Advanced Green Manufacturing Systems

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Lecture - 41
Green Factory through Green Unit Processes (Part 1of 2)

Welcome to the last week of the course Advanced Green Manufacturing Systems. We have discussed statistical techniques and design for greenness, the design for green product design; and the life cycle assessment certain modules have been discussed. In this lecture specifically in this week, we will like to take an example to apply what we have learnt in the previous weeks. I have picked an research that was conducted in IIT Kanpur itself and I would like to demonstrate how can we develop a green factory using unit manufacturing processes.

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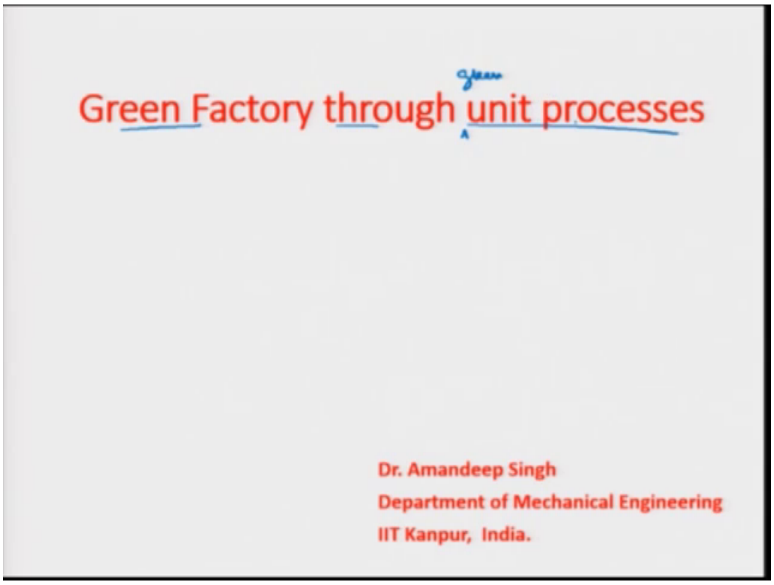

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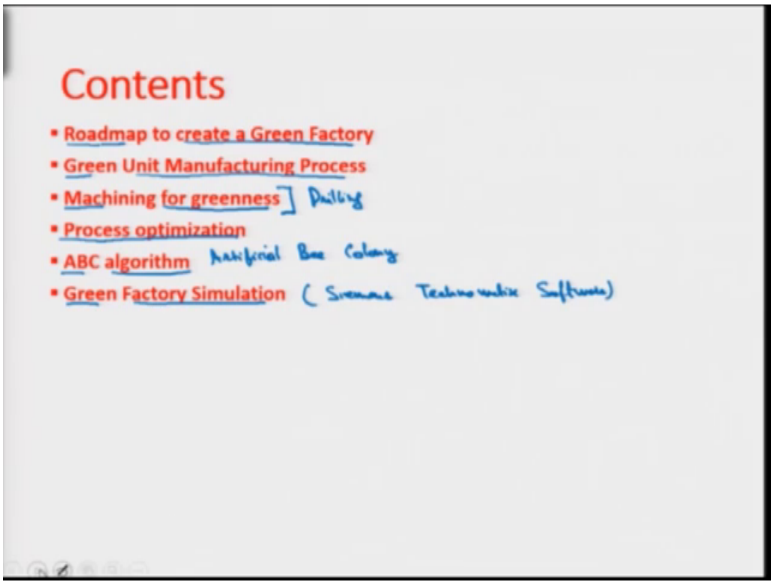

So, this lecture is started in this way green factory through unit processes this is actually green unit processes. The contents would go like this first roadmap to create a green factory, that we selected then what are green unit manufacturing processes we have discussed about a single process about multiple processes single process two processes, then flow line multiple processes.

So, green unit manufacturing process what does this comprise of this we will see, then we will focus the structure more on machining for greenness. And the process that we have picked is drilling, this is the green unit manufacturing process that we have picked. Then we will see how to optimize the process. For optimization the metaheuristics algorithms those who are discussed in the last week like Tabu search then genetic algorithm and certain other metaheuristic algorithms were discussed. I have picked a similar algorithm here which is ABC algorithm, which is artificial b colony algorithm. So, I will discuss what is this, then we will move to green factory simulation this will do using Siemens Tecnhomatix software.

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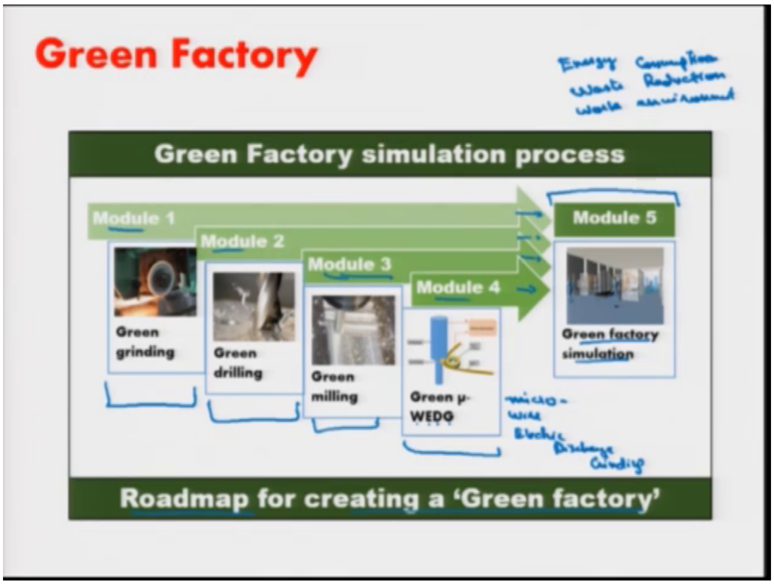

So, roadmap to create a green factory or roadmap for creating a green factory is taken like this, the green factory simulation process we call it in the other way. So, there are different modules; module 1 2 3 and 4 which are totally independent in which different unit processes are chosen; grinding, drilling, milling and a non conventional unit manufacturing process which is which is micro WEDG this is Wire Electric Discharge Grinding. Wire Electric Discharge Grinding moreover it is micro wire electric discharge grinding, these four processes are optimized with respect to greenness.

