**Laser Based Manufacturing**
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**Module - 7**
**Lecture - 22**
**Lasers in Manufacturing Automation**

Hello everyone. I welcome you all to the week 7 of NPTEL MOOC course on Laser Based Manufacturing. In this week, we will be studying various aspects related to application of lasers in manufacturing automation. Moreover, we will also be studying the CNC technology being used in the Laser Based Manufacturing.

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let us begin our lecture number 1. This lecture is focused on application of lasers for manufacturing automation. We will have a quick review of variety of areas where lasers can be used at the shop floor so that we can enhance the productivity. Moreover, we will be having a case study for the machining operation to sense the tool wears by using laser-based technology. let us start our discussion.

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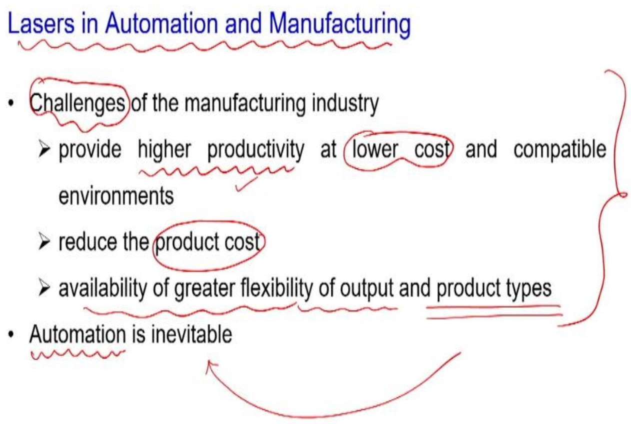


Lasers in automation and manufacturing; why it is essential to employ the lasers in automation and manufacturing. The global manufacturing industry or the Indian manufacturing industry has certain challenges. here, the challenges are in terms of enhancement in the productivity to produce more and more products per unit time. That is the one challenge because the demand is very high.

The second challenge is, we have to produce the products at an affordable price. So, cost effectiveness has to be there. And the next is flexibility. The product cost, the affordability of the product, higher productivity and flexibility of output or the product types. So, these 3 are the main challenges the industry is facing. My friends, the market is now customer driven. customers are demanding the variety, customers are demanding various functions in the products and the industry has to respond to that.

The industry has to provide the products with required specifications or the features of the customers. So, in view of this, it is very essential to respond to the market. And to respond to the market, we have to employ the automation, we have to automate the processes, maybe a communication, maybe transformation of raw material into the semi-finished shape or to the finished product, packaging, then even in the dispatch, all the logistic operations; we have to involve the automation, we have to automate the processes, and then we can achieve the required objectives and we can survive in the market.

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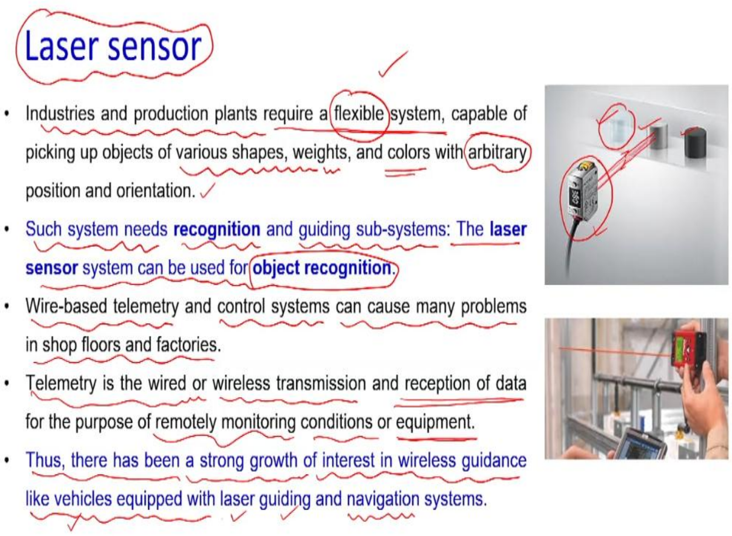


Now, let us look at what are the various ways in which we can help the industry. The fundamental application is sensing. We can use sensor; we can use lasers for sensing application. The industries and production plants require flexible systems. Now, the age is of the batch type of production. here, it is a mid-variety type of production we have to produce.

It is not like only one product is there and continuously we are producing at a mass scale; or it is not only 1 product would be developed in the company and then we are selling it out. So, we have to produce the products in batches and there has to be some sort of flexibility in our manufacturing unit as well to respond the changes in the size of the product. To incorporate the flexibility in the system; then to manufacture the parts of various shapes, weights and colours; these are the things that we are regularly doing.

But when we are handling such parts which are having different shapes, weights and colours and these parts are provided or these parts are located in the industry or at the shop floor in an arbitrary position or the orientation. consider we are having a conveyor over which the products are moving. They do have various shapes; they do have various weights; their colours are also different; and their position is also arbitrary.

Now, the task is to recognise the products which are moving on the conveyor. how to sense or how to recognise the parts? So, that technology we want and lasers are helping in this. Such system needs recognition and guiding sub-systems. And the laser sensor system can be used for object recognition. the primary application or you can say the prominent application of laser is in object recognition.

Wire-based telemetry and control systems can cause many problems in shop floors and factories. So, what is the meaning of telemetry? telemetry is the wired or wireless transmission and reception of data for the purpose of remotely monitoring conditions or the equipment. wired telemetry or the telemetry is a process where we are monitoring the remote equipment or the vehicles by using wired connections.

But consider there are many products or many equipment which are lying in the shop floor and we have to track them by using the wired connection; then the system will be very much complicated. It would be very cumbersome, difficult to handle. And when there are environmental parameters coming into picture such as humidity, noise, temperature or the vibration, these parameters are affecting the performance of the wire-based system such as the wired telemetry.

Here we should have some sort of equipment or the technology which is wireless, which can remove the wired connection and lasers are helping to solve this problem. Thus, there has been a strong growth of interest in wireless guidance. Where this system is used? Vehicles which are having laser guiding and navigation system. now, the automated guided vehicles which are there on the shop floor in automated industry or factories, these are laser guided and the navigation system is based upon the laser guidance.

