am sorry this is this is not delta p I mean I wanted to say this as h infinity that thickness. This is the thickness this h infinity and the delta p is equal to 10 r by sigma into capillary number to the power two third.This is the relationship that we had talked about in the lastclass what I have on top of itthen we discussed few things for example, we discussed about this h infinity r c divided by h infinityrh infinity 0.

Where there is these bubbles are not exactly separated by spherical cap rathertheit is a very thin lamellar that separates a separates a twodroplets or two bubbles.So, the for that this r c was the contacted radiusand we discussed about what would be the functionalrelationship.Andfor a noncircular channel how you will address this. So, I talked about this in the last class at a end of the last class on top of thisunderstanding of brethertons equations or bretherton.

The solution of brethertonsanalysisor the analysis we have another point to be noted here before we move to other topics is something called a bretherton scaling.The bretherton scaling is something like this one may not that the curvature at the cap.At the cap issomewhere similar to one by r what is r. r is the radius of the tuberadius of that micro capillary. So, it can be this can be approximatethis an approximate 1 defiantly. I mean this is not true, but, this is an approximate one on the other hand the film curvature.The film curvature is written as second derivative of h; that means,d square h d x square.

Now, this is this is nonzero in the transition region.Region between the caps and middle

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Parallel section of the bubble. So, this h x x now it can be said in a that these two curvatures are they are to be balanced at the transition. So, what was done in bretherton scaling is they have equated this.Basically they said thatif somebody wants to know the scaling if somebody wants to know say I have these parameters.That I have this is the dimension of the micro channel this iswhat I have now can you tell me what would be this value ofh infinityor what would be the value of h.

Can you give me some idea of the average hthat is there I mean in instead of going through this analysis? I meanwhatever we discussed in the last class simply by lookingat it as this problem of scaling.If somebody gives me an idea thatthis is the capillary number, this is the radius of the micro channeland this is what I haveflowing through this micro channel can you tell me what would be the average value of oran approximate scale.For example, let say it is 10 to the power minus 4 or 10 to the power minus 1 or 10 to the power. There can you give me some idea what portion would be occupied by the liquid and what portion would be occupied by the gas.

So, if can somebody give me this idea.That is that is something whichif somebody interested in that fact rather than a rigorous solution whatthe way it has been done here is this has been equated with 1 by r.That means, what they are saying isin some portion it is d square h d x square and at the end this is going to be close to one by r. So, if somebody wants to know what is the approximate h?As far as this bubbleannular region is concerned then one should what one should do is he should equate this with this and try to find out how the h depends.

Now, what they have done is they have. So, they equated this, they are trying to find out what would be the scale of h.What would be an approximate order of magnitude as far as this h is concerned.If I talk abouth divided by thatradiusor radius or two r of the micro channel what is that order itis close to 0.5?Or is it close to 0.5 in 10 to the power minus 5. So, that order if somebody wants to know probably this analysis could be useful. So, that is what has been done in bretherton scaling now this has beenprobably was integrated withsome boundary condition maybe at x equal to 0 x starts from here.

So, at x equal to 0, d h d x equal to 0.So, with these uses of these boundary conditions. I mean they ended up with very likely d h d x is equal to x by r and then they further integrated. I mean what they have what the bottom line is that they have said that h scale.h is proportional to x square divided byrthis relationship they have come up with byintegrating it twice.It is not a rigorous analysis once again what they have, what thistheobjective here is to find out what would be the scalingall right.

So, given these now, if somebody wants to find out what would be the viscous stress and relate that relate viscous stress with pressure drop relate viscous stress with drop.What he will write in that case ismu d u d y now I make this d u d y I write it as u dividedby h u divided by h at y is equal to 0 the velocity is 0 at y is equal to h the velocity is u. So, it is mu u by h. So, once you have mu u by h.So, that means, it is basically d u d y. Now, what you do in this case is when you relate viscous stress with pressure drop.Then what you would be doing is mu u divided by h thatdivided by h is proportional to d pd x.That is what you would be writing and you know that this delta p you know this on top of this you know that this delta p is equal to 2 sigma by r.

