Thermal Engineering: Basic and Applied
Prof. Pranab K Mondal
Department of Mechanical Engineering
Indian Institute of Technology - Guwahati

Lecture - 47
Regimes of Engine Operation and Simple Float Type Carburetor

I welcome you all to the session of thermal engineering basic and applied and today we shall discuss about the regimes of engine operation. And then we shall discuss about the operation of a simple float type carburetor. In the last class we have discussed about the stoichiometric air fuel ratio as such by discussing the need of an important element in the context of the operation of SI engine that is the carburetor.

We could, establish the chemically correct or stoichiometric air fuel ratio for a fuel having chemical formula C_8H_{18}. Following similar procedure, it is also possible to obtain the stoichiometric fuel air or air fuel ratio. And lastly, we discussed that it is not necessary that engine will always get stoichiometric air fuel ratio during its operation instead for any particular type of fuel, carburetor would be able to provide fuel air ratio or air fuel ratio for a range and that is known as combustible range.

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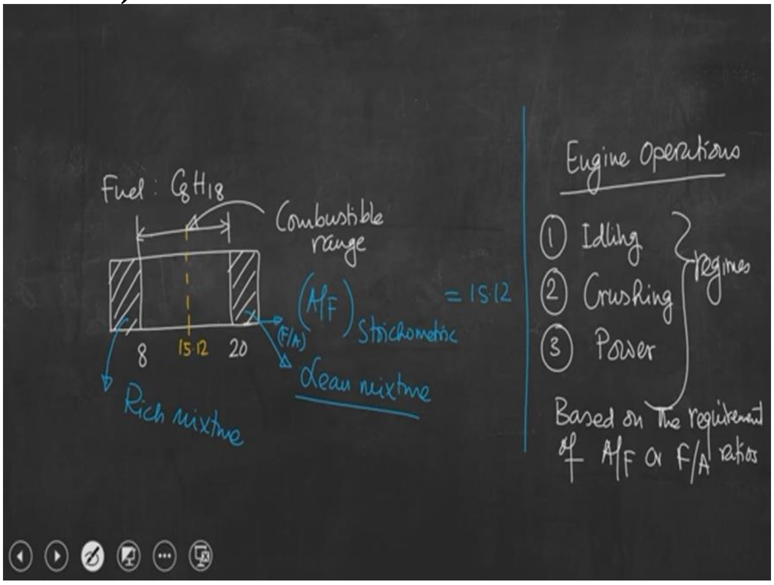

So, for the fuel C_8H_{18} for that fuel we could write that stoichiometric air fuel ratio is 15.12, still we had discussed that the range within which engine should get air fuel ratio from the carburettor for this particular fuel is 8 to 20 and that is the combustible range.

And if the air fuel ratio being supplied by the carburettor is above 20 then we can understand that the air present in that charge or mixture is higher than stoichiometric air fuel ratio and this is more air. So basically you can understand that if this is the regime of operation, then air present in that mixture is more so the heat that will be produced is dissipated by the air present in excess and the result is combustion will not sustain. So that means in this regime, when the amount of air present in the mixture is much higher than the stoichiometric ratio, it is known as lean mixture and if the mixture is lean, as I told fuel will act chemically. But the amount of heat that will be produced gets dissipated by the air present in excess in the charge and the result is combustion will not sustain, what about if the ratio is less than 8? So you can understand if we now focus on this particular regime that is shown by this hashed portion in this regime if you take out any particular point.

And if it is less than 8 then it is far away from this stoichiometric air fuel ratio what does it physically indicate? It indicates that the amount of air present in the mixture is less than this stoichiometric air fuel ratio. Even if it is below the combustible range then the amount of air, present in that charge or mixture is much less than this stoichiometric requirement. And what will happen, fuel will take part in the combustion, amount of heat that will be produced will be absorbed by the excess amount of fuel. Amount of air is less rather fuel is more, so this particular regime is known as rich mixture and here also combustion will be there.