So, they are made green individually then these unit processes are taken into a factory; and those are simulated and this simulation is known as green factory simulation because the input those are coming here are the green processes. So, this is the roadmap for creating a green factory this work has actually developed a practical approach to describe the relation between process variables with energy consumption right. Process variable with energy consumption and waste reduction and work environment improvement.

So, in this case these processes grinding, drilling, milling, micro radium were modeled and their corresponding process parameter were optimized to realize unit green processes. Then a floor shop facility is developed here in green factory simulation, this floor shop facility is modeled using optimized green unit manufacturing processes and production was simulated to realize target through put, while minimizing the environmental impacts and controlling the costs. So, this is the criteria that is picked in the research that is conducted in IIT Kanpur. So, this research first aimed at identifying green process parameter setting for unit manufacturing process, through an (Refer Time: 05:030) of experimental data the experiment were conducted live; then this data were generated through certain design of experiments like full factorial for grinding. And response surface methodology to design of experiments were conducted, separately for these four processes and then these were optimized then they were taken to a green factory.

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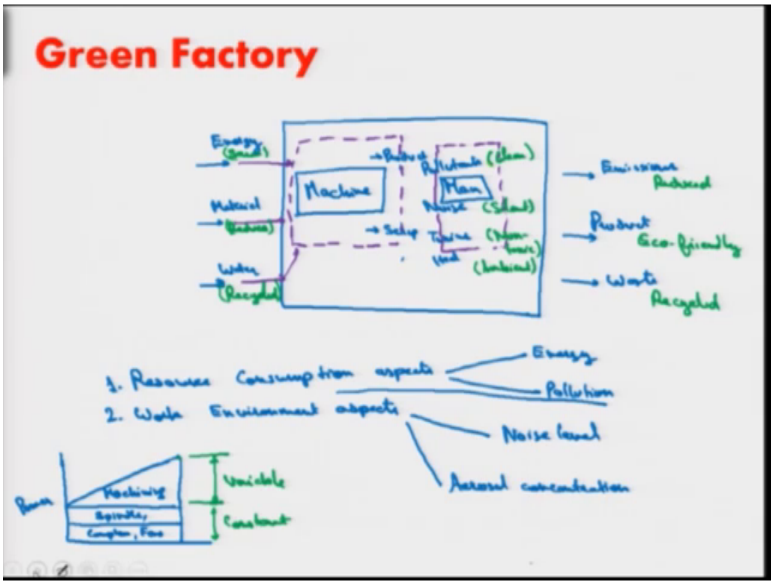

So, what is the green factory that we have chosen here, green factory here has inputs, the inputs are coming and the outputs are there; see in the factory we have machine and man as major components ok. Here we have energy that is one of the inputs then material, then we have I will put maybe water; then this machine does some processing and produce product and scrap. These are actually the boundary interaction with machines, the inputs to machine is coming from this side, this is actually energy is coming here material water this is going in boundary; and to man what are the inputs those are going. So, these inputs are pollutants, we have input here as pollutants right, if man here then noise, then toxins and heat.

So, it can produce certain short term effects like when we talk about green factory simulation we talk about a short term and long term goals. Short term long goals are reducing greenness and also controlling the environment present work environment of the factory in which the worker is working.

So, workers if they are prone to these kinds of inputs like pollutants noise, toxins, heat they can develop stresses fatigue allergies then long term hazards can come. So, these produce finally, emissions then the product is produced here the final product ok, then waste is produced here. So, our aim is to use the removable energy or save energy in a way, then to reduce the use of material and water can be recycled.

These specifically that we designed for the present factory simulation that example I am going to take here. And the machine that produced the outputs those are a product and scrap. And the pollutants those are produced we can have cleaned in place of pollutants we can have clean and noise has to be silent this is the ideal process; then toxins we must have a non toxic chemicals non toxic. The heat temperature has to be ambient, this emissions again has to be reduced, then product has to be eco-friendly and waste has to be recycled.

So, what are the different aspects those are taken in this process in this example? One is resource consumption aspect I will put it here resource consumption aspects and the work environment aspects. In resource consumption aspects we have energy and pollution, saving energy and minimizing pollution and in work environment aspects which is the second point, we have the noise level reduction and aerosol concentration control.

So, these are the aspects the sustainability aspects which I have taken into consideration, in the present study from one has a liable to provide safe and healthy environment that is why work environment aspects are taken into account. And energy and pollution reduction is already discussed; in energy saving when we talk about machining energy it is something like this, the power is here the power input to a machine and there is some fixed amount of energy that is consumed.

So, this can be divided into two parts; if we know the machining when we do drilling something if the drill spindle is rotating, but it is not machining at the time. So, then some energy is consumed because machine is working the machine, fan coolant system, the drill rotation all the things are working. However, the production is not happening, but this is the time when also the energy is consumed, haste energy is when the production is happening. So, this is something known as fixed energy it can wherever to components here, one I can say the computer or fans and coolant pump etcetera, next is spindle then tool change etcetera the time is consumed here.