One such slide we will be seeing in our next part of the lecture. Fine! On your screen you can see, some parts are there. this is a white part. All the parts are having same geometry but their colour is different, and a laser-based system can be used to detect the shape or to detect the colour of that particular part. when we are applying the laser beam energy, the part or the product or the substance or substrate is reflecting certain amount of energy.

And that reflection is colour of the surface. And as we are getting the reflection, we can measure its intensity, we can measure its wavelength. And based on that, we can easily recognise whether the part is of the interest or not. if suppose the system wants the part that to be sorted out which are of white colour, accordingly the CNC based selection system or detection system is trained and that training would be done based upon the lot of data which already has been fed to it.

The in-process detection is having a laser-based system. laser is applying the laser energy over the part. It is getting reflected. And based upon the reflections, some signals will be generated. That signals will be given to microprocessor-based system. And then the microprocessor-based system is taking the necessary action. either it is recording the data or it is activating certain actuation elements to push it from the conveyor or it may ask the robot to just pick it up from the conveyor from its place.

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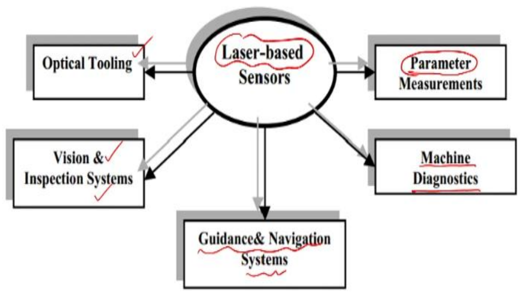
## Applications of laser sensors in manufacturing




Golnabi, Hossein. "Role of laser sensor systems in automation and flexible manufacturing." Robotics and Computer-Integrated Manufacturing 19.1-2 (2003): 201-210.

On your screen you can see a variety of applications of lasers in manufacturing. these laser-based sensors can be applied for optical tooling, then vision and inspection systems, guidance and navigation systems, parameter measurement and machine diagnostics. we will see these items one by one in our next few slides.

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## Quantity measurements

- Besides sensing distance, several other parameters can now be measured by using laser-based sensor systems.

| Sensor systems | Function |
|---|---|
| Process measurements | Parameters (distance, force, etc.) |
| Optical triangular scanner | Contour tracking |
| Optical binary picture | Pattern recognition |
| Optical gray level picture | Pattern recognition |
| Stereo systems | Machine vision |
| Machine diagnostics | Parameter measurements (speed, etc.) |

- Laser can be used as a coherent light source for the optical sensors.
- Some systems operate based on the interference principle, requires a very coherent light beam.

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The first one is quantity measurement. lasers are very much useful to measure the quantity, particularly the distance or the location of the part from a reference point. So, besides sensing the distance, several other parameters can also be measured by using laser-based sensor systems. And these parameters are the contour tracking; we can even track the contour, the movement of the product which is moving over the conveyor.

Then, recognition of the pattern, then vision; all these are the applications. Here, the parameters may be the distance, or the lasers can also be used to sense the force as well. So, here we are using laser as a coherent light source for the optical sensing. we are applying the coherent light source on work part. And then, based upon the reflection, based upon the response time or the record time after application of the laser, based on that, we can easily compute the distance or the location of that particular part from a reference point.

Some systems operate based upon the interference principle and requires a very coherent light beam. By collecting the interference pattern of coherent light beams, we can generate 2D patterns or we can even generate the 3D topographical data of various surfaces. lasers are very much useful to generate 3D topographical data. And based on that, we can even compute the various parameters such as the surface roughness, its R-a values and R-z values. Not only the surface roughness, based upon this interference data, even you can find out the form errors and variety of other geometry or the form parameters of the surfaces.

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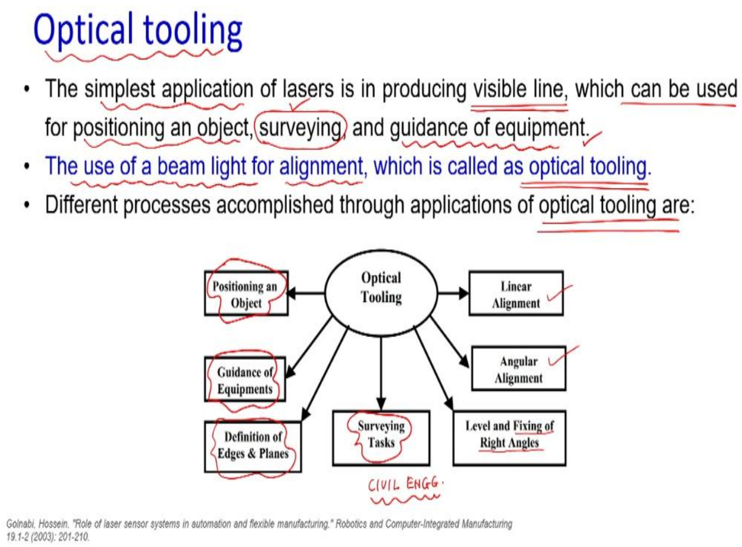


The next application is in optical tooling. It is a simplest application of lasers for producing visible lines. in this case, we are generating the visible lines and these lines can be used for positioning an object. And it is also being used for surveying. Based upon the surveying, we are deciding the various parameters related to civil engineering; for example, the road construction, for the dam construction.

We have to survey the site; we have to get the data or the elevation of the earth with respect to certain reference point. for that purpose as well, for big projects, the lasers are quite helpful for the surveying application. Of course, the guidance of the equipment is a very prominent way the lasers are helping, which we have already seen. In optical tooling, we are using a beam of light for alignment, which we call the optical tolling.

A simple beam of line light is used for the alignment. And when there is a misalignment or when there is a changes in the alignment, that will be calibrated as some sort of error or some sort of measurement during this application. Various processes which are accomplished through these optical tooling, these are there on your screen. here, the applications are: Positioning an object: consider a product or part is to be positioned on the table of a machine tool.