Because combustion will be initiated by the spark plug but the amount of heat that will be produced will be absorbed by the fuel which is present in the mixture in excess. And the flame will not sustain so whether if it is above 20 or below 8, in both these regimes combustion will not sustain. So the condition is, it is very unlikely that carburetor would supply always stoichiometric air fuel ratio.

But the carburetor should be designed in such a way that it would be able to provide airflow ratio within this range. And that is the combustible range, since we have understood that it is not possible to supply stoichiometric airflow ratio for this particular fuel. So depending on the need of the fuel air ratio based on the power output or load of the engine, the engine operation can be you know divided into 3 different regimes.

What are those 3 different regimes? So basically try to understand neither we are trying to go to the lean mixture regime nor we are trying to arrive at the rich mixture regime, instead we are trying to be in this combustible range even within the combustible range, depending on the requirement of air fuel mixture which is solely based on the power output or load of the engine we can divide the engine operation in 3 distinct regimes.

So these 3 regimes are known as idling, crushing, power regime. So these are 3 regimes of engine operation solely based on the amount of fuel air mixture being supplied by the carburettor to the engine cylinder. And whatever the amount would be either for idling or for crushing or for power that requirement must lie within this combustible range. So if we try to draw the schematic it would be clear to you all.

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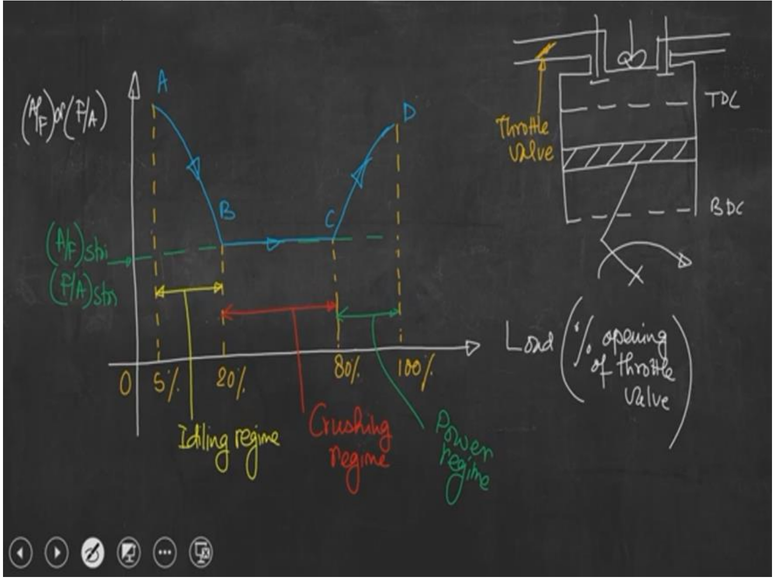

So, if we look essentially we could classify this 3 different regime depending on the load or power of the engine.

So this is air fuel ratio or say fuel air ratio and this is engine load, if we use any particular fuel say C_8H_{18}. And if we mark this is the air fuel stoichiometric, it would be 15.12 or if it is fuel air mixture it would be 1 upon 15.1. Now this is load or percentage opening of throttle valve. Now let us draw the schematic of the cylinder, this is exhaust valve, this is intake valve, say this is spark plug, and BDC, TDC and piston is coming up and down like this. If we say this is the throttle valve. What do we do?

We tune the throttle valve opening area to supply air fuel mixture into the cylinder definitely during intake stroke. But now the requirement of fuel air mixture we are trying to map with a change in load. Because if we demand higher load from the engine, then this opening area should be more so that is why I have written 100 percent.

So, this opening area increases it is equivalent to the percentage opening of the throttle valve. So, if we need more power, more load from the engine, we need to open throttle valve fully. So intuition says that when load is less, theoretically the fuel air ratio or air fuel mixture to be supplied by the carburetor to the engine should be less.