So, this is almost constant. The variable energy that is there, that is the machining energy this is variable energy. So, this part is variable and this part is constant, though we can also reduce the constant amount of energy that is the use of spindle fans there are certain techniques to do that like the idle time has to be minimum. We are more concerned here is about reducing the variable energy while we are doing the machining.

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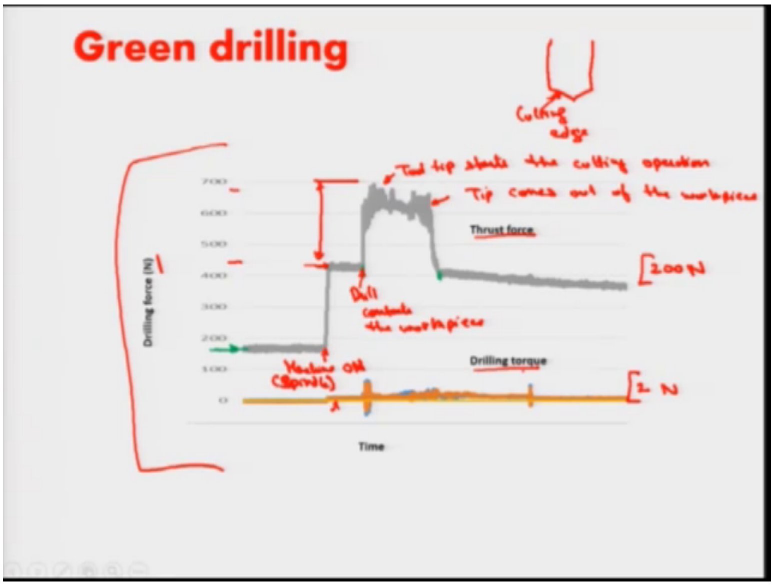

So, how does energy work here? This is the actual plot that is produced when we did drilling, this is the drilling force that is recorded by dynamometer that is fixed on the drilling machine. So, this is the point when the machine was fixed, machine was actually not running, when the machine when the spindle was not rotating at this point when the spindle rotated it rosed to this level. So, machining is happening from this point to this point it is doing a drilling process. So, before telling about various steps in this specific thrust force how it is varying I like to show you how we conducted the drilling process.

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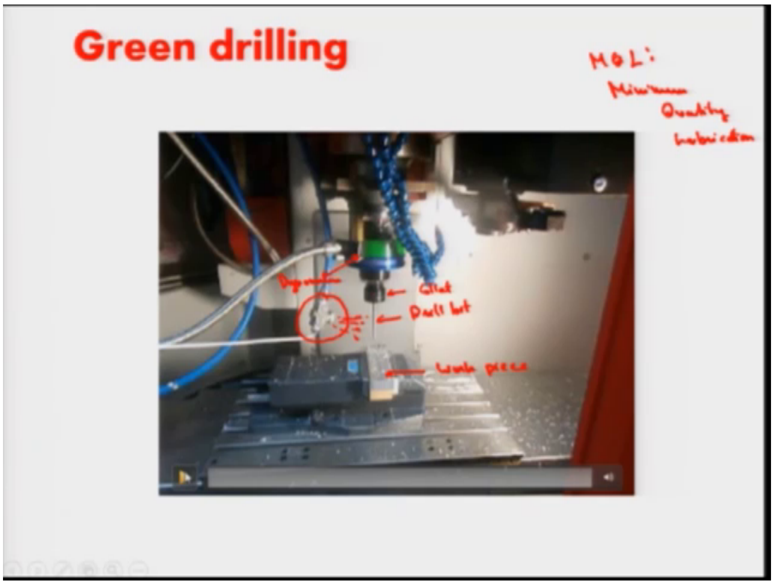

So, this is the drilling process that we conducted, in this case this is the dynamometer; this dynamometer has a collet in it, in the collet we have drill bit here this is dynamometer ok. We have drill bit and we have a collet here in which this drill bit is fixed, this is our work piece.

What is this component? This is a nozzle that is throwing mist on the work piece to cool, they set a metals to cool the work piece or the tool while we do machining. One is flood cooling we provide a flood of the fluid and that cools, but in that case the coolant is; however, recycled, but a lot of coolant is consumed in this that case. The flow rate of mist is quite lower than what we use in coolant another way is dry milling, dry machining and dry machining none of the fluid is used, but in that case the quality is suffered.

So, in this case mist is one of the alternative that is used MQL, MQL is; MQL it is Minimum Quantity Lubrication. So, this technique or this phenomenon is used here to conduct this milling, this is a video while I will just like to play this video and you can have this sound and also watch how this drilling process is happening. So, this is the drilling process happening.

So, the drill goes in, this is the noise that is coming here; the noise is coming. You can also see this is spraying mist here; drill is coming out. Now this dynamometer that is recording the data when drilling drill is going down, two types of forces are happening one is thrust force another is torque. So, both these forces are being recorded. So, this force in ton is the energy consumption; that is consumed by the machine.

However, other parts of energy consumption is this bulb and other parts may be the coolant system this coolant system is however, we using pneumatic spray here. So, that is one of the part of the machine, but yes energy consumption is happening here so this is the drilling process. Now, this drill bit has a shape something like this, this edge is known as cutting edge; this cutting edge at this point the drill contacts the work piece.