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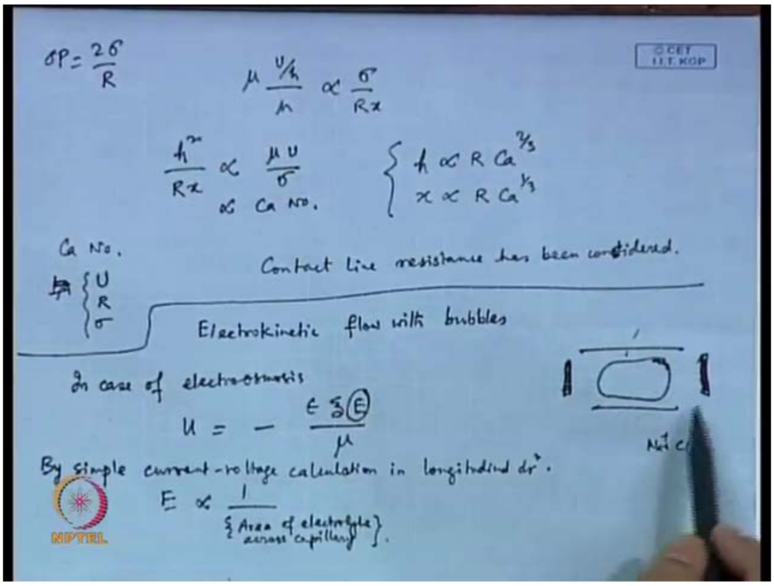

So, from this you can conclude that this mu u by h divided by h is proportional to sigma by r xall right. So, on one hand you have this relationship on the other hand you have said that this h is proportional to x square over r or you can say.Here x is proportional to square root of r h. So, this is another relationship coming from herex is proportional to square root of r h. So, x is proportional to square root of r h this is what you haveandotherwise you have this relationship.If you club them together what you get is h square divided by r x is proportional to mu u divided by sigma,which is basically.

That means, it is proportional to capillary numberand on top of that I have this relationship x is proportional to square root of r h.Now, if you put this in here what you get is h is proportionalto r capillary number to the power two third.All right and also x is proportional to r capillary number to the power one third. So, you have some idea what would be this average h. So, you have some idea that you are introducingmulti phases.You are using immiscible phases into the micro channel, butit would be splitted intothere would be an annular portionfor the liquid part.And then you will have the other part droplet or the bubbleat an axisymmetric location, butwhat are their dimensions without getting into a rigorous calculation.

You can get the some idea of these dimensions simply from scaling of course. This is a scaling analysis I mean what this means is if somebody knows the capillary numberthen it issay for a example for a bubble speed of one micrometerof course.It depends on a dimension I mean depending on depending on what is the bubble speed.That means, what is uyou can find out depending on what is a value of r what is the value of sigmasay.If you know these valuesyou can probably find out, what is the capillary number?And from that you can find out, what would be the film thickness what h we are referring to what h we are referring to that can be that can be found out here.

So, whether it is that means, whether this portion this annular portion is one tenth of the actualdimension of the channel or one hundredth or one thousandththat understanding .You can get from this scaling and one thing I must point out before I move to other topicsis that nowhere in this analysis the contact line resistance has been considered. Butstill I am I mean you have a pressure drop because of two immiscible phasespresent in the channel, but, it is not a contact line the distance.

So, that is needs to be that needs to be understood here. I mean we are we are not talking about the contact angle, we are not talking about the hydrophobicity etcetera. So, we are just talking aboutwe are not talking about these contact line resistance. I mean that is that is one assumption in this entire analysis, but still you have a pressure drop just because you have two immiscible phases flowing.Now, in the last class I justmentioned probably one line that there is some interestingissue hereof these flow of two immisciblephases through a micro channel.