But it is not the case, let us plot it then we shall discuss. So if we plot this is the curve, then say this is A, this is B, this is C, and say this is D, what we can see from this particular curve is that when, load is less 5 percent to 20 percent that means what does it indicate? It indicates that the engine is almost in the idling condition no load is extracted from the engine.

And in that condition, we can see that the requirement of fuel air mixture that is needed for the engine operation is high. In fact if we consider 3 different regime, it is the requirement is even higher than the last one, this particular regime is known as idling regime, why it is idling? You have seen that may be engine is started but no power is extracted from the engine just someone has started the engine, but engine is not in the running condition or there is no power developed by the engine, to be precise there is no load extracted by the engine. In that case I cannot say that the load is not extracted by the engine because engine is in the running condition. So if it is 5 to 20 percent that means it is almost in the idling condition no load is extracted from the engine.

In that case we can see that the requirement of fuel air mixture is even higher than 2 other regimes and this regime is known as idling regime. We shall discuss the reason behind such a high requirement of air fuel mixture, you can see this is the stoichiometric air fuel ratio but the requirement is even higher than the stoichiometric air fuel ratio during the idling zone.

Next is B to C and in this regime, we can say that engine is almost getting stoichiometric air fuel ratio from the carburetor and this is from 20 percent to 80 percent. So that means if someone has started the engine during the idling zone, now at the moment some load is extracted from the engine but what we can see from diagram is that the requirement is getting reduced and almost it is running at the stoichiometric air fuel ratio. So this is basically the economic setting of the engine so that most of the time engine runs in this regime wherein the air fuel mixture or fuel air mixture to be supplied by the carburetor to the engine is this stoichiometric air fuel ratio.

And this is the maximum fuel economy regime, so this is known as crushing zone. That means in the crushing regime, we need to open the throttle valve, so when engine in the idling condition throttle valve is almost closed. It is almost closed but not fully closed and we need to supply fuel air mixture to the engine cylinder that time the mixture should be rich with fuel not air.

So, basically throttle valve is almost closed or partially open and in that regime that is the idling regime, we need higher fuel air mixture ,when you are trying to have a change from the regime from the idling to the crushing regime we can see that we are trying to bring maximum fuel economy by supplying stoichiometric fuel air ratio to the engine. And this is the regime wherein the fuel economy is attained and engine runs most of the time in this regime then you can see that the throttle opening area, should be increased. So that means we are trying to extract load from this slowly and when the load is varying from 20 percent to 80 percent, then I mean engine is giving us maximum load at the best fuel economy. And that is what we can see from this regime is that stoichiometric air fuel ratio is being, supplied by the carburetor. Now when we need to open this throttle valve from 80 percent to 100 percent that means we are extracting more load/more power from the engine.

And it is quite logical even that if we need to shift the regime from crushing to the power. That means we are trying to extract more power from the engine if it is the case, then definitely we need to supply more fuel air mixture because you are trying to get more power, more load. So, throttle opening area should be more and because we need to supply maximum or higher mass flow rate of fuel air mixture. And the requirement of fuel that would be supplied through that mixture to the engine also should increase and that is why we can see that it is also increases, I mean the required fuel air mixture also increases. But try to notice that the requirement during even power regime is not equal to that which is needed during the idling regime.

So, this regime is the power regime, why it is power? Because we are trying to obtain maximum power from the engine and if it is the case, the required fuel air ratio should also be higher than the crushing regime. What we can understand from this discussion is that crushing regime is the regime in which we are getting maximum power with a best economy in fuel so this is the most important regime of the operation of engine and the requirement is this stoichiometric air fuel ratio.

Now so long as the required ratio is this stoichiometric ratio, we are trying to attain best fuel economy at times getting maximum power. But the requirement is maximum during idling regime and also in the power regime. The higher requirement in the power regime is justified quite logical even because we are trying to get more power. And you can see that the throttle opening area is increasing but why the requirement is so high during the idling regime. Now let us look into that particular aspect and for that we need to draw the schematic once again.

