MARINE ENGINEERING

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Lecture49

Gas turbine- Basics(contd)

turbine. So, gas turbine system again compressor, shaft and turbine. So, here you are taking power compressor, turbine, combustion chamber. We discussed compressor, we combustion chamber, now turbine. So, turbine

blades are very important because it will be facing very high temperature. So, your material is very important here. Let us say my turbine. So, here you can see this is actually airfoil shaped. So, if this is my stator, this fluid if I put, this is separated.

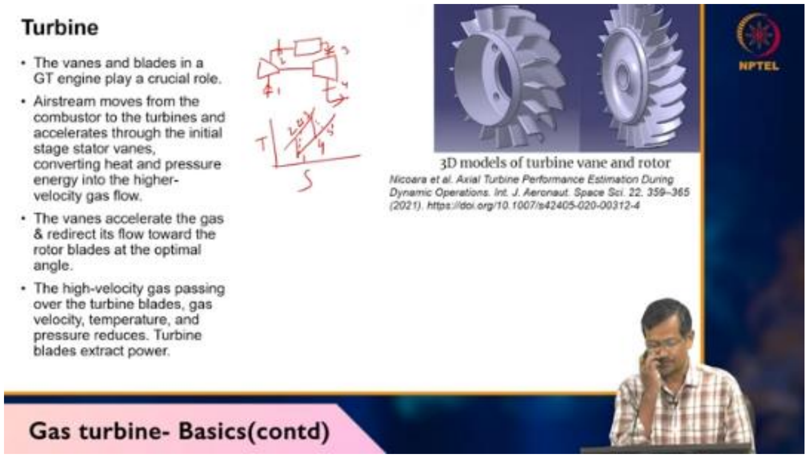
Now, if I move it closer, so this angle will be hitting this one hit this surface okay and your turbine blade will be rotating fine so turbine blade shaft it will fixed with shaft okay and this one will be fixed with your casing so non-rotating part now stator if I draw same way Stator blades are like this. Top view I am seeing. I am not drawing any other part.

I am only showing top part of airfoil. Now fluid is going like this. Now you see the turbine blade. Turbine blade is like this. stator, rotor.

Then rotor, after rotor blade velocity direction is like this. then again I must have one stator same way as compressor ok then stator will be giving again angle my rotor will be having another ok so that way one stage two stage three stage you can harness energy the same way compressor turbine basic principle same rotor stator will be consisting one stage and stator will not harness or will not give any energy rotor will be harnessing only energy okay and it will be facing very high temperature so material consideration is very important for turbine rotor especially rotor blade because stator is not rotating so because of centrifugal force something will be happening chance is less but rotor is rotating so there is one centrifugal force and vibration there plus high temperature so material creep is one important parameter creep so creep means at long temp long time if it is facing uh that high temperature what will happen permanent deformation of blade is possible so at high temperature uh centrifugal force is there and it is harnessing energy also so extra force is there again temperature is high so in that case blade material can be changed permanently that shape or size will be modified so that will be a harmful for turbine system okay it may be harnessing less energy or it may fail continuously it may fail because of his rotation and if he's failing failing means like for example aircraft one blade is broken means whole thing gone right so