If you want to induce the flow through thethrough say electro kinetic mode.That meansif you want to have an electro osmotic flow of these two immiscible phases.If you want to have electro osmotic flow through this micro channelthen there are some points that would be .That you need to consider here. So, what I let us write this here what is discussing we are going to discuss is electro kinetic flow with bubbles.That means, you have this microchannel.You have a bubble placed axisymmetricallyand then you have anelectrode here and you have an electrode there just the way you have conductedconductedelectro osmoticflow orat the electro kinetic.

So, you have this electrodes here and you haveyou want to induce a flow.Then what happens if you do this the problem here is that in case of electro osmosisvelocity u is equal to minus epsa zeta e divided by mu. This isthese expression we have already we have this is called electro osmoticvelocity.This expression for velocity we havederivedsometime back not in last or last to last classes, butsome other in the non-linear part of this lectures.

So, lecture series. So, we have this expression there this defines the velocity under electro osmoticflow now if I look at this term e if I look at this term eby simple current voltage calculation in longitudinal directional e is inversely proportional to area of electrolyte across capillary I hope you can you canyou can appreciate the fact that here in this case you are applying voltage, but, voltage means you are basically say for example, I have n a c l here. So, n a c l breaks down into n a plus and c l minus right and these are the ions and they would be responsible for movement.Right now here I am talking about this much of cross section for the liquid and this much of the cross section for the liquid.

So, this case the electric field e that you get and the case where you have the entire channel filled with liquid these twowould be different because theit is it is you are applying the same voltagesame voltageis applied, but, over a smaller volume of electrolyte this case and the larger volume of electrolyte in the other case. So, when it comes to you are applying the same voltage, but, when it comes to the electric field that you get that would be proportional to the area of electrolyte across capillary. So, what these means is what this implies is if we if this is the velocity if this is the expression for velocity then you can say u is proportional to 1 dividedby this areaall right.Now, you have on the other hand the flow rate.

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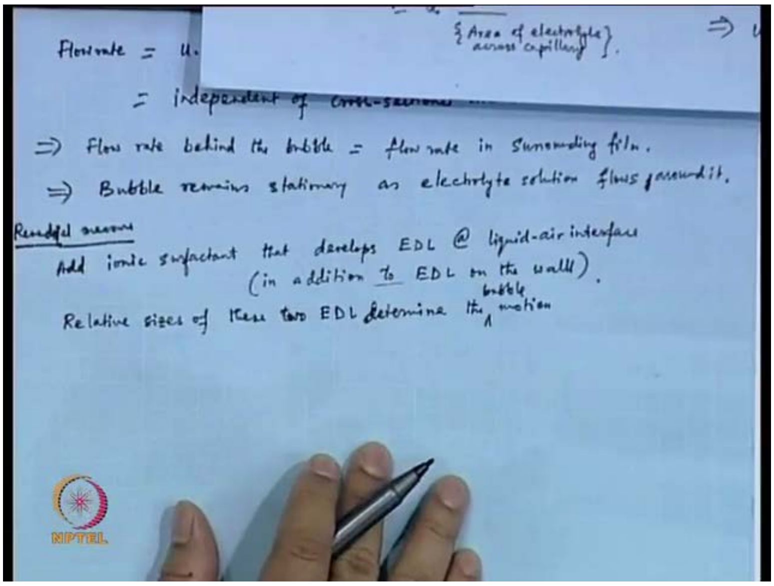

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Flow rate is basically u multiplied by areaall right. So, what you will have here is then flow rate is equal to since u is inversely proportional to area the. So, the flow rate will be equal to independent of cross sectional area. So, what the implication this would be that the flow rate here where the bubble is not therethe flow rate hereand flow rate in this surrounding films that would be same. So, what; that means, is that flow rate behind the bubble is equal to the flow rate in surrounding film. So, the what these implies is bubble remains stationary as electrolyteselectrolyte solutionflows around it.

