Manufacturing of turbines (gas, steam, hydro and wind)

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Lecture 24

Welcome to this course on manufacturing of turbines. So, in this lesson 24 of the course we will see the machining processes used to manufacture the hydro turbines. So, the outline of the lesson will be as follows, where we will first discuss the CNC machining, basics of CNC machining, then how CNC machining is utilized in machining components for hydro power. Then, we will specifically look at machining operations which are used in manufacturing of Pelton turbine, Kaplan turbine and Francis turbine. So, first we will see the basics of CNC machining. So, machining as we know it is basically a subtractive manufacturing process where material removal is done via contact of a hard tool with workpiece.

Now, here what happens that in CNC machining we add computer numerical control. So, in computer numerical control what happens it is basically a manufacturing process in which A pre-programmed computer software decides the movement of tool and machine that is the machine tool. So this process is also used to control. So this computer control, numeric control is also used to control other functions of the machine tools such as turning on the lubricant or turning it off, changing the tool, etc.

So, in CNC machining, what happened that numerical control software, it is predesignated with the use of G codes and M codes. So, we here with G codes, and combination of M codes comprise the basic of the CNC code which is basically a language to control the behavior of the machine tool which includes speed, feed, depth of cut, changing tool, turning off or turning on the lubricant and so on. So, we can say that modern CNC protocol, they enable production of parts via pre-programmed software mostly with respect to the accurate dimension of the part and converting this part from the CAD model into the actual tangible product using computer-aided manufacturing software. So, there are some advantages why CNC machining is used. So, their advantages, they include the greater precision.

It also includes consistency in manufacturing. It also includes less waste production or waste generation. we can say it also improves the faster production and it also improves lastly worker safety. So, because of these reasons CNC machining is very popular and especially when we are machining large components such as, the components used in hydropower, CNC machining is a very valuable tool. So, what we can summarize from this slide is that CNC machining is essentially a conventional machining process.

The difference between conventional machining and CNC machining is that the control in case of CNC machining is done via CNC computer numeric control which is largely an automated process in which combination of G codes and M codes which form the body of the CNC code are used to control the machine tool, the movement of the tool, speed, feed, depth of cut and other essential machining parameters. So now we will see how the CNC machining is used in hydropower manufacturing. CNC machining for hydropower is largely used for some specific components such as turbine housing, shaft and runner, guide and vents. So, in case of turbine housing we can see the robust enclosures in which the hydropower turbines are functioning in which they are able to harness the energy of flowing water to produce electricity. CNC machining it facilitates production of these housings using the durable materials such as steel or stainless steel and precise machining capabilities of CNC ensure efficient water flow through the turbine, minimizing energy loss and enhancing power generation efficiency.

In the second part where, CNC is used for shafts and runner machining so as shafts and runner they form the crucial component in the hydro turbine where, they have the role to transfer the energy from the flowing water to the generators. The advanced machining facilities enable production of these components with precise dimensions and smooth surfaces, thereby minimizing friction losses and ensuring smooth rotation for maximum power output. In case of guide and guide vanes, the guide vanes and stairings are essential to direct water of flowing effectively towards the turbine runners. CNC machining enables creation of these components with exact geometry and polished surfaces, optimizing water flow within the turbine. It also reduces turbulence and enhances power generation efficiency.

So, here we can see how machining operations are specifically used in Pelton turbine manufacturing. So, as we have seen earlier Pelton turbine is basically an impulse turbine in which on these six components essentially the machining operations are carried out. We will see in detail each of the component how machining operations are carried out, what are the machine tool, cutting tool etc. used and what are the outcomes of the machining process. So, first is basically the shaft preparation.

So, here the tool equipped with peeling head is utilized which is application for bar peeling for heavy machining operation. So, heavy machining here indicates higher depth of cut. So, in this process the materials which are used in case of this shaft are high strength alloy steels. Operation involves peeling the bar stock by removing the surface imperfections and achieving a uniform diameter. Specification of machining process involve cutting speed of the order of 200 to 300 meter per minute and feed rate of 0.

2 to 0.5 millimeters per revolution. Benefits of this process involve clean, precise and uniform starting material, reduced subsequent machining time and improved material properties. In the second part, we see the utilization of CNC machining in blade milling. So, in this case tool using MaxiMill HFC high feed system blade is used for blade milling of the Pelton buckets. So, the process involves the materials which are used to make these buckets as we know they are made up of stainless steel or high strength alloy steels.