Lasers are very much useful to locate that particular part at that particular location. If there is certain offset, that would be communicated to the robot or that would be communicated to the handler. And then, the correct position of the object can be maintained. Then, guidance of equipment: Guidance of equipment such as automated guided vehicles. Then, definition of edges and planes: in textile applications, when the textile is moving on the conveyor or the fabric is moving on the conveyor, whether the fabric is following the required path or whether there is any offset or not, that can be detected by using the lasers.

The edges of the fabric or the edges of the garment are appropriate or not, that can be continuously monitored by using the lasers. This I have just now talked to you, that is the surveying tasks. in civil engineering applications, we are using the lasers for surveying operation. Then, alignment: To have the linear alignment of the parts or the tools; even for angular alignment as well, we are using the optical tooling.

And then, fixing of the right angles, which is very essential in machining operations. To have proper right angles to be maintained with respect to the application of forces, there the lasers are helping a lot.

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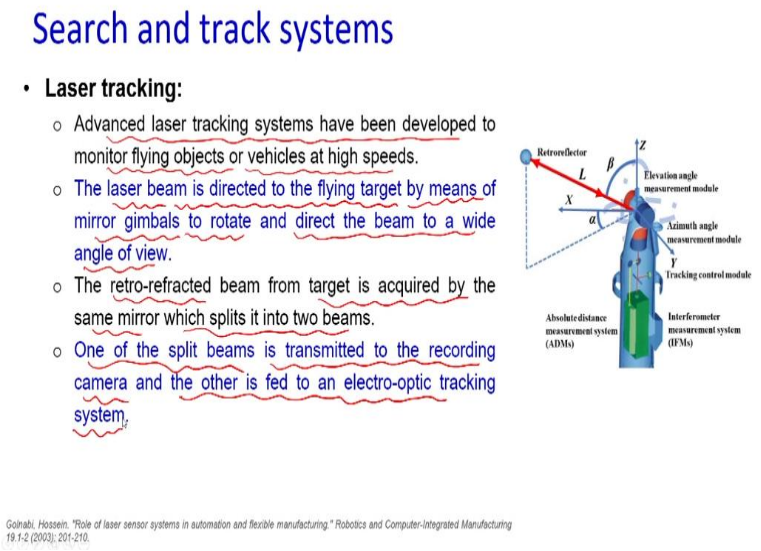


Lasers are also used for tracking purpose, for the search purpose. advanced laser tracking systems have been developed for monitoring the flying objects or vehicles at high speeds. in the shop floor as well, there may be lot of vehicles which are moving and some of the vehicles may be at a very high speed. to monitor the speed of the vehicle and to control the speed of the vehicle, we have to have some certain system and laser beam can be used.

We are applying the laser beam on the flying target or the moving object by means of mirror gimbals; and these mirror gimbals are getting rotated and we are directing the beam to a wide angle of the view. we are applying the laser beam energy by using mirror gimbals on the part which is moving in the shop floor. The retro-refracted beam from the target is acquired by the same mirror. now there is retro-refraction.

There would be refraction of the beam from the part, and that would be acquired by the same mirror which splits it into 2 beams. when we are getting the reflection on the mirror, that is the mirror gimbal, and there is a splitting of that beam at the mirror. one of the split beams is transmitted to the recording camera and the other is fed to an electro-optic tracking system.

So, once we are getting the split beams, one would be there at the camera itself and the other one would be at the electro-optic tracking system. Based upon the calculations and the speed or the time that we are getting by the split beams which are coming to the electro-optic system and the recording camera, we can easily track or we can easily recognise the parts which are moving on the shop floor.

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Lasers are not only recognising the moving objects or flying objects, they are also helping us to find out the range. range finder is a device that uses a laser beam to measure the distance. It is not only the recognition, to compute the distance as well, we are using the laser beam system. This is accomplished by projecting a beam to a target whose distance from the laser source is to be measured.

We have to project a laser beam at the target of which we have to measure the distance. active ranging devices such as laser range finders can provide accurate range data in real time which is very much valuable in CIM process. CIM is a philosophy and it is the popular acronym of Computer Integrated Manufacturing. this is quite wide term, the Computer Integrated Manufacturing, and it involves the automation as well.

Range finder finds a variety of applications such as vehicle navigation, robotic environmental sensing applications. as far as the manufacturing automation is concerned, the range finder helping us for vehicle navigation and robotic environmental sensing applications.

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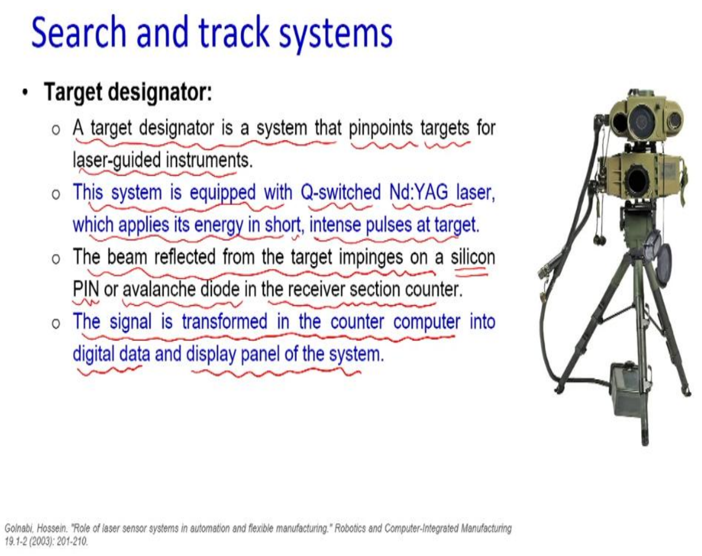


The third application of lasers as far as the search and track systems are concerned is target designator. A target designator is a system that pinpoints the targets for laser guided instruments. This system is equipped with Q-switched Nd:YAG laser, which applies its energy in short, intense pulses at the target. here, target designator is being used to choose a particular target for further its operation.

It may be its processing, picking up or we have to just look at the object, record its position. in this case, we are using Q-switched Nd:YAG laser, solid state laser, which is applying the energy in a very short duration, and these pulses are the intense pulses. by using the pulses of lasers, we can pinpoint the target. The beam which is getting reflected from the target is impinging on a silicon pin.