So, that means, the bubble remain stationary, butthe liquid will be flowing around. I mean youincrease a voltage you expectthere would be morethere would be movement, butit would be the liquid that would be flowing through the surrounding film, butthe bubble will remain in that same position. So, this isone issue with electro kineticflowelectro kinetic flow with bubbles this is this appears to be very interesting.But andthis does not happen in case of a pressure driven flow. So, that that you must you must understand that is there is a difference.

So, the remedial measure that is there I mean remedial measure that has beenstudied here is add remedyremedial measure.That researchers have thought about isadd ionic surfactant that develops electric double layer at liquid air interface.If it is a bubble liquid air interface this is on top of I mean this is in addition to mind it.Because already you have some electric double layer in addition to e d l on the wall because to implement electroosmotic flow.You have to have anelectric double layer at the wall and that is how you are dragging right.

So, here in case of here you have ionic surfactant that is added to develop over and above this electric double layer on the wall, which is responsible for theflow.You have additional electric double layer at liquid air interface now relative size relative sizes of these two e d l that means.So, what is the size of e d l we know as for as size is that is basically d by length. So, the relative size of these two electric double layer one electric double layer is at the wall, which is responsible for electro osmotic flow and the other electricdouble layer is at the liquid air interface.

Now, the relative size of these two double layers that means,is the Debyelengths of these two double layers.That becomes responsible for that basically determines the determine the motion determine the bubble motion. So, this is one issue, which you need to know. I mean when we are talking about immiscible flow of immiscible phases the pressure driven immiscible flow and the electro kinetic immiscible flow.They have some there is some difference between the two.

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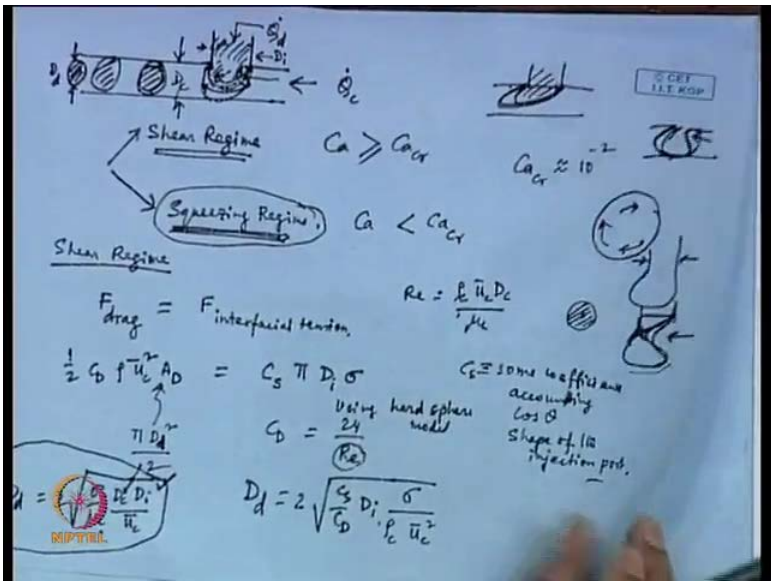

With that being known now, I want to spendsometime on theformation of these droplets and bubbles. I mean that is also equally important, how will you form these droplets?how will you form droplet of certain size.Now, when it comes to this I meanwhen I go to the literature what I find is that a common way of forming a droplet would be something like.This you have a t jointyou have one fluid, which is flowing say, which is flowing. I am calling this carrier fluid, which has a flow rate of q c dot and I have a droplet phase, whichis flowing at a flow rate of q d dot. So, this is the dropletphasenow, this droplet is coming out and this is on the other hand you have this carrier flow and what you would be getting is dropletsthen another droplet.