And this point the spindle is on machine ON, I will put machine ON that is actually the spindle on ok, when spindle gets on it tries to throw drill away out and some thrust force is here. But this is the variable force that is there this is the force that is taken into consideration. Now here the tool tip starts, tool tip starts the cutting operation then at this point the tip comes out of the work piece right. So, this is the point where we had a lot of noise so this noise if workers are exposed to this kinds of noise for many years, they can have some serious health hazards.

So, those are taken into consideration, that is why we also we have also tried to monitor the noise. So, these are the drilling forces those are there also an interesting thing here to notice that thrust force and drilling torque is there, the torque is not varied a lot. The torque is varying the magnitude of variation is only 2 Newton's here. The drilling torque is force is in Newton; and the thrust force is varied this is from may be 430 to 630 something. So, it is around 200 Newton's, this is the magnitude of variation.

So, we will work only on the thrust force because drilling torque is not significant in front of a thrust force, this is how drilling operation takes place.

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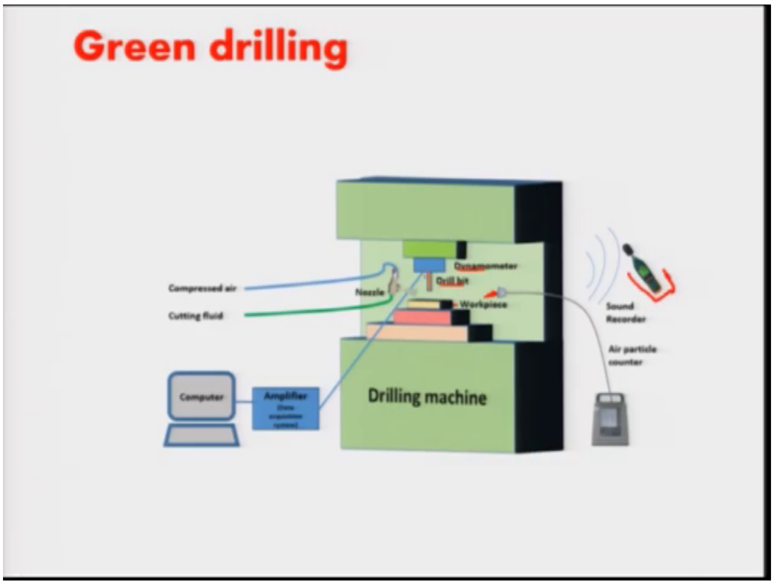

The equipment which are used in this experiments this is the nozzle that we have just shown you, so this is the schematic of the machining setup that we made. Sound recorder records this sound. This is kept at a distance of 50 centimeters to represent the human ear and this is the aerosol collector. Aerosol collector what is happening when the machining is happening because mist is there, in the terms in the case of fluid also some aerosols are being produced. [FL] Those aerosols are affecting or that can deteriorate the health of the worker, [FL] those are also collected the concentration of aerosols are noted and those are recorded that can be taken one of the response variables here [FL] those are actually taken.

So, this is the aerosol collector, this is dynamometer that measure the force, this is drill bit work piece is there and nozzle this dynamometer is connected to computer that records the force so this is a schematic here.

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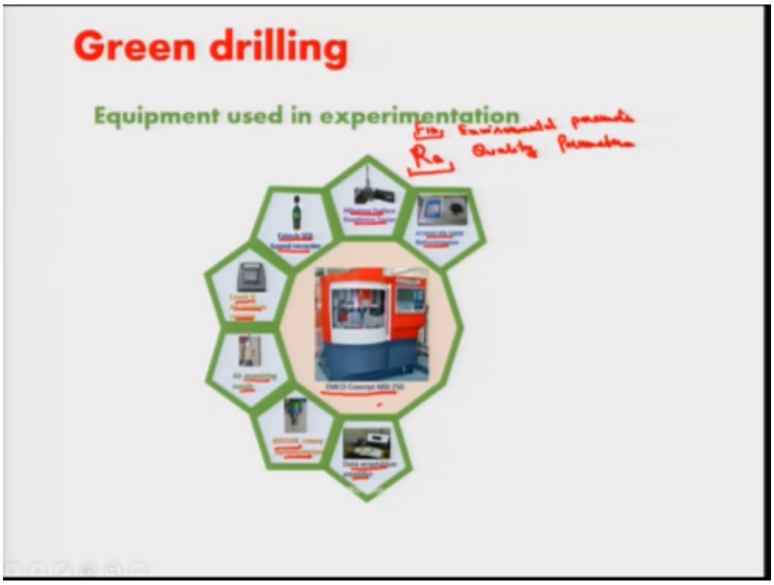

So, these are the different instruments those are taken Extech h d l sound recorder, with the surface tester this is surface roughness R a the surface roughness is one of the output parameter which is actually a quality parameter. So, we have environment parameter that is force that represents the energy; that is thrust force; this is environment parameter ok. That force is recorded using the Kistler rotary dynamometer then, air atomizing nozzle these are different instruments which are used. Then this is a machine tool that is used mco concept mill 250 and data acquisition amplifier data acquisition using dynamometer data is acquired in a computer system here.

This is a turbo refractometer, when we use the cutting fluid we chose cutting fluid and we also saw the reflectibility of the cutting tool that is the concentration of the fluid these are (Refer Time: 21:07) a particle counter, which collects the aerosol and tells us the concentration of the aerosol or that maybe dust particles in the environment.