It is impinged on a silicon substrate or avalanche diode. whatever the reflections are there from the target, we will get on the silicon pin or avalanche diode which are there in the receiver section counter. based upon the number of pulses which we are getting reflected back, that gives certain pattern to us. These signals are transformed in the counter computer and that is generating the digital data and it would be displayed on the system.

We are applying a pulse laser on the target and there is a reflection of the pulse laser back to the receiver. And based upon that, we are getting the data of the surface, the target location and its movement as well.

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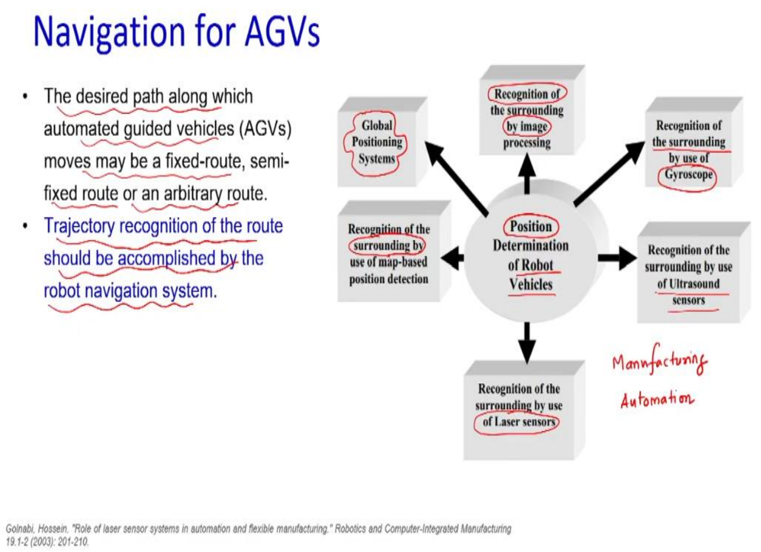


When we talk about manufacturing automation, the robots are playing a major role. the manufacturing automation, the robots are the integral part of these automation systems. And robots are not only helping to carry out the hazardous tasks, they are also helping for manoeuvring, they are also helping for conveyance in a very great extent. However, when we are using robots for movements, there is challenge to locate their positions, to determine their position.

Variety of techniques are used in the industry to locate the robots on the shop floor. The first technique is global positioning system. by using GPS, we can easily track the movement of the robot-based vehicle. We can take the photographs of the vehicle which is moving on the shop floor; and by processing that images, we can easily recognise the vehicles and we can even recognise their movements as well or we can record their movements.

However, there may be certain errors during collection of the images; the images may not be proper due to lot of environmental factors and errors. Then, gyroscopes are also helping us to recognise the surrounding of the robots. Then, we can also use ultrasound-based sensors to determine the position of the robot vehicles. Then, based upon the maps, we can even recognise the surrounding of the robotic vehicle and then we can take the appropriate decision.

However, the lasers are to a great extent are helping for position determination of the robot vehicles. the desired path along which the automated guided vehicles moves may be a fixed route or a semi-fixed route or it may be utterly arbitrary. it is changing as per its own intelligence or as per its own knowledge as well. trajectory recognition of the route should be accomplished by the robot navigation system.

When the robot-based vehicles are moving in the shop floor, their trajectory has to be recognised, it has to be monitored continuously, then the robots are to be navigated. there the lasers are helping us to recognise the trajectory and helping the controller to navigate. And then, that data will be given to the microprocessor-based controller. The controller is then navigating the robot-based vehicle in an efficient manner.

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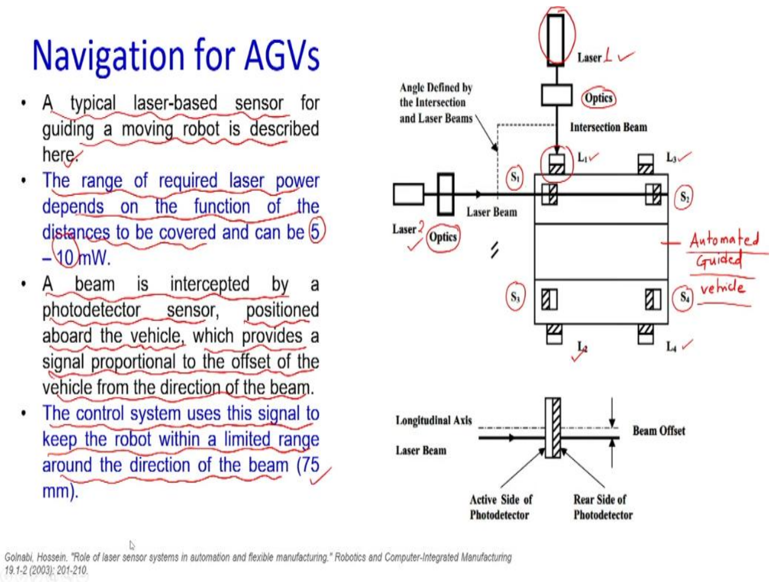


Now, let us see how these lasers based AGVs are helping. on your screen, you can see an automated guided vehicle. this is the automated guided vehicle. Fine! if you just notice, there are 2 different types of sensors are attached. sensor number S 1, S 2, S 3 and S 4, these are the on-board sensors. And the sensor L 1, L 2, L 3 and L 4, all these sensors are attached at the side surface.

The functions of these 2 sets of sensors is entirely different but their principle of operation is very similar. Now, we want to find out or we want to monitor the movement of this automated guided vehicle. We have to track the trajectory of this automated guided vehiclethat we can find out whether the guided vehicle is moving in a proper direction or not. If it is not, if it is offset, then in that case, the signal can be given to the controller of the AGV and the controller will be taking action accordingly.

Here you can see, we are using 2 lasers, the laser number 1 and laser number 2, and the orientation of these 2 lasers is orthogonal to each other. through optics, the laser beam energy is continuously being given from laser 1 as well as laser 2. this is the optics or the lenses that we are using. When the object is moving, the laser number 1 irradiation will come on the sensor L 1.