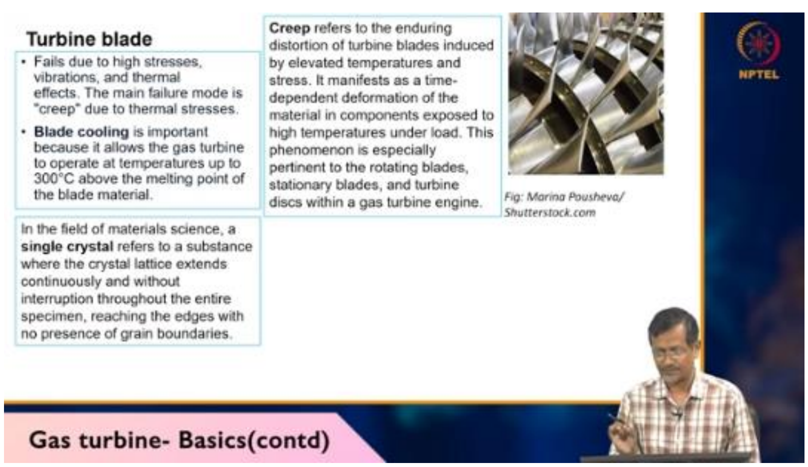
everything must be safe so material research and vibration analysis all the things must be done when you are designing a gas turbine system okay so velocity if i draw in a rotor blade like i have stator rotor stator rotor okay then velocity pressure will be like little bit drawing down down down so every time pressure will be down actually and your velocity in the stator velocity will be increasing again rotor will be taking velocity again it will be increasing again decreasing so that way uh stator when it is guiding sometimes will create increasing velocity okay and rotor again it will be extracting energy so velocity will be down but pressure continues to be going down when pressure is down so your fluid is actually expanding fluid expanding is your turbine when you are drawing it must be expanding actually right so turbine drawing will be like this shaft is here so stator rotor stator rotor gradually expanding okay gas turbine will have one compressor system compressor will be connected to a turbine and there will be one combustor or combustion chamber fluid entering exiting and it is going out okay if i plot in ts diagram it will be looking like this 1 to 2, 2 to 3, 3 to 4 is the flow path. So, in TS diagram if you plot it, it will be like this 1 to 2 we are assuming this is isentropic process, 2 to 3 heat addition process constant pressure, 2 to 3 and 3 to 4 is your turbine. So, turbine also I am assuming this is isentropic process, but if I assume actual cycle.

So, in that case actually your figure will be like this 2s So, actual cycle will give less power, but in ideal cycle we will calculate more power. that one also you can calculate if you know the values at different points. And turbine blade will have guide vane and stator. guide vane will be guiding the fluid flow and it will be giving to turbine blade or rotating blade.



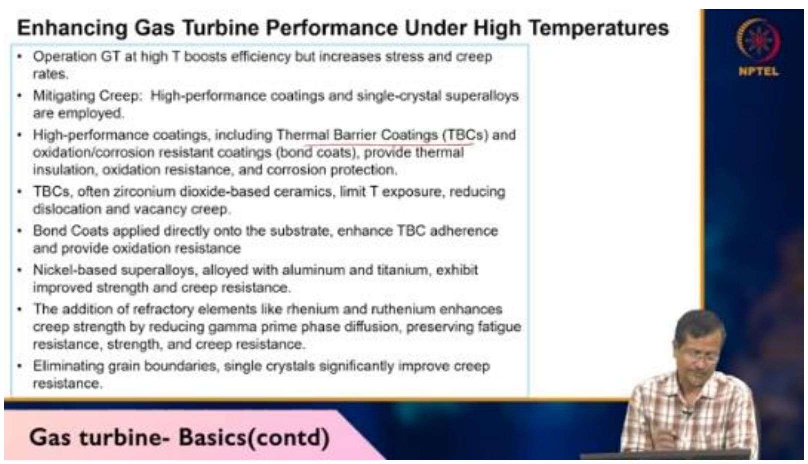
Rotating blade will be harnessing energy or it will be extracting energy from the moving fluid. So, turbine blade so turbine blade will be failing normally because of your temperature at high temperature it will have failure because of creep blade creep creep means like permanent deformation of blade material. Very high temperature and high stress also the blade material can be deformed because of that a turbine can fail or it will be giving less power output. So to avoid creep we have to select material such a way that at high temperature it will not be affected so much. we need a blade cooling arrangement.

Blade cooling arrangement means like we have we must have certain arrangements so that temperature can be limited within certain limits. several types of turbine blade materials will be available and you can go through the book also. Single crystal material normally it will be used to avoid creep. creep is very important parameter for turbine blade. So, you should remember the definition and what is the effect on turbine blade you should remember.



So, enhancing gas turbine blade performance under high temperatures. So, if it is operating a very high temperature then single crystal or super alloy specific material you can use or sometimes they will be using thermal barrier coating. thermal barrier coating actually it will be it will not allow the higher temperature gases to give heat to the actual material. that coating will be preventing little bit, but not absolutely very high temperature difference cannot maintain but certain amount of temperature it can maintain difference.

So bond coating and different types of coating will be there, nickel based superalloys also can be used for turbine blade material because it is working under high temperature and that temperature gas temperature may be more than the melting point of the blade. So that is why this is very important part to consider coating or cooling or spacing material of the turbine blade. turbine blade cooling so because turbine blade is facing very high temperature so turbine blade must be cooled also so how you are cooling so you have one blade okay I'm drawing one blade here let's assume this one blade okay and fluid will be going through this through the passage passage means like turbine blade is here for example And in between the space between the blade, this is called passage. So, the passage will have very high temperature.



