Heat Transfer And Combustion in Multiphase Systems

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Lecture 12
Governing equations: Averaging techniques-II

So, the last class where we started was we started looking at the volume averaged multiple fluid models. And we started to if you if you recall the equation we first did continuity.

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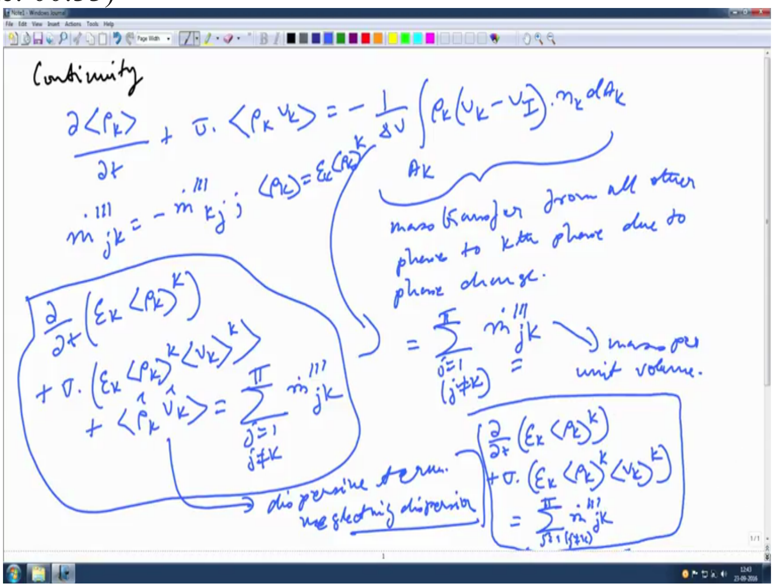

It is the mark we did continuity and this was using the volume averaging technique that I showed. This was the expression that we wrote okay. Now this particular stuff actually designates the mass transfer from all other phases to kth phase due to phase change okay. Now this we said is equal to summation of j = 1 to all the phases Pi.

But j is not equal to k okay, so, this is m triple prime in jk okay. So, from all other phases it is actually something over j. So, therefore from all other phases how it is transferred to the kth phase okay. So, this basically represents the mass per unit volume okay and we also said that m triple prime jk is the same as -m triple prime kj okay.

So, applying now converting this and also recalling that Rho k is nothing but Epsilon k Rho k is the intrinsic and extrinsic phase average. This is given as Epsilon k Rho k + Epsilon k Rho k Vk k plus this expression that you get okay. These are basically the dispersive term which we defined in the last class right. So, that is the dispersive term.

We saw that what that is dispersive terms are right in the last class. So, if we neglect this dispersive term in many of the cases they are actually small right. So, neglecting dispersion what we get is okay, that is what you get okay. If you neglect the dispersive term this is the net equation that you get. This is the continuity equation okay.

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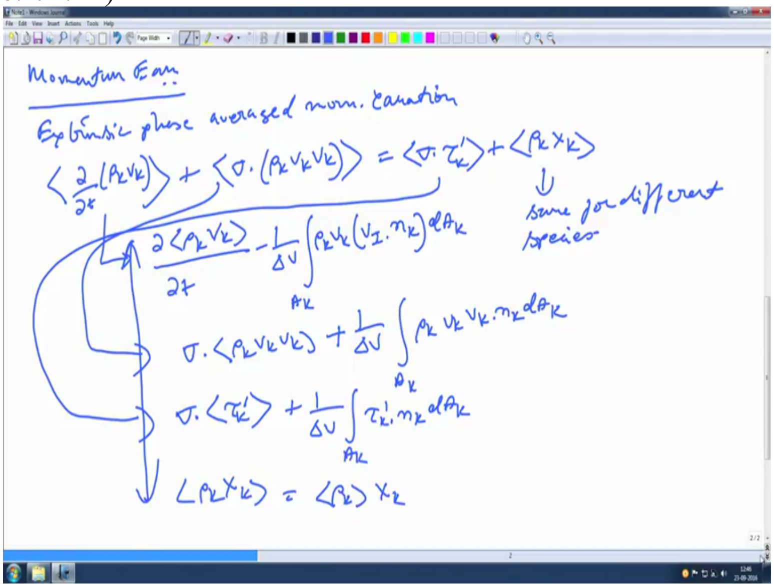

Now moving on let us go to the momentum equation okay. Now the extrinsic phase averaged momentum equation okay, so, this is basically the body force term same for different species. If we assume it that way okay. Now as per the rules that I covered in the last class, if you recall the rules okay.