And if it is in line, if it is according to, if the angle of the irradiation on L 1, it is right angle, it is fine. In a similar way, we are also recording the angle of incidence of the laser beam from laser 2. And based upon the comparison of the angles which are coming from laser 2 and laser 1, we can easily find out whether the orientation or the movement of the vehicle is in proper direction or not.

If there is a change in direction of the AGV, then certainly this angle will not be orthogonal to each other and we may have certain other value. a typical laser-based sensor for guiding a moving robot is shown over here. The range of the required laser power depends upon the function of the distances to be covered. And generally, it is in between 5 to 10 milliwatt.

Laser power, how much to be applied or how much laser power is sufficient? It all depends upon the distance of that laser beam from the guided vehicle. In general, it is in between 5 to 10 milliwatt and it all depends upon the distance. If the distance is too large, then we have to go for the higher levels of the laser power. A beam is intercepted by a photodetector sensor positioned aboard the vehicle, which provides a signal proportional to the offset of the vehicle from direction of the system.

All these sensors which are detecting the laser light and based upon their detection values, we can easily find out whether there is any offset or not. The control system uses this signal to keep the robot within a limited range around the direction of the beam, that is about 75 mm.

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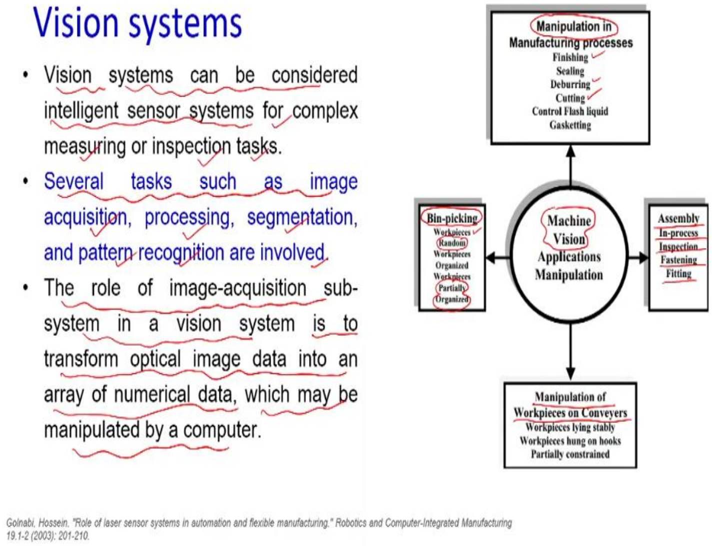


In automation, the machine vision is also playing an important role. There are various applications of machine vision system. these are there in front of you. The first application is bin-picking. When we want to pick up certain parts, it may be workpieces and these workpieces may be randomly oriented; if the workpieces are organised very well, then also we can sense, we can even pick up the part.

If the workpieces are partially organised; the situation may be the randomly oriented work parts, partially organised work parts or you can say completely organised work parts; by using the machine vision system, we have to pick a specified part or the product from the shelf. The second application of machine vision is in manipulation of workpiece on conveyors.

Lot of movements, lot of conveying operations are being done in the manufacturing industry. lot of parts, products, assemblies, sub-systems, finished products are moving on the conveyor system to get it transformed to the final product. when they are moving, the workpiece is lying stable, the stability of the workpiece on the conveyor, or the workpieces maybe hung on hooks or they are partially constrained.

All these 3 cases maybe there. Either the workpieces are simply kept on the conveyor, they are stable and they are moving in a very uniform way, or the workpiece is are hung on hooks and then we are doing the operations on these workpieces, or some of the workpieces may be partially constrained on the conveyors. in all the cases, we have to have a machine vision system which will help us to solve the problems.

Then, we also need the machine vision system in assembly, in-process inspection, fastening and fitting. After generation of various parts, now we have to assemble the parts together. at assembly station, we have to pick up the part and then we have to inspect it and then put it for its proper fit. the in-process inspection, fastening of the part with the other parts of the assembly and ensuring the fitting of the part with respect to other sub-parts or the sub-members and fitting of the part with the other elements, their relative position in the assembly of the product.

Then, there is a very important application of machine vision that is there in transformation processes. we have seen a lot of transformation processes in laser-based material removal. On shop floor, we are having lot of the mechanical based transformation processes such as cutting or the turning operation or the milling operation or material removal operations, then finishing operations, deburring operations.

Here we need to monitor the process continuously to have the efficiency in that particular operation. to enhance the efficiency, continuously we have to monitor these transformation operations. And if something goes wrong, that can be detected at the right time so that we can avoid the delay in the production time. machine vision systems can be considered intelligent sensor systems for complex measuring and inspection tasks.

This machine vision system involves very complex process, because we have to consider the shape of the product, its orientation, its colour, texture, illumination. by considering all the things, we have to develop our machine vision-based system for recognition or for recording of the objects. There are several tasks such as image acquisition, processing, segmentation and pattern recognitions are involved in a vision system-based automation.

The role of image acquisition sub-system in a vision system is to transform the optical image data into an array of numerical data which may be manipulated by the computer. this is the main task as far as vision system is concerned. We have to acquire the data, image data; then we have to transform the optical image data which we have acquired into an array of numerical data.

The image data has to be converted into numerical data and that data will be given to the computer. computer may be having the ideal image of that product saved or it may be having the data in terms of its possible orientation during the operation. So, the computer is a learned system; we have given knowledge to the computer; the computer is intelligent enough to compare the data which is coming from the shop floor through these optical vision systems and then it will be compared with the ideal data which is there stored inside the computer; and based on that, it takes the decision.