This is a common way of forming droplets.This is referred as a t joint because itthough I mean I should have drawn itthis arm should have beenat the bottom side.Then it looks perfectly anyway you can invert this and you can still feel how it is you can still feel here.Now, this one you have herenow you have you have the you have the carrier fluid here and the droplet phasehere.Coming innow, what you would be interested to know is that I what you would be interested to you know is the what are the forces responsible for generation of this droplet.For that I must point out that there are two regimes possible .When it comes to formation of dropletwhen it comes to formation of droplet there are there are basically there are basically two regimes

One isone is called shear regimeand the other is called squeezingand there is a critical capillary number, which determines you are inwhich. I meanthat formation of droplet in, which regime.If it is if the capillary number of this whole formation process is less than capillary critical then it would be a squeezing regime.On the other hand if it is greater thancritical then it would be shear regime. In fact, I should put a equal to signsomewhere because thenyou are say if c s c s e r.

How will you count that?So, somewhere it has to be put that the critical capillary number it is typically its value is 10 to the power minus 2what is the difference between this shear regime and squeezing regime.Let us first talk about the shear regime which is easy to understand here the process what is like this you have a flow of carrier fluid this is called carrier and there are otherthat are I mean there are two phase. So, they are differentiated as c and d carrier and droplet phase. So, you have this flow ofcarrier fluid. So, this carrier fluidimposes some drag on this on this on this droplet phase nowone analysis I meanvery common analysis suggests I mean if somebody wants to know if have q c dot is this q d is this and capillary number is this.

What would be the size of the droplet and for doing that for shear regime asimplecalculation would be that the drag force by this carrier fluid is equal to the interfacial tension.What this means is this fluid is growing, but, this fluid is held up by the interfacial tension here. So, when this drag force is more than the interfacial tension you can expect that is the thresholdpoint.When this extended plume that has come out of this arm that would detach and then interfacial tension it will continue as a single droplet.

So, if drag is equal to f interval this is a commonway somebody can find out the quick way offinding what would be the diameter of the droplet.Now drag is typically given by half c d rho u c bar square into a d, where the a d is the a d is the projected area. So, a d would be equal to pi d droplet square by 2. So, that is droplet squarediameter of the droplet square by two piwhatno if this is this is the area.That means, it would bepi d square by four I should not be taking it a by two.

Let me point out the dimensions here I have this dimension is given as d c.That is the diameter of the capillarythe diameter of the droplet. I mean this does not necessarily fill the entire part of the channel. I mean. In fact, the drawing is little bitit shouldportion of the channel occupying and this diameter is d ddiameter of the droplet.And then maybe this diameter would be d Ithe injection port this diameter would be d I.

So, I can I mean what you were doing we are going to do here is we would be equating with c s pi d I sigma.You understand d I is this basically this is this is the diameter of this is the diameter of the arm and this perimeter is holding by interfacial tensionthe droplet phaseat the time of detachment. So, pi d I sigma you can understand and on top of that you have something called a c s,which is some constant c s is some coefficient. c s is some coefficient c s is some coefficient accountingsay cos theta then shape of the injection port.

So, there are there are something, which we do not we are not accounting here. So, thatis clubbed into this parameter c s. So, c s pi d I sigma I mean if it comes to this you can take c s 1. I meanit is like the adventury coefficient.You have I mean people who are from fluid mechanics background. So, it is a similar one. So, you can have a c s that is fine this part I understand and this part is drag.Why it should be pi d dsquare by two the area.The area would be area would be area would be pi d d square by four actually, but, that is at the time when droplet has been fully formed and it would be zero when droplet has not formed.

And I do not, butat the time of droplet formation however, the plume this that you have here this may not take the full area. I meanthis say for example, if I if I look at thisdimension here.It would be something like this it will take a shape like this. In fact, then it would take a shape like this.And then it would break probably we will try to touch upon this point why we should be having thisor let me point outlet me see what would be the final result I this case.