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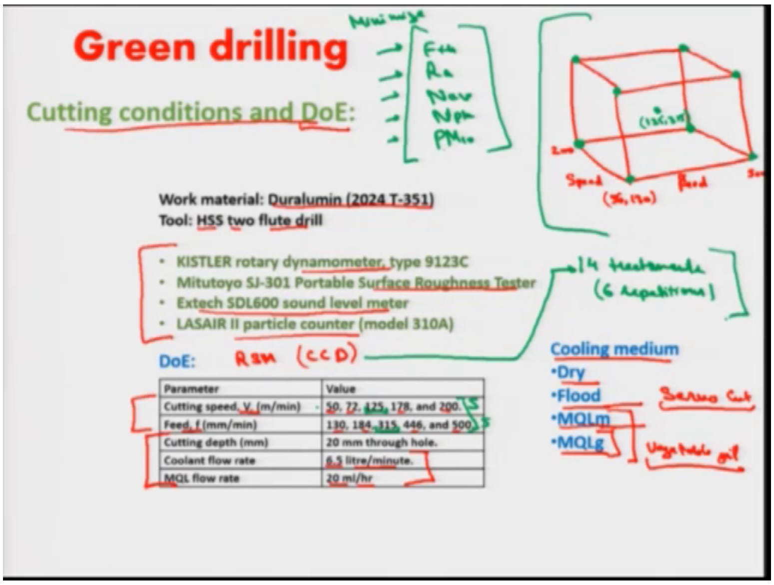

These are the cutting conditions which are chosen for the experiments design of experiments here, design of experiments is discussed by professor Deepu Philip in the course. So, we have chosen duralumin as the work piece material; duralumin 2024 T-351 which is used largely in manufacturing of aircrafts; and the tool that is chosen is High Speed Steel two flute drill. These are the different instruments that I have just shown the dynamometer then surface roughness tester, Extech sound level meter and air particle counter.

So, these are the parameters which are set. These are the fixed parameters; cutting depth, coolant flow rate and MQL flow rate. You can see the difference; the coolant flow rate is 6.5 liter per minute and MQL flow rate is 20 milliliter per hour. So, see the difference that is of the order of 10000 times may be; and the front cooling medium are now chosen dry, flood, MQL m and MQL g. MQL m is Minimum Quantity Lubrication, as I said this is a technique that employ a spray of small oil droplets in a compressed air jet.

This lubricant is dispersed directly into the cutting zone as a substitute for the immense flows of cutting flood coolant. So, since air jet transfers the oil droplets directly into the cutting area, it ensures efficient lubrication as well. And a special setup and arrangement are demanded when MQL method is to be used that we have made in this. So, certain researches have demonstrated MQL is one of the promising technique for green manufacturing. What is MQL m and g? MQL m is the mineral oil that is used for flood as well that is a servo oil, servo cut. Servo cut oil MQL g I have put g here because this oil what I call is green oil, this is a vegetable oil that is used for cooking. This is used because if the aerosols which are produced during the vegetable oil, that might not affect the health of the operator who is working there if the mineral oil get into our lungs or that we would breathe that that would definitely have a significant effect on the health.

So, this MQL g is using MQL technique, but with a green oil that is a vegetable oil ok, that was mixed in specific concentration this was also mixed in 1 is to 10 concentration, so these were mixed and these were chosen. So, this is one of the processes I am discussing, drilling we have chosen four processes and take we have taken them to green factory simulation. The four output parameters were there, the two input parameter which were taken were the cutting speed and feed, these are the input variables which are varied and these levels are taken this is the this response, surface methodology.

RSM, Response Surface Method specifically CCD oh this is the RSM which is CCD. It is actually known as Central Composite Design Response Surface Methodology. So, this is actually what we do? We do these are the two parameters; in two parameters 14 treatments are there 14 treatments are taken of which 6 repetitions are there, what happens this is the cube that we have ok, these are the two parameters cutting speed and feed you call it speed and we call this as feed minimum feed here is 130 maximum feed 500 minimum speed here is 50 ok, here maximum speed is 200.

We conduct experiments at the 8 corners of this cube here is the 8 experiments are conducted and at the centre. The central point here is 125 and 315 at the centre this is actually 125 and 315 this point. So, this gives us the picture that what happens when we conduct experiments at the corners and what is the central movement, how does our response moves from this centre? The response here can be any of the responses that we have chosen that can be thrust force then, surface roughness, then noise intensity noise average and noise peak that we have chosen the total noise average noise during the machining that happens the total peak noise.

Or the specific peak instant that is there that is noted and also aerosol concentration we call it aerosol ok and also aerosol concentration which I have put PM 10. PM 10 is the Particulate Matter 10, all the particles of size lesser than 10 micrometer those are taken into account. So, this PM 10 these are the 5 output parameters. And these are these can be taken here what does his design of experiments helps us to do this is discussed before in the lectures as well, that instead of conducting this 5 this is the 5 variable 5 into 5 25 experiments. If we have another variable let me say 5 into 5 into 5, 125 experiments if it is four variables 5 into 5 into 5 into 5 it can 625 experiments with very lesser number of experiments, we can have the overall picture what is the variation with respect to any of the response variables? So, this helps here.

Now, the 14 total experiments are conducted 14 treatments I would say, which is conducted using this RSM central composite design method of which 6 repetitions are there what are those 6 repetitions? At the central point why? Because this central point 125, 315 it is repeated multiple times to know the noise variables. Is the roughness that we are noting is it is same or is the variation very higher lower if we keep repeating the experiments that is also important to note here. So, in the sensitivity analysis also that is noted when we have the final output. Now, our purpose here is to minimize the force that is minimize energy and minimize roughness and minimize the noise in aerosol levels; so minimizing of these parameters is the target.