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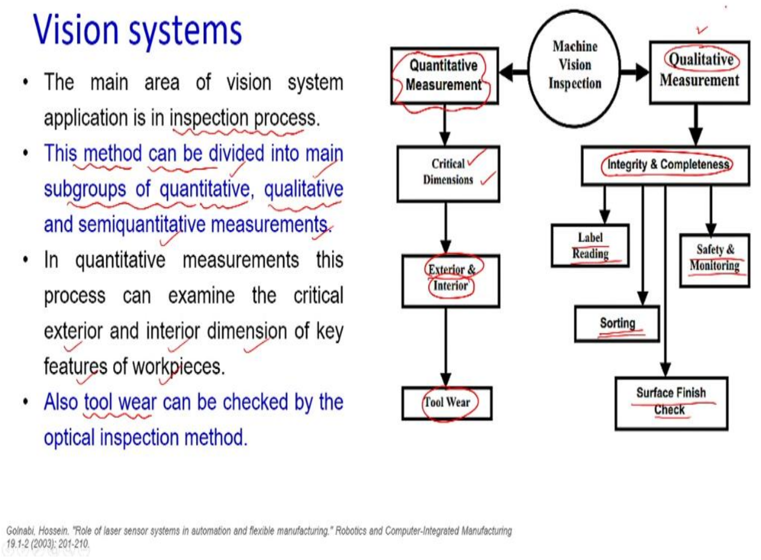


The main area of vision system application is in inspection process. The inspection is a critical operation during the product manufacturing. We have seen that transformation we can do. However, it is very difficult to have the manual inspection all the parts. there the vision systems are helping us. The vision system-based inspection process can be divided into various subgroups.

The first one is quantitative, then the qualitative and semi-quantitative measurements. In quantitative measurements, the process can examine the critical exterior and internal dimensions of the key features of the workpiece. Consider there is a product and there the product is having some critical dimensions as far as its overall geometry is concerned, and some dimensions are very critical as far as its features are concerned.

For example, cylinder bore. the cylinder bore should have the accurate internal diameter and it should have the given surface, accuracy surface finish. quantitative measurements are examining the critical exterior and interior dimensions. The overall dimensions are to be checked by using the machine vision system and the internal dimensions of the cylinder bore has to be checked by the machine vision system.

It is not only the internal dimensions, the surface finish or the surface quality has also to be ensured. The tool wear is another parameter which is very critical as far as the shop floors are concerned or the tool rooms are concerned. When we are employing the tool-based manufacturing, the tool changing time is significantly affecting the product development time or the production time.

We can have the quantitative measurement. And this quantitative measurement is of the critical dimensions, maybe the exterior or the interior key features, or we can have the tool wear measurement as well. As far as qualitative measurements are concerned, the integrity or completeness of the product has to be checked. For example, the label reading, the safety and monitoring, the sorting out or the surface finish check. all these are coming into the qualitative measurements.

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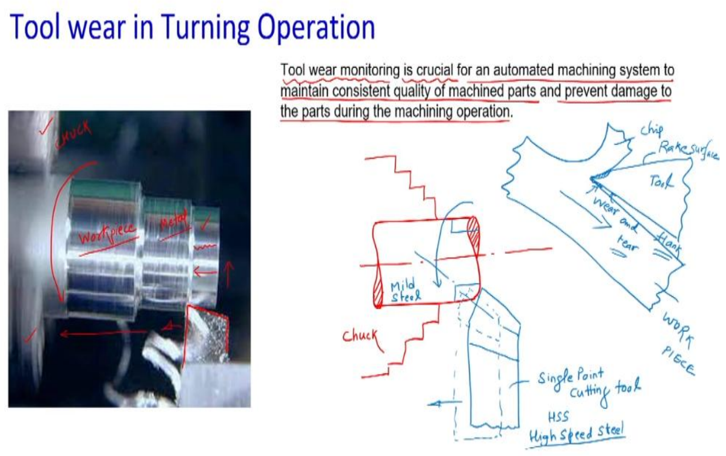


Now, we have seen some of the applications or some of the aspects of using lasers on the shop floor in manufacturing automation. Now, let us take a case study, how exactly lasers can be helpful to solve the problems of the monitoring. here we have taken an example of turning operation. turning operation is very common, very important and very general application of material removal in the shop floor.

All the shop floors are having the lathe machine. You also might have worked on the lathe machine. in the lathe machine, we are reducing the diameter or we are processing the axisymmetric parts. on your screen you can see a workpiece. It is a metal workpiece. And we are having a cutting tool. this is the cutting tool. The workpiece is held in a holding device; it is called as chuck. And this is the cutting tool.

The workpiece is rotated at a high speed and then we are having a relative motion between the tool and the workpiece. here the tool is moving in this direction along the longitudinal direction, as well as, we can have the moment of the tool in the transverse direction as well. the transverse direction movement would be gradual. However, there would be a continuous movement along the longitudinal direction.

When there is a movement of the tool along the longitudinal direction, there is a generation of chips, there is a plastic deformation of the work part. And in this way, we are reducing the unwanted portion from the work part. During this operation, there is a lot of wear and tear of the tool surface. As the tool is getting worn out, it is affecting the geometry of the work part.

It is desired that during the process of the turning operation, the tool must not get changed its dimensions. During the operation, it is expected that the tool should not get worn out, it should not lose its dimensional stability, it should not get deformed. But in actual sense when the tool is working with the workpiece, then there is a generation of the temperature. And due to that temperature, there is a lot of wear and tear of the tool surface.

This tool wearing out is affecting the dimensions or the surface finish of an already machined part. here you can see, if the tool is accurate, tool is not worn out, we are getting a smoother finish of the machined portion. However, if the tool is worn out, then we may not get proper surface finish on the machined portion. by looking at the machined portion, we can easily dictate or we can easily notice whether there is a problem with the tool geometry or not.

We can say that the tool wear monitoring is therefore crucial for an automated machining system to maintain consistent quality of the machine parts and prevent damage to the parts during machining operation. now, let us see where exactly the wear is getting occurred. let us consider a cylindrical part. And this cylindrical part we have to turn, we have to reduce its diameter. we have held this part into a check.

This is a check arrangement and this is the cylindrical part. Now, to remove the unwanted portion or to manufacture a step over here, we have to use a single point cutting tool. consider a single point cutting tool that we have taken.  the single point cutting tool has 2 edges. this is the side cutting edge and this is the end cutting edge. This is the single point cutting tool.

Generally, it is made up of HSS that is the high-speed steel which is commonly used in the tool rooms to process the parts made up of mild steel. Fine! when we have the relative motion of this workpiece with respect to the tool, then there is generation of chips due to the plastic deformation. if I take it here, the tool something like this and if I take the cross-section here, then I will get the formation of chips in this manner.