So, the first term will be okay, you can represent this as -1 over delta V Ak okay. Similarly this particular term, the second term, the second convective derivative. The second part of the convective derivative is given as okay, similarly the third term which is basically the stress term that we have okay and the last term okay.

So, what we do is now we combine all the three terms all, this all the terms not three, four terms together move to the next.

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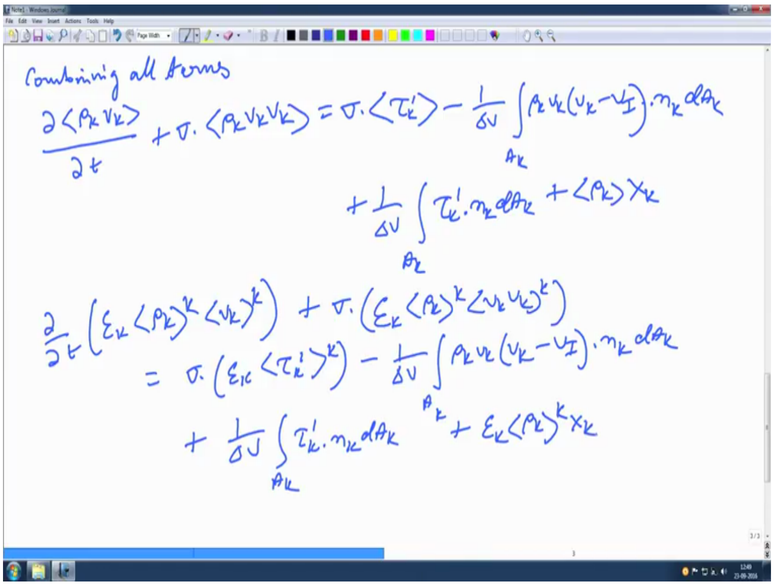

To the combining you okay, right, so, that is the total equation combining all the things together the momentum equation, right. Now we can also from an extra; from an intrinsic point of view, these are the expression is equal to; these are long lengthy equations but it is required to understand the physics of the problem Rho k Vk Vk - VI dot nk dA k plus; because of this additional terms that we are carrying.

Because of the transformation that we did okay that is the expression that you get.
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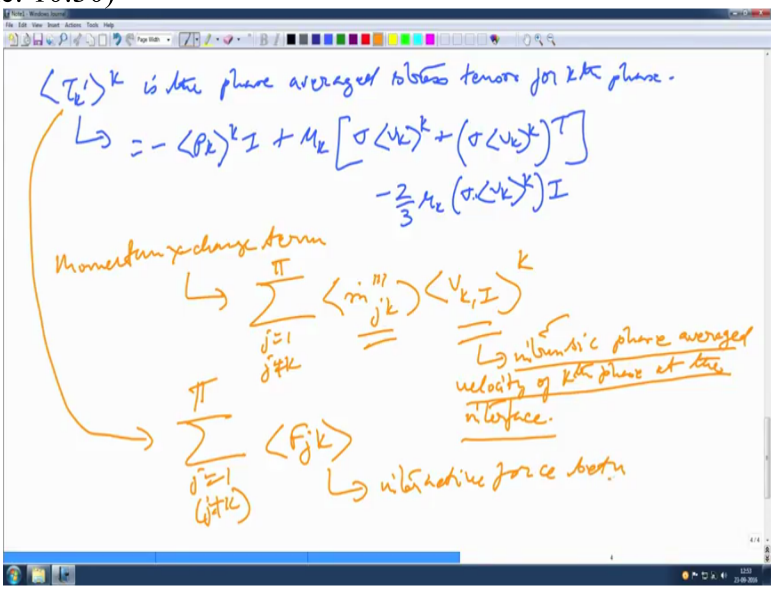

Whereas, here Tou k prime k is the phase averaged, this is averaged stress tensor is a phase average stress tensor okay for the kth phase. So, that is what you have right, so, that is what it is. So, this stress tensor can be further written as corresponding to the pressure. This is the viscosity minus two-third Mk okay. So, that is the stress tensor that you see.