C dfor a hertz sphere model using hertz sphere model c d is equal to 24 by Reynolds number using hertz sphere model. So, c d would be 24 by r e in that case the what would be the droplet diameter? In that case it would be I meanit would be definitely c s divided by c d. I see the value t I appearing here thensigma is there and if I it comes to r e r e is based on the based on carrier fluid. So, this r e in nothing, but, rho c u bar d c divided by mu c.

We can call this u c bar if we are talking about about u c bar here. So, this is something we have and d I sigma divided by rho c u c bar square. So, this is something we haveand on top of that I have a factor here. All right on top of that I have a factor herethat depends on what projected area you take for this for thisdroplet. I mean if you take this as two then it would be probably 2 into 2 it would be 4 it would be 4 and it goes to that side. So, when you take the square root it will come out as 2 that is the possibility.

Now, if somebody assumes c s to be equal to 1 and c d to go there then the droplet diameter would be in that case would be equal to. Then you have square root of sigma divided by mu cd. I divided by u c barif you bring in this Reynolds number. I think you take c s as 1 and c d as 24 by r ethis multiplied by 2.If it is taken as pi d square by 2. So, this is basically the equation for droplet diameter,which is equal tothe functionality.Here is we have capillary diameter d c is there.We have d I is there that is the diameter of the injection port.That is there we have u c bar the average velocity of the carrier fluid which is nothing, butq c dot divided by pi d c square by four.

So, that u c bar is there carrier fluid viscosity is there interfacial tension is there. So, thatthat that gives the diameter of the droplet.So, if somebody wants to produce droplets of certain diameter.He can choose the dimensions, he can choose the velocity of the carrier fluid and he can come up with the right disulphidemensionsdimensionsthat is possible now, this is what you have what I called is shear regime right we have another regime to talk about.

Now,it isone thing I must point out that, when you are working in shear regime then, when you are forming droplet like this.It has been found from imagingstudies that there would be some shear going on inside the droplet. I meanafter the droplet forms if somebodythere is a method calledp I v particle image velocimetry, where you put you can see what are the velocity vectors within this droplet.And you will find that thisdroplet because of the formation process itself the droplet after it formed after you see an isolated droplet.If you study you will see that there is a vortex inside the dropletbecauseyou are producing a shear look at it the carrier fluid is shearing it right.

So, within the droplet phase itself there a shear. So, if this is the droplet phasewe are talking about you will find that there is velocity profile like this there is a vortex generating within the droplet itself. In fact, this is whythere is a preposition that this droplet can be used as a mixer.That means, you have two streamsyou mix them you put them together and then you want them to be t thoroughly mixed. So, put it in under this regime and you will find because of this small micro vortex inside the droplet you will be you will be carrying out mixing.

So, that the this is the one mode of mixingthe researchers have suggestedalso. So, this is this is this is a possibility now this one second this one second underscore the fact that this process is shear regime; that means, since you have the shear. So, that is why you have caused this type of moment within the droplet. So, the velocity vectors if somebodytries to find outthey will find a substantial development of vortex inside the inside this droplet.

On the other hand in case of squeezing regime I do not expect shear toshear to get into this. So, this is this would be in athis would be formingthis would be again a t joint a same thing only thing is the shear would be absent. So, if some if you ask me I mean how do I know a capillary number is greater thanc a c r.That it is the shear modethat isresponsible for the breaking up that already researchers have observed within the droplet that that there are remnants of thatshear already present at the down stream.

So, now I must talk about the squeezing regime in nutshell.What squeezing regime is here?That this thing grows this droplet phase grows and hits the wall it fills this channel completely.Then in that case, where will this (( )) peculiar fluid gothe carrier fluid will start eating awayor carrier fluid has to has to push it right. So, you will find thatthis isthis has formedthis hasthis has filled a channel.Then you will find that this is takingthis kind of shape the droplet has advanced a little bitand carrier fluid is pushing it further similarly. So, carrier fluidwould be pushing it carrier fluid cannot pass by the side of it.There could be some leakagethat is negligible, butpredominantly beyond this point the job of the carrier fluid would be to eat away this portion.