This is the tool surface. This is the workpiece which is rotating here. And this rotation here we can consider the linear movement. And this is the tool. And this is the chip. when the tool is applying the compressive forces on the workpiece, there is generation of heat. And due to the heat, there is wear and tear on its top surface. It is not only due to the heat, there is a friction of the chips which are moving over the tool surface.

This surface is called as the rake surface. the heat generated due to the plastic deformation, moreover, the friction of the moving chips over the rake surfacethere is wear and tear of this surface. there is bottom surface of the tool which is in contact here as well. here also there is a wear and tear of the surface, bottom surface. this is called as the flank; on the flank surface on the bottom surface.

Due to wear and tear of the flank surface, there is a change in geometry of the tool. And when there is a change in geometry of the tool, that is affecting the surface roughness of the machined portion.

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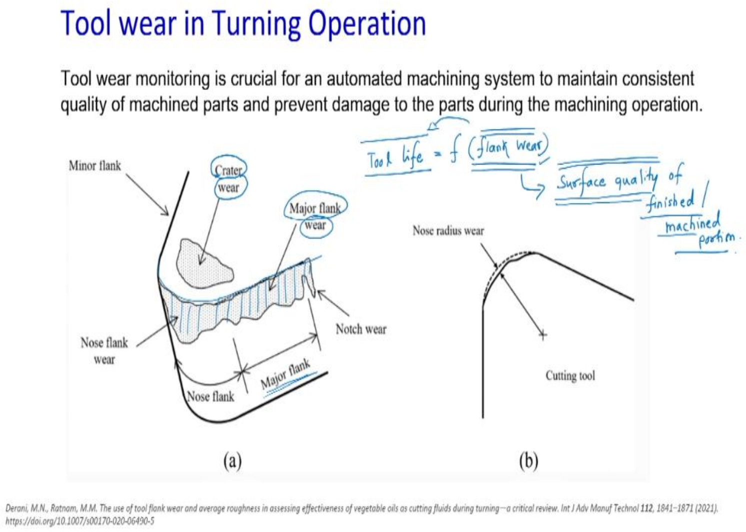


Here you can see the crater wear which is occurring on the rake surface, and this is the flank wear. this tool is having a nose. It does not have exact point contact of the edges. And the wear which is on the flank surface; this is the flank surface; and the wear which is having the flank surface is called as the flank wear. this is the major flank. And by computing the flank wear, we can easily find out the tool life.

The tool life is dependent on the flank wear; it is a function of flank wear. And flank wear is affecting the surface quality, the surface quality of the finished part, the surface quality of finished or the machine portion. now, how the lasers can help us to find out the tool life? we have to go in a reverse way. can we find out the surface quality, in situ surface quality, in-process surface quality measurement by using some laser-based technique which will give us the flank wear values?

And that flank wear values can help us to find out the tool life. If the machined portion or the finished portion is not of good quality, it is not of desired roughness value, then we can easily find out there is some problem with the tool. in this way, the surface quality of the finished part can be sensed. And by using that sensing, we can find out the health of the machine tool and the productivity or the efficiency of the machining operation. Well, let us have a look at the case study.

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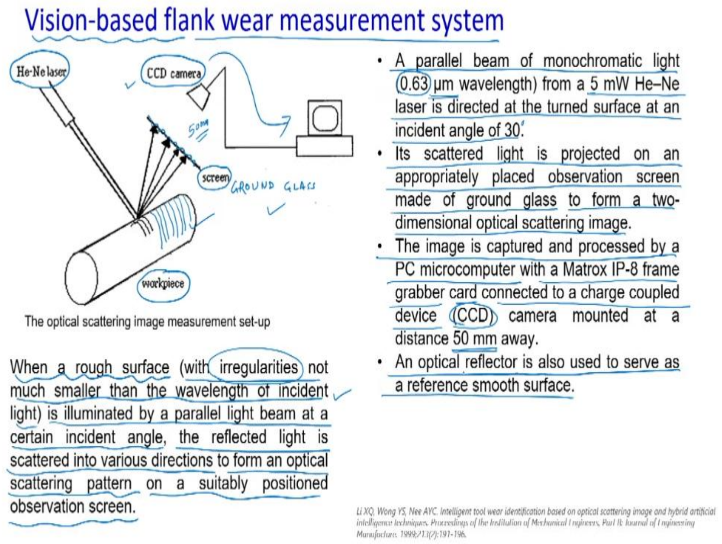


It is vision-based flank wear measurement system. As we have seen that the machined surface or the processed surface can give us some indication of the tool wear; here you notice a workpiece and the workpiece is having serrations or the roughness on its surface. can this profile be used to find out the tool wear? to find out the tool wear, we are using a He-Ne laser. The laser beam is applied and the reflections are recorded on the screen.

And further, a camera is used to get the photographs of the screen and that camera is connected to the computer. based upon the images of the reflected beams, we can easily find out whether the surface is proper. If surface is proper, the tool is in a good condition. When a rough surface with irregularities not much smaller than the wavelength of incident light is illuminated by a parallel light beam at a certain incident angle, the reflected light is scattered into various directions to form an optical scattering pattern on a suitably positioned observation screen.

Here we are applying the parallel light beam, that is a laser on the surface. when the light beam is incident on the surface, there is reflection. And that reflection is, the scattered way it will be there. those scattered reflections can be sensed and can be utilised to find out the pattern of the surface. A parallel beam of monochromatic light and which is a wavelength of about 0.63-micron wavelength is used in this case.

A parallel beam of monochromatic light of wavelength 0.63 micron is used. And here, the He-Ne laser, helium-neon laser of 5 milliwatt is used. The laser is directed on the turned surface at an incident angle of 30 degrees. here the laser is applied at an angle of 30 degrees. Its scattered light is projected on an appropriately placed observation screen made of ground glass to form a 2-dimensional optical scattering image.

This is the ground glass. in this case, whatever the scattering from the surface is taken on a screen; it is ground glass screen; and then we are using a CCD camera. The image is captured and processed by a PC microcomputer with a Matrox IP-8 frame grabber card which is connected to a charge coupled device; that is a CCD camera. we are using a CCD camera to capture the image of the scattering pattern which is generated on the surface.