Now also if you go back to the previous one let us put a couple of thoughts on these on a few terms okay. So, for example this particular term over here, change the marker this particular term that you have over here what does this designate? This designate some kind of a momentum exchange right, okay.

Now that the term, this particular term what does this designate? This designates some kind of interactive forces. Forces between all other phases and the kth, got it, okay. So, that is interesting. So, you can see that this is the nature of these two important terms that the additional terms that we have carried.

One is that one represents the momentum exchange the other represents the interactive forces okay. So, we go to this next page where we actually did all the things. So, the momentum exchange term, if we look at it okay, when we tell that it is momentum exchange then it must can be cast in this particular form, right.

So that is the mass that was exchanged okay and this is the corresponding velocity, okay, at the interface okay. So, the intrinsic, this is intrinsic phase average velocity, averaged velocity, velocity of kth phase at the interface. So, is the intrinsic phase averaged velocity of the kth phase at the interface okay.

Similarly; so, we know that what this term will be this term on the other hand, the interactive force term okay can be represented by some kind of a force expression now j not equal to k given by some kind of F jk what is F jk, this is interactive force between the jth force between the jth and kth phase, okay.
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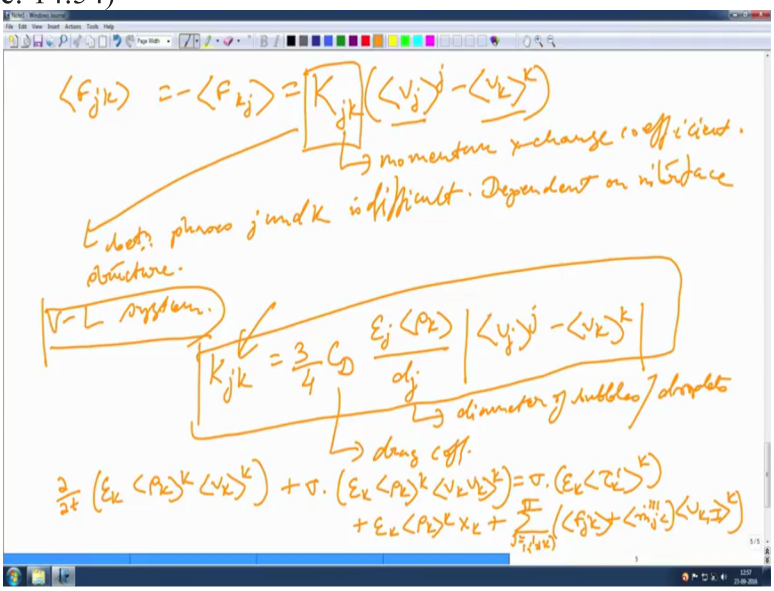

So, F jk is equal to - Fkj and can be written as some kind of a parameter K jk which we will come later what that parameter means? This is called; something called the momentum exchange coefficient okay. So, momentum exchange coefficient, so, this essentially means that this is this is an ad-hoc kind of a term and these are the velocities in the; or the intrinsic phase average velocity in the two phases.

So, this is a momentum averaged quantity. So, determining this particular quantity between phase between phase's j and k okay is difficult, right. It depends on the structure of the interface also right. So, it is highly dependent on interface structure that is the that is a very crucial thing, right.

So, how do you actually determine it, so, if we for example have a vapour and a liquid system like can be vapour bubbles or liquid droplets whatever it is, K jk is given by 3 4th CD Ej Rho k dj Vj j Ek k okay so, this is basically the diameter of bubbles or droplets If it is a system like that.

So, this is a very ad hoc example this is the drag coefficient okay. So, that is the drag coefficient. This is a total expression, so, this is like 1 for liquid vapour system this can be cast in this particular fashion, okay. So, that is one way of casting the whole thing okay. So, now if we assemble the full momentum equation and this is just one example that we gave.

The whole momentum equation become is the full momentum equation okay. So, the full momentum equation attained that particular form okay. So, that is one thing let us move to the next page.