And that high-temperature fluid is touching the blade surface. Now, how to reduce the surface temperature? Especially surface temperature is very important. So, what will they do? They will be putting lots of holes, internal holes.

And this hole will be passing through from bottom to top. okay so when you are pushing very high pressure fluid or low temperature fluid low temperature air or any gas you are passing through so the turbine blade temperature will be reduced okay that is the purpose of turbine blade cooling so sometime through hole from bottom to top or sometime there will be hole around this also so that you can maintain temperature within certain limit if you are not maintaining temperature temperature will be shooting up and that will be detrimental to your system okay if you see the picture also this is the turbine blade okay and turbine blade have multiple holes here or multiple holes here okay and fluid will be going through this from bottom okay and this portion is shown like turbine blade will be fixed on hub So hub means like you have one shaft hole and this portion one extra material is here. blade will be fixed here.

this is called hub. And hub and turbine blade there will be some fixing arrangement. So blade you can replace and you can fix quickly also. That is why this specific arrangement is there. This is called root.

So blade will be fixed on root and when hub rotating because of shaft rotating it will be everything will be rotating together. and whenever you are going for blade cooling so there are lots of research going on on blade cooling channel these are called flow channels okay flow channel means let's say I have one flow path like this okay so flow path if you have smooth channel then it will have less turbulence less turbulence means less heat transfer less turbulence means lower heat transfer low heat transfer okay now if i want to if you want to increase the transfer rate i can increase turbulence inside the flow channels okay so how can you increase turbulence so i can put some barrier like this okay when fluid will be moving like this they'll be getting disturbed they'll be creating turbulence here and there Lots of turbulence will be created. When flow channel is having lots of turbulence, it will be increasing heat transfer rate.

And if you have only smooth surface, heat transfer rate will be lower. But you are putting some extra arrangement, roughening surface or you can disturbing the flow. When you are disturbing the flow, it will create turbulent flow. And if you are not disturbing, smooth channel is there. It will be creating laminar layer will be there.

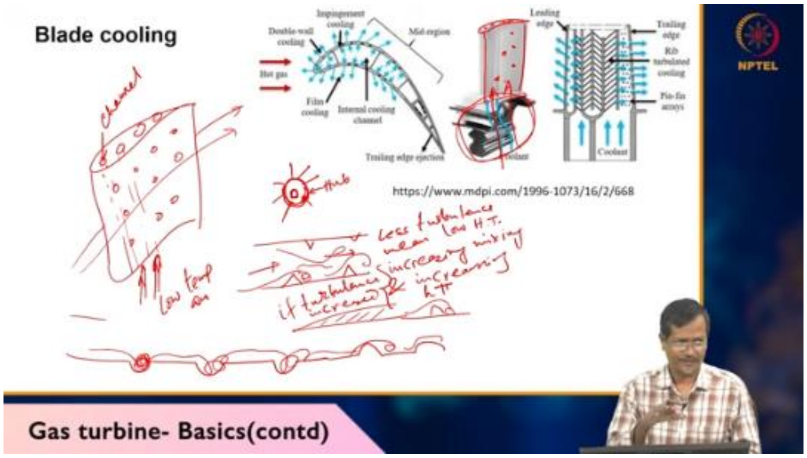
So, laminar layer actually it will be preventing turbulent heat transfer. So, if you can break that laminar layer. For example, the surface is here. Normally, I will have laminar layer. You can remember like this.

Now, if I put one bump here. So, what will happen? This laminar layer will get broken. When it is getting broken, the cold air Temperature air so that will be touching the metal surface but if you have a laminar layer will not allow it to touch the main fluid stream on the metal surface if you create turbulence then what will happen is that mainstream will be touching the surface again it will be increasing turbulent heat transfer rate okay it will be increasing more mixing so increasing mixing and increasing heat transfer rate HT if turbulence increase . So, turbulence increasing method one will like there surface upper surface is there or pipes surface is there you put lots of pins or fin or any or you can create dimple channel like this surface is here you can create cavity okay so what will happen fluid is coming it instead of creating laminar boundary layer it will get disturbed here it will create lots of turbulence here it will be going out again it will create turbulence it will again create turbulence so you are promoting turbulence because of cavitating or creating cavity or dimple surface Or you can create protrusion surface like this. This also will create turbulence.