Operation involves high feed milling to roughen and finish the turbine blades. Specifications of the machining process involve feed rate up to order of 3 mm per tooth because milling as we know is a multipoint cutting operation. Cutting depth of the order of up to 3.3 mm is used and a spindle speed of 1000 to 2000 rpm is utilized to perform this machining operation. Benefits involve high material removal rate with excellent surface finish which is critical for aerodynamic performance of the turbine blades.

So, in the next process we use the machining operation to develop the blade opening cut. So, we can see various cuts on the blade. So, this opening cut are developed using maximal universal button milling insert cutter where the blade opening cut is developed. So, the process involves again the materials are same which are used for the buckets which is stainless steel or high strength alloy steel. Operation involve rough cuts to create blade opening and initial shaping.

During this operation, the machining specification of process parameters such as cutting speed of 150 to 250 meter per minute is utilized. Feed rate of 0.1 to 0.3 millimeter per tooth is utilized. Depth of cut 2 to 5 millimeter is utilized.

Subsequently, we can see the benefits of this process are there that it ensures material removal while ensuring dimensional accuracy and stability which is essential for fine machining. In the fourth component, which is involving mounting the hole drilling. so here, maxi drill indexable insert drill is used, in which we develop the mounting holes via drilling that is the holes are created. so, in this case also the workpiece material is the high strength alloy steel or the stainless steel. So, drilling this precise mounting hole is essential for assembling the turbine components.

So, in this case drill diameter of 10 to 50 millimeter is used cutting speed of 120 to 180 meter per minute is utilized at a feed rate of 0.1 to 0.25 millimeter per revolution. The process achieves high dimensional accuracy and surface finishing ensuring proper fit of the turbine components. Next is basically the fine boring of hub and its components.

So, here twin cutter fine boring is done. So, material involve alloy steels and high strength composites. Here fine boring of the turbine hub and other critical component is done to achieve precise dimensions. Specifications involve diameter range of 365 which is varying of plus minus 40 millimeters to 2000 varying over plus minus 40 millimeters. Cutting speed of 100 to 150 meter per minute feed rate of 0.

05 to 0.2 millimeters per revolution benefits of this machining process involve high precision and surface finish which is essential for proper functioning of the turbine assembly. In the next step the cutting, hole opening and roughening is developed. So, this is developed using a multi-purpose tool and it has the application in opening and roughening of the hole. So, material of various grades of steel and alloy steels are used in which multi-purpose machining including turning, face profiles, internal profiles, outside profiles and drilling are carried out. Machining process specification involve cutting speed of 150 to 250 meter per minute, feed rate of 0.

1 to 0.4 millimeter per revolution, depth of cut of up to 10 millimeter is utilized. So, benefits involve versatile tool reducing the need for multiple setups, enhancing productivity and reduced tooling cost. So, next we see how the machining processes are utilized for Kaplan turbine which is one of the popular axial flow reaction turbine. So, in case of Kaplan turbine essentially machining is carried out at four components. So, here the first start we start with the blade roughening where the maximal is again used for blade roughening.

So, materials which are used to manufacture the Kaplan turbine, they involve high strength alloys and stainless steels. In the blade roughening operation, we perform the rough milling of the turbine blade to remove large amounts of material. Specifications involve cutting depth up to 3.5 mm. Number of cutting edges that is 16 per indexable insert.

Spindle speed of 1500 to 2500 rpm is utilized. A feed rate of 0.2 to 0.6 mm per tooth is utilized which ensures high process security even in conditions of unmanned or unsupervised production environments. The master finish geometry provides outstanding surface quality, setting a strong foundation for subsequent finishing processes.

In the next step, the drilling of the mounting hole is carried out using maxi drill indexable insert drill. Again, the workpiece material here is high strength alloy steel and stainless steel. So, drilling with precise mounting hole is required for these turbine components. Here drill diameter of 10 to 50 millimeters cutting speed of 120 to 180 meter per minute feed rate of 0.