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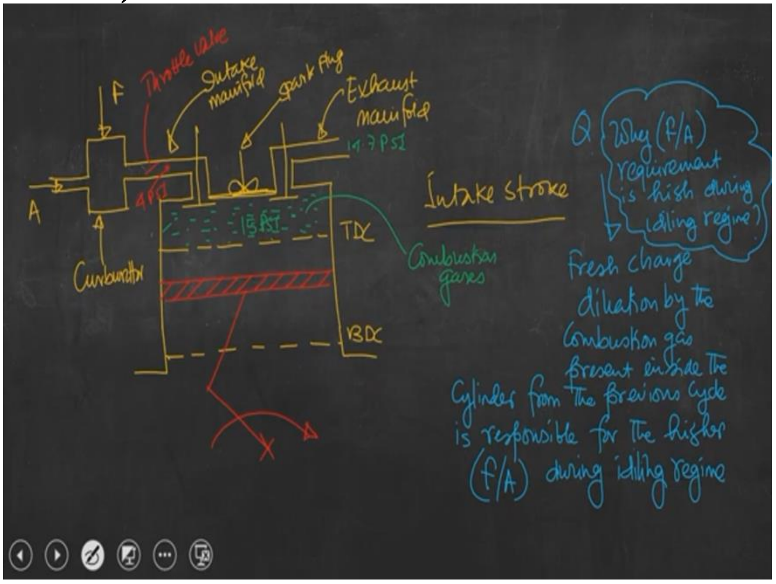

So if we draw the schematic, so this is carburetor and this is intake manifold, intake valve, this is exhaust valve, this is top dead center, this is bottom dead center, this is exhaust manifold, this is spark plug and this is carburetor, this is fuel supply this is air supply. So let us now recall the strokes.

So if it is intake stroke, so when engine is in operation, intake stroke will follow the exhaust stroke immediately. And say if we consider such an intake stroke which is maybe after a few cycles of operation of the engine, then what is happening you know that this space is filled with combustion gases. So when intake stroke will occur the volume between TDC and the cylinder head also called as clearance volume is occupied by the combustion gaseous or combustion products from the previous cycle. So pressure, inside this cylinder will be even still higher than the atmospheric pressure.

Exhaust valve will be closed at the end of the exhaust stroke, so pressure still is higher. Now if we look at the idling regime opening area is 5 percent to 20 percent. That means engine is almost in the idling condition, throttle valve is almost closed because it is not needed to supply even stoichiometric air fuel ratio as no load is extracted from the engine so what will happen now.

So, if that is the case the upstream pressure is the atmospheric pressure. So, this is almost fully closed but the downstream pressure is very less let's say 4 psi. So if we open the intake valve you can see that this is 15 psi whereas pressure further downstream of the intake throttle valve is 4 psi. It is because of this pressure difference the moment when intake valve opens and cylinder is coming down from TDC to BDC for the new intake stroke this combustion gases will rush towards the throttle valve. Because throttle valve is not fully open it is partially open and pressure downstream of the throttle valve is less upstream is atmospheric pressure. So combustion gases which is having relatively high pressure, accounting for that pressure difference combustion gases will run towards the intake manifold as a result of which we are supposed to get fresh charge by partially opening the throttle valve. But that fresh charge we will get resistance by these combustion gases not only that we need fresh charge for further combustion instead what we can see that the fresh charge will get diluted by the combustion gases which is there from the previous cycle.

This fresh charge dilution will result in combustion issue that is I can say that combustion will not sustain. So what will happen when the engine is in idyllic condition issue is throttle valve is almost closed it is because of this pressure difference that you have understood the fresh charge which is going to come to the engine cylinder will get diluted by the combustion gases those are there in this engine cylinder.