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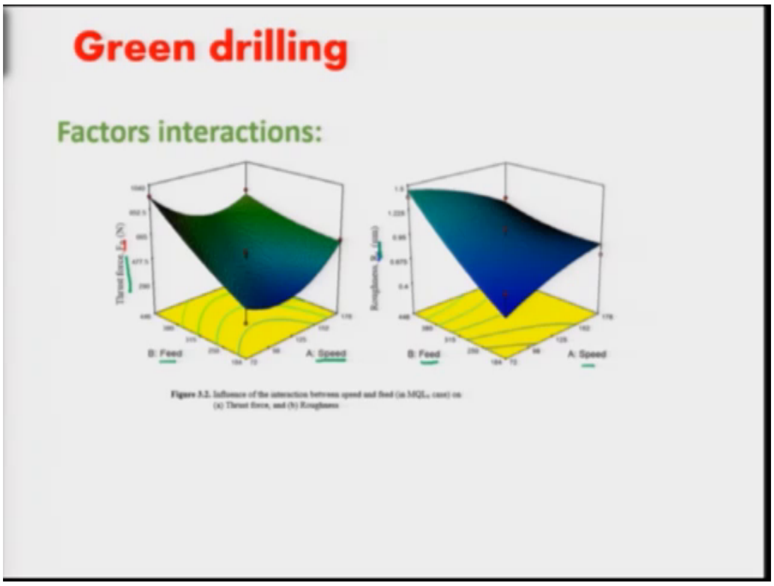

So, for this once we conduct the experiments this 14 experiments are conducted we got these kinds of plots and the data. So, this is the factors interactions interaction of feed with speed in thrust force interaction of feed and speed in roughness. So, this is the interactions, so to see whether the interaction significant of not, we can see the regression models for them and those regression models are also produced.

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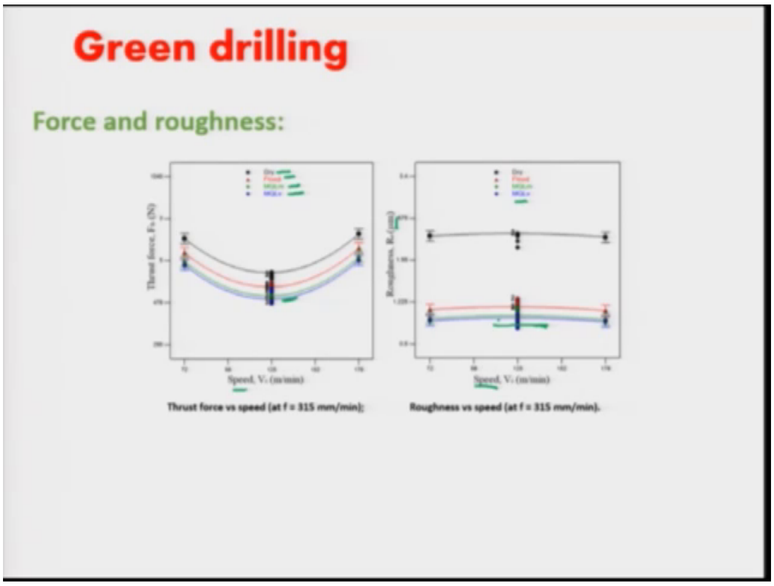

So, these are force and roughness thrust force and roughness with respect to speed and this 4 lines, are the 4 different mediums dry, flood, MQL mineral and MQL vegetable or MQL green. So, we can see here that the dry is exhibiting the maximum force and MQL vegetable and MQL mineral are the lower one the minimum force that is exhibited is by MQL vegetable oil.

Here also the roughness, roughness value is the R a value which is in micrometer that also has to be minimum that is also exhibited by the same MQL vegetable the blue line; for this data this is a plots.

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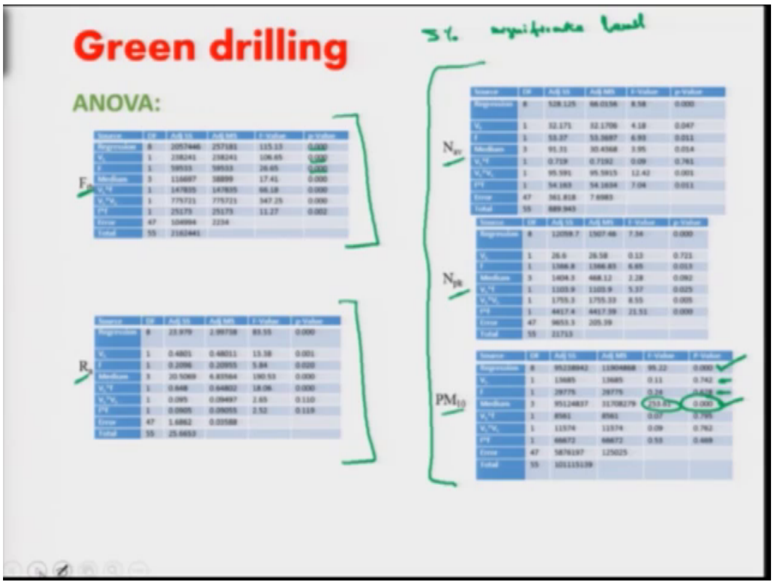

The more important point to discuss here is the ANOVA table. So, we have got ANOVA tables for these different output parameters this is thrust force surface roughness, average noise intensity peak noise intensity which is put in decimal. And PM level particulate matter 10 which is in micrograms per meter cube. Now, as you know how to read the ANOVA table we can see in these two ANOVA tables that the speed, feed and medium of fluid application they all significantly influence the force and roughness ok, because the p value here is less than 0.05 less than 5 percent of 5 percent significant level we have put here; 5 percent significance level.