1 to 0.25 millimeter per revolution are utilized. So, in this case the tool which is used cutting tool is coated using physical vapor deposition or pvd to create the CTPP430 grade inserts with four cutting edges. This ensures optimal dimensional accuracy under difficult

conditions, ensuring proper fit and alignment of turbine components. In the third step of machining of the Kaplan turbine, the maximal 251 is again used for blade finishing where the materials involve the stainless steels with high strength alloys. Along with this blade finishing, the machining process also performs finishing cut on the turbine blade to achieve the final precise dimension and surface finish.

So during this machining operation, the cutting speed of 150 to 250 meter per minute is utilized. Feed rate of 0.1 to 0.3 mm per tooth is utilized at a depth of cut of 2 to 5 mm. Benefits involve stable, soft cutting inserts with positive installation position resulting in lower cutting forces and less pressure, making it ideal for multi-axial machining, ensuring blade meet the aerodynamic performance requirements.

In the fourth step, in while machining for Kaplan turbine manufacturing, we can see the multi-lock exchangeable head is utilized for milling the transition radii. So, various grades of steel and alloy steels are utilized to mill the transition radii and other critical geometry on the turbine components. So, cutting speed of the order of 150 to 250 meter per minute at a feed rate of 0.

1 to 0.4 mm per revolution are used. So, tool of trigon interface is used and system offers cost-effective intelligent design which closes the gap between indexable insert and solid carbide milling cutters, eliminating the need for regrinding logistics as well as providing versatility for range of applications. Next, we see the use of machining processes in case of Francis turbine. So, Francis turbine is by far the most popular hydro turbine. It is a reaction based hydro turbine and is widely used in several hydropower plants. So, in case of Francis turbine, the machining operations again involve the blade milling where the maximill blade is used to mill the blades made up of high strength alloy steels and stainless steel.

So, high feed milling on the turbine blade for efficient material removal and precise shaping is carried out. Depth of cut of the order of 3.3 millimeters, feed rate up to 3 millimeter per tooth and number of cutting edges that is 4 per indexable inserts are used. Spindle speed of 1500 to 2500 rpm is utilized. Benefits of this process involve compact and stable design ensuring process security and efficiency, allowing for significant material removal in a short time while maintaining stability and precision.

The second machining operation carried out on Francis turbine involve outside profile rough turning, in which a indexable insert is utilized on a tool holder. So, outside profile turning is done on high strength alloy steels and stainless steel. Rough turning on the outside profile of turbine component is done to achieve the desired shape and dimensions. So, indexable inserts with a clamping system with a robust claw clamp is utilized with a cutting speed of 120 to 180 meter per minute at a feed rate of 0.

2 to 0.5 millimeter per revolution. So, the process offers high process security with perfect chip breaking at optimized insert geometries. The wear resistant performance upgrade also provide maximum machining performance with long to life even under demanding conditions. So, in the third step the milling of the transition radii is conducted using an exchangeable head system. So, again various grades of steel and alloys used in manufacturing of the Francis turbine are machined. So, milling of the transition radii and other critical geometries on the turbine is carried out at a cutting speed of 150 to 250 meter per minute feed rate of 0.

1 to 0.4 mm per revolution using a trigon interface. The system utilizes cost-effective intelligent design for closing the gap between indexable insert and solid carbide, eliminating for regrinding logistics. So in the fourth step, the outside profile finishing is done again using an indexable insert where, the high strength alloy steels and stainless steel are finished or are conducted on finish turning for outside profile to achieve the final precise dimensions and surface quality. So, using the indexable insert and a claw clamping which is robust, cutting speed of 150 to 250 meter per minute and a feed rate of 0.

1 to 0.3 millimeter per revolution is utilized. So, the process offers excellent surface quality, process security and the optimized seat ensures accurate clamping for the inserts and consistent high quality finishes during the machining process. So, with this we come to the end and we will now summarize what all is covered in this lesson. So, in this lesson we have seen the basics of CNC machining. We have seen how CNC machining is utilized for carrying out machining operation on all the turbines.

We have seen the advantages of CNC machining. Then we have seen how CNC machining using various tools specific to machine the components specific to the components in the hydro turbine are utilized. And then we have seen the application of CNC machining for all the turbines that is Pelton, Kaplan and Francis. So, in the next lesson we will see the overview of the various coating processes which are used in hydro turbines for their effective operation. Thank you.