So, that means, it was it was originally it was the droplet was forming like this and this is the d I this whole thing is the d i, butat next moment,this is taking, this kind of shape, this is d I and this q c is q c is pushing the liquid.It is squeezing that that is why it is the squeezing mode. So, it will continue to squeeze and add some point this thickness would be too small this thickness would be too small and then probably. I mean if you want to consider it you can look at thisRayleigh plateau instability.Or otherwise also you can find out how long it takes for thistofrom the geometric consideration you can find how long it takes to reach the end.

Because moment the end is reached the droplet is released. So, it is completely you can find out the entire analysis would be best on geometry and if you will the Rayleigh plateau instability. I mean if you\do not want to give thefrom geometry.You can say when this thickness gets 0 because this q c dot that you have that is fixed that is constant. So, it has to eat away and rest of it is geometry now, you can say thatit will reach the end when it reaches the end I will consider the droplet to be released.

Or you can say thatif still there is some delta left and at that pointsome Rayleigh plateau instability caused.This to rupture because here it is a nick here at this point here.It is a nick. So, at some point there is a rupture.So, butthat I knew it that delta would be very small. So, this is coming purely from geometricconsideration geometry andyou have to satisfy the q c dot if you if you assume that there is no leakage around. So, q c dot cannot pass by.

So, q c dot will be eating away. So, from geometry where wherever it goes and you it goes that way. So, that defines the diameter of the droplet. So, that is exactly what is squeezing regime. So, you are not sharing the droplet, but, you are doing it this way. So, this is the difference between the formation of true this is the difference between two dropletregimes. I mustsay now typically if somebody wants to find out what is what would be the dimension of the droplet.It would be the point of viewof geometry that is for certain I i mean I one can.

I meanif time permits probably I will talk about it further, buthow this geometry can be applied to find out what would be the diameter of the droplet.It may not be asimple analyticalform like this the way we put it here, but, let us see. I mean for the time being let us just appreciate that there is such possibility, there is such regime and you understand how this regime works? I think that is important and later on we will see can.How we can make use of it further.Now,there is another possibility,which goes by the namelambda junction,which goes by the name lambda junction which is something like this that you have a this a t joint.

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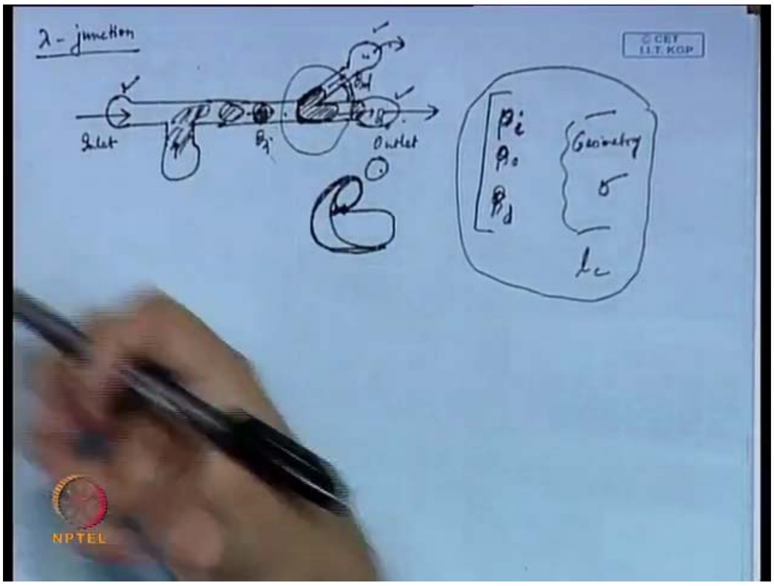

And you have an inlet here you have an outlet here.And you haveanother outlet here. So, you have that you have the droplet phase coming in and droplet phase is forming. So, you are forming the droplets fine.Now, you are collecting you have a possibility of collecting fluid through this side you have a possibility of collecting fluid from this side as well. So, what will happen is once this droplet comes and reaches here. So, it will tend to take what shape it will go like thisdo you agree with this.