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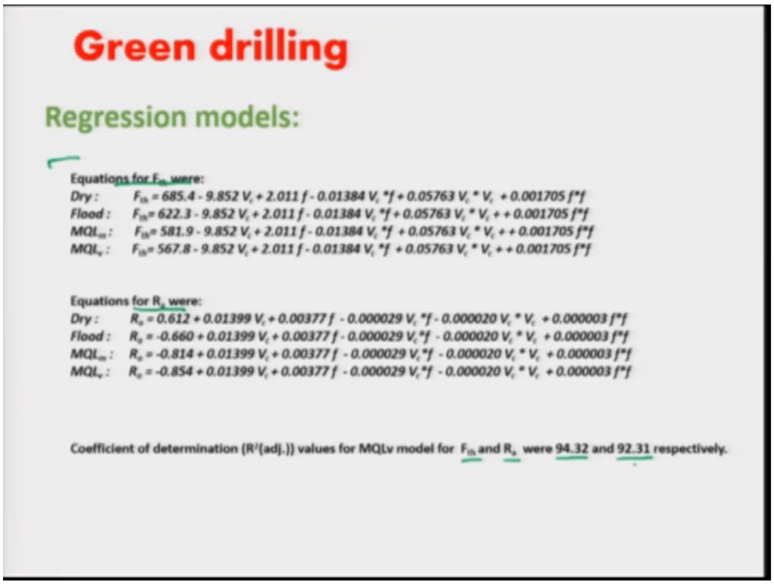

So, regression models were obtained for these force and roughness also we have coefficient of determination for them. This is regression models are for force and roughness coefficient of determination that is R square adjusted values for these models for the thrust and roughness were 94.32 and 92.31 respectively. These two models were taken forward for optimization. However, in these three models R square adjusted value was not very high; that means, the model were not obtained significant.

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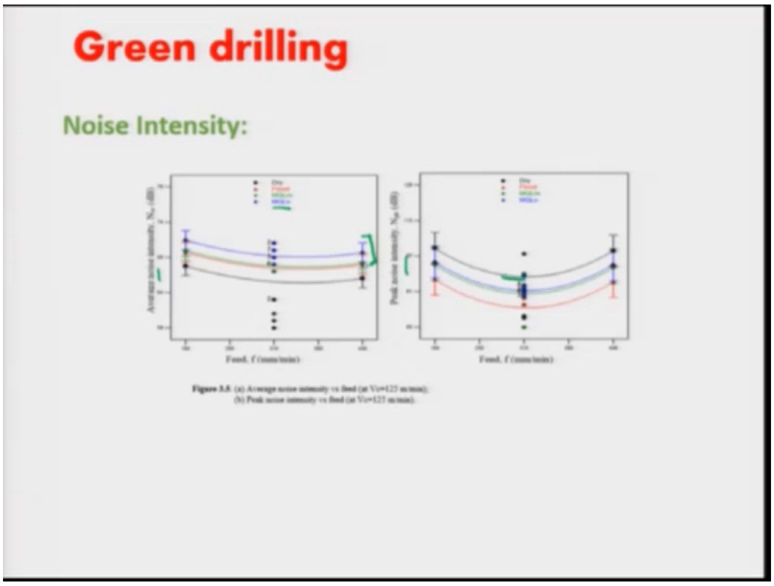

But still we can have the feel of the data here that for the average noise intensity and peak noise intensity the MQL v had higher values here, the 5 MQL v value is higher because when we spray the fluid there is some noise of air pressure there. So, that rises the level of the average noise here; in the peak noise intensity in dry what happens because the machining is completely dry there is no lubrication.

So, then the noise that we just heard in the machining that we saw the peak noise is high. So, in case of dry the peak noise is high and in case of MQL the average noise is higher, this gives us the feel of the data here.

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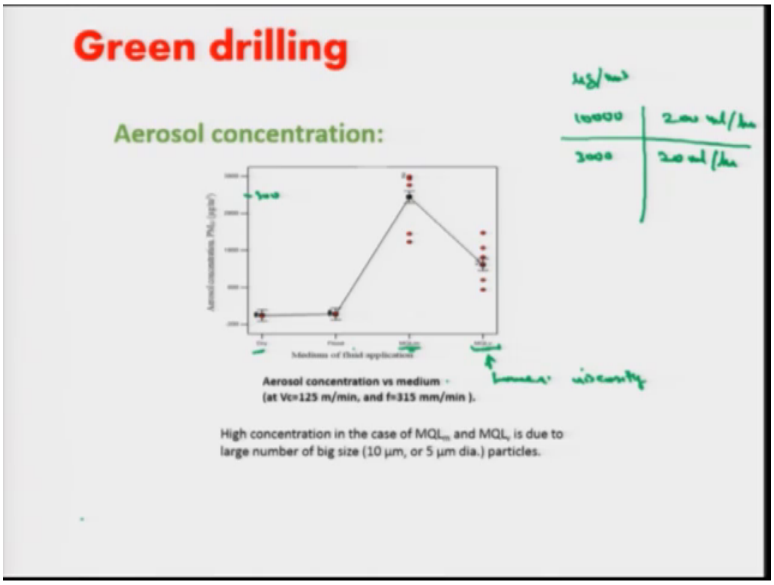

And aerosol concentration we can see that for dry it is too low because no fluid is here it is completely dry only small dust particles or small scrap it is very if it is very small that is only recorded here. In case of flood it has a little rise but in case of MQL the rise is quite high, because a lot of aerosols are there the mist particles are there which are recorded here by the aerosol collector. So, the medium of fluid application considerably impact the process the medium here the medium here is dry flood MQL, MQL m and v also we can see this in the table here; you can see this speed is not at all significant, feed is not at all significant, this is significant.