So, there are several methods. People are doing research on this one. How to improve heat transfer rate in turbine blade system. Because turbine blade surface temperature is very important for its life. For example, aircraft engine.

It is running for several years. Right. So, without any problem. So, their small problem not allowed. Right.

Whole disaster can happen. So, that is why lots of people are doing research on how to limit the maximum peak temperature on the blade surface. Now, I am giving one example here. This is GE General Electric one gas turbine engine which is used for marine application.



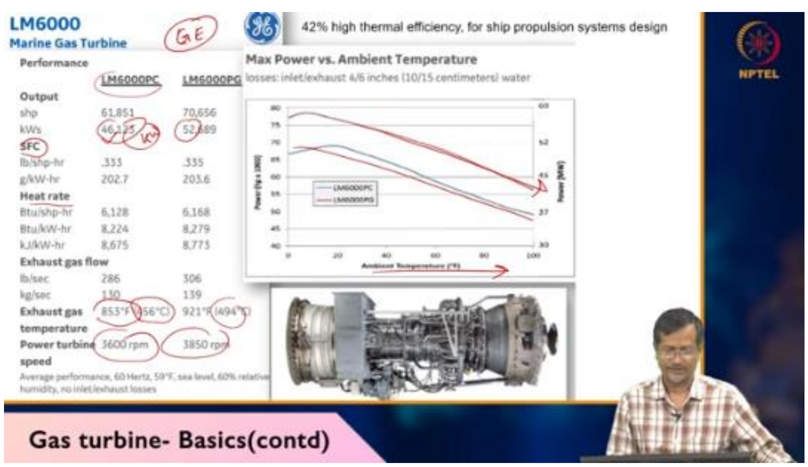
So, this power output 46 megawatt. this is kilowatt so for 46.123 megawatt okay so two diff many different uh different types of engines are there so here uh they have given two example two type of gastronomy system 146 megawatt power 152 megawatt power and you can see this how much heat transfer rate is happening specific fuel consumption okay sfc means specific fuel consumption so how much fuel it is taking Exhaust gas temperature is given. You see 5, 4, 6 degree centigrade. About 500 degree centigrade temperature is there.

Exhaust gas temperature. That means turbine is facing much higher temperature. Exhaust means after turbine has taken power. That means temperature has reduced already. That means turbine is facing much higher temperature.

So, an rpm of the turbine that are main shaft of the turbine is 3600 or 3800 within that range based on this may be electrical frequency they have set this one. Again the power output will be based on ambient temperature, ambient temperature is increasing your actually performance will be dropping. Why dropping? Because gas turbine engine the compressor is taking atmospheric air. So, atmospheric pressure inlet

Atmospheric air temperature inlet temperature is very high then in that case actually your performance will be dropping. You can remember the Carnot cycle formula. inlet temperature and maximum temperature right the ratio. inlet temperature increasing your performance is dropping. this curve is saying like that.

Ambient temperature increasing so your performance is dropping. here this engine is having 42% thermal efficiency but actually the total efficiency will be lower because it is saying only thermal efficiency but whole system efficiency if you see like there will be lots of losses in bearings and air and there then performance will be much lower. you cannot get more than 42% actually because if you include other losses. another term is there micro gas turbine. Micro gas turbine is actually very small turbine.



It is few hundred kilowatt, 30 kilowatt to 200 kilowatt power about that range is called micro gas turbine. Micro does not mean there is millimeter or micrometer. This micro means like kilowatt level power output. But normal gas turbine will have megawatt level power output. So that is why they are saying micro gas turbine.

So micro gas turbine sometimes they will be using for combined heat. heat and power production cases you have excess energy somewhere you can use this type of turbine and you can harness some energy okay so combine heat and power system there you can use MGT or micro gas turbine many lots of aerospace applications also marine applications also there for using micro gas turbine so these are smaller turbine so micro does not mean it's a millimeter or micrometer level thing micro means like kilowatt level power normally one or two megawatt also maximum possible But normal gas turbine will have several like 46 megawatt I have shown already one example. thank you very much for this lecture. I will start new topic.