This is the type of shape it will take. So, this is the type of shape it will take and then you have depending on. What is the pressure here and what is the pressure here.It canone possibility is that it can go in a little bit and later on it negotiates andit just simply comes out.It goes in and then you have interfacial tension, which is pulling the droplet phase together because you have a why is it a sphere becauseit is there is some reason to be.So, why is it intact why is it a droplet why it is not a completely dispersed one because it has a reason to it I mean it has it has surface tension holding it together.

So, there that you will that will negotiate. I mean on one hand you are trying to push a portion of the droplet outon the other hand you have the surface tension which is trying to pull it together and. So, basically bottom line is that the back side of this droplet if if this is the front side and the back side back side of the droplet you are stretching.This side you are stretching all right. So, once you stretch thisif you if you if you stretch this too much then you can expecta daughter droplet forming out of it. So, it you will you will see this portion is stretched too much. That means, you have you have a droplet of shape like this and this layer is stretched too much for this.

So, this is layer is gradually it will go like this and then this thickness becomes toothey are too close to each other this cornerbecause of this Rayleigh-plateau instabilitythen you see that this is forming a droplet and going in. So, this is referred as daughter droplet. So, this is this is the this is the major you are already in the micro channel that you are in a microscope I mean you are forming small droplet, butif you are interested in forming a smaller one.Then you can negotiate between these two flows and you can literally you can form something called a daughter droplet on the other hand if you are this see you have a pressure here you have a pressure here and you have a pressure here.

So, if the pressure is not if the pressure differential between this point and this point is not sufficient then what will happen is it will go in a little bit, butit is not gone in sufficiently. So, it will refract and again proceed just like a droplet and again this would be forming like a droplet. So, depending on how you play these 3 pressures you can be forming daughter dropletor not I mean that your will. So, and this droplet is expected to be much smaller because it is originally you formed a droplet and then you chopped of a small portion of that and putting it as a daughter droplet.And this because of this shape of this as lambda this device is lambda there is an angle to it you give this youthe name of this is given as lambda junction.

Now, there are certain theories already put forward wherewhat you consider in this case because since you are in this squeezing regime this entire formation process is in squeezing regime. So, one thing you must understand that what you are doing here is simply you have the flow rates here.One is say again a carrieror you write it as this q I q o and q d where this is say q d this is say q oand this is what is coming inis q i.So, again you are and depending on the relative values of these q I q o q d and the geometric consideration; that means, what is this thickness.

What is this angleand what is this delta that up to, which it to it can go and beyond which there would be a rupture. So, what is this delta beyond,which isthis becomes unstable. So, that. So, the.So, other than this what you need is geometry.That means, the dimension of the channel the angle and that delta etcetera.That governs something called the l c by up to what extent this what is the length of this back part of the droplet that is been stretchedand that governs. So, these factors primarily since you are in squeezing regime.

You do not need to consider shear here this governs what should be the diameter of thedroplet andmoreover. I mean you do not need to you do not need to write q I q o q d you can write simply p I p o p d the pressures at this point. So, pressures and the geometry that would govern whatwhere the no most importantly, whether you are form a daughter droplet or notit could be that therate.That p I p o pp d that you choose and the geometry that isand geometry and of course, sigma very importantly.

So, that the values that you choose the matrix that you choose is not capable of forming a daughter droplet.Then you see some introduction of droplet phase into this otherarm, butthen it is again pulled and continued.Where as if you tinker it further you may see at some under some configuration you are forming daughter droplets. So, this is a very interestingpoint hereif I wish I can discussthis squeezing regime moreif possible.Let us seeanywaythat is all I have for todays class and I will meet you again tomorrow thank you.