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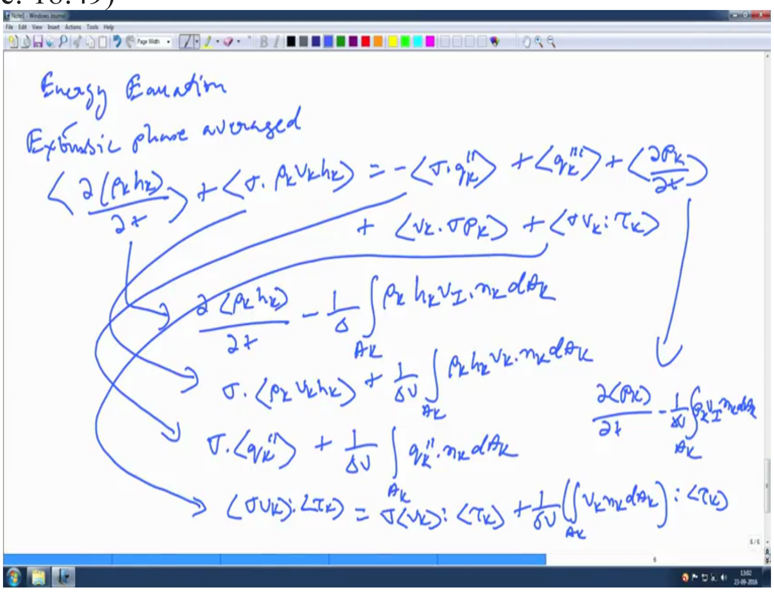

We can also similarly do the energy equation. So, once again we start from extrinsic phase averaged that is the extrinsic phase averaged equation okay. Now if we look at the each individual terms of this particular expression once again this term will be Rho k hk dt minus these are long expressions as I said and sorry hk VI dot nk dAk was the first one okay.

Similarly the second one you can write it in a very similar fashion. Similarly the third expression okay and similarly this particular expression over here or the Pk expression can be written as. These are all just you apply the rule that is it. So, I am not putting the Ak always because you know that it is taken with respect to the Ak, okay.

Similarly the contraction part, this particular part of the expression okay is almost equal this is equal to that and this is equal to Vk Tou k + 1 over V innately okay contract on tou k, okay. So, that is the expression that you get. So, each and every individual term is in this way taken care of and if we neglect the dispersions.

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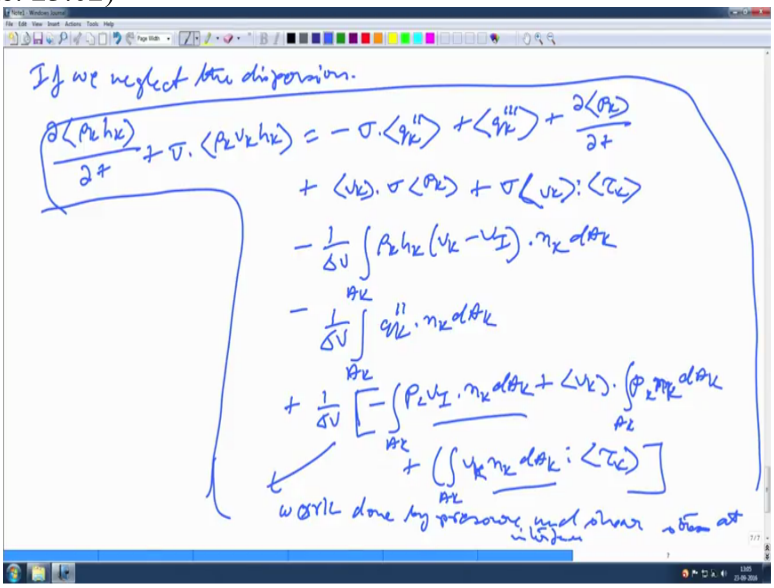

If we neglect the dispersion which we have done in the case of your continuity and as well as in your momentum expression okay and so that is an important part because if we neglect the dispersion part then all those additional quantities will just go off, okay. So, if that is the case then we can write it in no holistic fashion indicate okay.

So, this particular part what you see over here okay this is this Pk, sorry this is actually Pk. So, this is basically the work done by the pressure and shear stress; done by pressure and shear stress at interface okay. So, this basically completes this part of the energy equation. So, you know the individual terms, if you look at it, it is pretty obvious that this and this terms are particularly important.

And we will see what those terms are in the next lecture. But right now so what we have done is that by neglecting the dispersion of the; dispersion of part of the energy equation we have been able to cast it, in terms of these equations over here, right. So, we will see that what happens when you actually take the full volume averaged equation in the next lecture.

We will stop here at this particular point and we will take it up in the next lecture, okay, thank you.