So, this is the model is significant and the medium is significant so this is significant; that means, the medium of fluid application significantly impact because of very high F value here as well, significantly impact the process. So, the high concentration of this MQL m and MQL v may be due to the large number of big size that is 10 micrometer or 5 micrometer diameter particles. Trial experiments also exhibited that the PM 10 level increases upto the level of 10000 micrograms per meter cube at a very higher flow rate, a very higher flow rate of the mist, but the flow rate that we have here is a little lower that was around that it is around at 10000.

So, I will put at 20 milliliter per hour we have obtained the maximum value here is at around 3000 that is 3000 this is microgram, microgram per meter cube that is the concentration and at 20 milliliter per hour, it is 3000 and at 200 milliliter per hour, while the trial experiment this is going to be around this level.

So, this is high flow rate that is reach that reaches upto this level. So, lesser concentration in MQL v level in comparison to MQL m this may be due to the low viscosity of the vegetable oil. So, I can put lower viscosity, so that is why the particle size is lower. So, lower viscosity of vegetable oil and water emulsion generates smaller size is particles. So, we recommend the MQL v method here now we need it to optimize and we need to set the specific machine settings in which we get the lesser energy.

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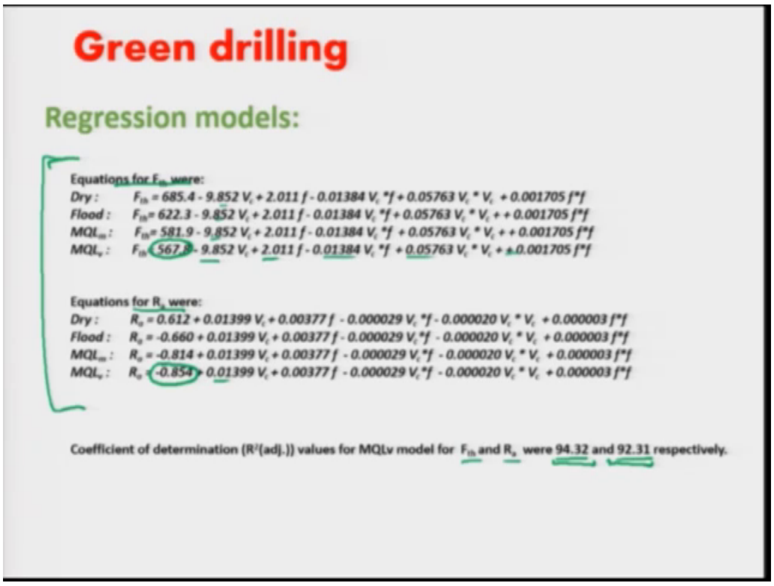

So, these were for the other factors like the peak and average noises and the aerosol concentration. Now let us come back to these significant model that we have obtained, significant means the R square value is higher. So, these equations or model were obtained from all the four models, here also we can see that the all other values these are actually parallel lines models, all other values are same here only the intercept differs. So, intercept value for MQL v is minimum for the thrust force and the roughness, the intercept level is minimum that is this line is at the lowest end; blue line.

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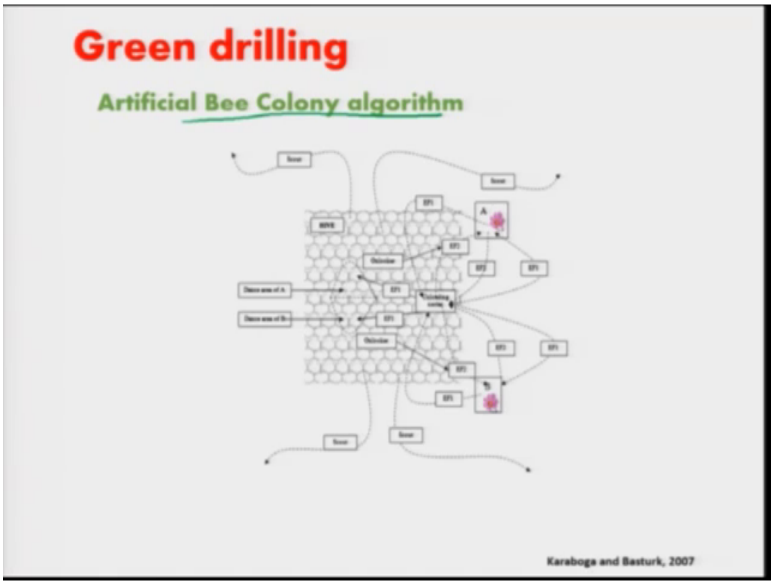

Now, these models were to be optimized and these values are to be minimized these two models for this, we chose an algorithm that is known as artificial bee colony algorithm. So, this algorithm I will like to take in the second part of this lecture. So, I will like to have a break here. I will meet in the second part we will discuss, the general information how does artificial bee colony algorithm works or what is the swarm optimization method. And we will see how do we optimize the process and we chose the parameters or the times for green factory simulation.

Thank you.