The camera is mounted at a distance of 50 mm away. the distance is just a 50 mm away from this screen. We are also using an optical reflector to serve as a reference smooth surface. we are getting various images of the rough surface but we have to have some reference, some datum, and for that we are using an optical reflector which certainly will give a smoother surface.

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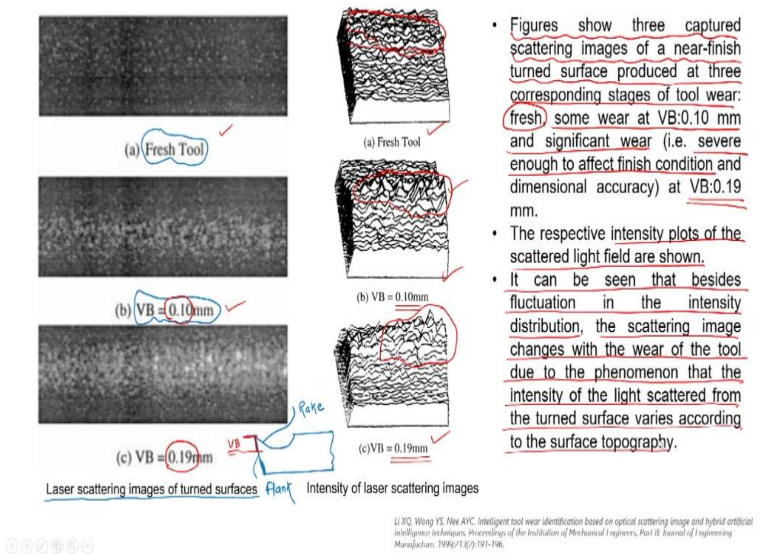


Now, when we got various images; so, these images are there on your screen. here you can see the laser scattering images of the turned surface. This is this turned surface. When we are using fresh tool, the tool is freshly used, it is not used previously, the edges are intact; it is a new tool that we have employed over here. The next one is VB = 0.10 mm. VB is the length of the wear; its average length of the wear that is on the flank surface.

If we just look at the tool surface; this is the tool surface, this is the tool geometry, this is a rake surface and this is the flank surface. here, the value of VB is from its top position over here, top position of here and how much distance or how much is the length of the wear from the top position. this is the VB value. And we can easily find out this VB value.

When we are using a tool, the tool is deliberately used here who is having a VB value of 0.10. Sthis point must be noted. We have used in first case a fresh tool, then we carried out the turning operation; but during that operation, we have deliberately used a tool with 0.1 mm. In the third case, we used a tool which is worn out, severely worn out and its value is 0.19.

Now, when we have used these 3 different types of tools, what is the surface that we have got? these are the scattering images of the surfaces when we have used these 3 different types of tools. you just look at the asperities or the undulations on the surface. The fresh tool, almost there are not many crest or you can say the crest are there, but they are uniform. But here, when we are using VB = 0.10, there are certain portions or certain patches which are showing lot of crest.

There are lot of undulations are there. With VB = 0.19 as well, you can notice there are lot of asperities which are present on the surface. when we are comparing these images with the smoother surface, by comparing these 2 different images of the smoother surface and this rough surface, we can easily find out whether the tool is worn out or not. for this purpose, we have to generate a lot of data and then we have to give the data to an intelligent system.

We have to generate or we have to develop an ANN based model, Artificial Neural Network based system, intelligent system. And then, that system can be used to detect intelligently the the tool wear or the surface roughness values. figures show 3 captured scattering images of near-finished turned surface produced at 3 corresponding stages of tool wear. The fresh one, some wear at VB = 0.10 mm and significant wear severe enough to affect the surface condition, and that is about 0.19 mm.

The respective intensity plots; these are the intensity plots are also shown over here of the scattered light. it can be seen that besides fluctuation in the intensity distribution, the scattering image changes with the wear of the tool due to phenomenon that the intensity of the light scattered from the turned surface varies according to the surface topography. here the concept is that the reflection from the machined surface is according to the surface topography.

And as we are changing the tool, the surface topography is getting changed, the surface profile is getting changed. With fresh tool, the surface topography was different; with worn out tool, the surface topography was different, surface profile was different. So, by capturing the image of this surface topography, we can easily find out or we can easily detect the tool wears or the tool life.

So, these kinds of systems are very much useful to give the warning to the end user, to the operator. And we can replace the tool which will avoid the catastrophic failure of the entire system which will save lot of energy, money and time.

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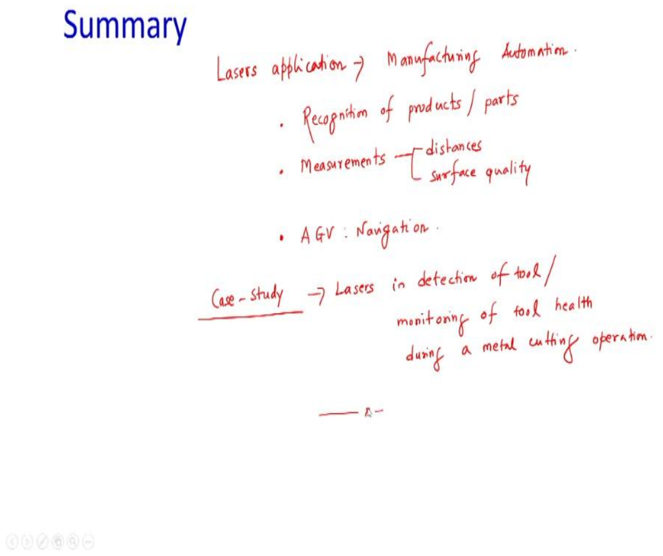


So, with this I would like to conclude my lecture on the lasers in manufacturing and automation. We have seen a variety of lasers. We have seen the lasers applications in manufacturing and automation. So, these are in particular the recognition of products or parts. Then, measurement of quantities, particularly the distance and the surface roughness; distances and the surface quality.

Then we have also seen that the application of lasers in AGV navigation. And at last, we have seen a case study how lasers are helpful in detection of tool wear or we can consider monitoring of tool health during turning operation, so, during a metal cutting operation. With this I would like to conclude this class. Thank you for watching this lecture. Goodbye.