So the fresh charge dilution with the combustion gases from the previous cycle will result in inefficient almost incomplete combustion. But still the engine is in the running condition so we need to have combustion. So, to ensure that the throttle valve is partially open the fresh charge is coming, despite the possibility of having fresh charge dilution by the combustion gases to ensure the combustion, the amount of fuel that should be supplied by the carburetor to the engine should be higher and it is because of this reason the requirement of fuel air mixture during idling regime is high. Next why we need to supply higher fuel air mixture for the power regime this is quite obvious. As I discussed it is even logical to set the requirement from the economy setting to the higher setting during power regime because we need high power or high load from the engine.

So you can see that if we need high power or high load from the engine, so percentage opening of the throttle valve is almost full. And that means the mass flow rate of fresh charge consequently the mass flow rate of combustion products will be higher. So, when the higher mass flow rate of the combustion gases are trying to go out through the exhaust manifold into the surroundings. So, we need to supply more amount of fuel air mixture to obtain more power that means the rise in temperature and pressure inside the cylinder also will be more. The rise in temperature and pressure inside the cylinder during power stroke also will be more.

And that high temperature combustion gases when leaving from the engine cylinder to the surroundings through the exhaust manifold, high risk areas are exhaust manifold and exhaust valve. So exhaust manifold and exhaust valve will be prone to high temperature and that high temperature may lead to the failure of these two components. Intake manifold is in a safe position while the exhaust manifold and exhaust valve through which always high temperature combustion gases are in contact and those are continuously passing through those areas, as a result these two areas are prone to mechanical damage and that tendency will be more during power stroke. Because the rise in temperature and pressure also will be more, so engine will not be able to utilize the temperature that we are getting even during power stroke.

You have studied in thermodynamics that may be in the power stroke we are trying to produce more temperature, more pressure by burning more amount of air fuel mixture. But issue is it is not possible to utilize the temperature that will be produced. So if the developed temperature is also high, the loss of temperature also will be very high. So that high temperature combustion gases when leaving through this manifold, temperature will increase and that temperature will try to destroy these parts. So to reduce the possibility of having maximum rise of temperature in the exhaust manifold and in the exhaust valve, it is needed to increase the amount of fuel with the mixture that is supplied. Now question is, if we supply more amount of liquid fuel to the mixture, What will happen?, the liquid fuel will try to absorb some amount of temperature from the temperature that is being produced. So that reduction will help to set this two high risk parts of the engine so that we can increase their life. So the requirement of higher fuel air mixture during power stroke is quite obvious from the fact that we are trying to increase power or load that will be produced by the engine.

So if we are trying to get more power we need to supply more amount of air fuel mixture and that is what we can see that the percentage opening of the throttle valve will be more. But in this regime if we need to supply more amount of air fuel mixture then issue is the rise in temperature also should be severe. And that temperature rise will you create several mechanical problems issues of the exhaust manifold and exhaust valve.

So to reduce the temperature during the combustion process we need to supply more amount of liquid fuel with the charge. And that excess fuel will try to absorb some amount of temperature which is produced during combustion and it will save this location from their mechanical failure. So this is why the requirement of fuel air mixture during power stroke is also high that we can see from this plot.

So now if we try to summarize, today we have tried to discuss about the engine operation from the perspective of the requirement of fuel air mixture. And starting from the stoichiometric air fuel ratio we had seen that it is very unlikely, that engine always needs stoichiometric air fuel ratio and that we had seen today that during idling and also in the power regime, we need to deviate the operation from the crushing regime operation that is the ratio of air fuel mixture or fuel air mixture to be supplied to the engine is definitely not this stoichiometric air fuel ratio. But the amount of fuel air mixture or air fuel mixture to be supplied even during idling condition and the power regime should be within the combustible range, if the ratio is not within the combustible range, then either it would be too lean to sustain the flame or it be it would be too rich to sustain the combustion. And we had seen that the requirement of fuel air mixture during idling and the power regime is very high and we have also explained the reason behind such a higher requirement of fuel air mixture during these two results. So, with this I stop here today and we shall continue our discussion in the next class. Thank you.