NPTEL Online Certification Course
Industrial Robotics: Theories for Implementation
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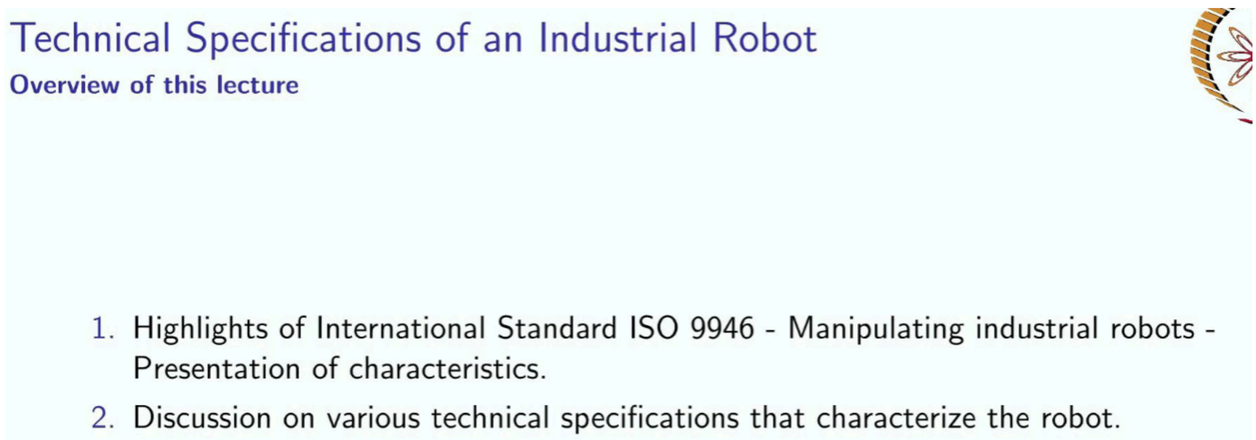
Lecture: 03

Technical Specifications of an Industrial Robot

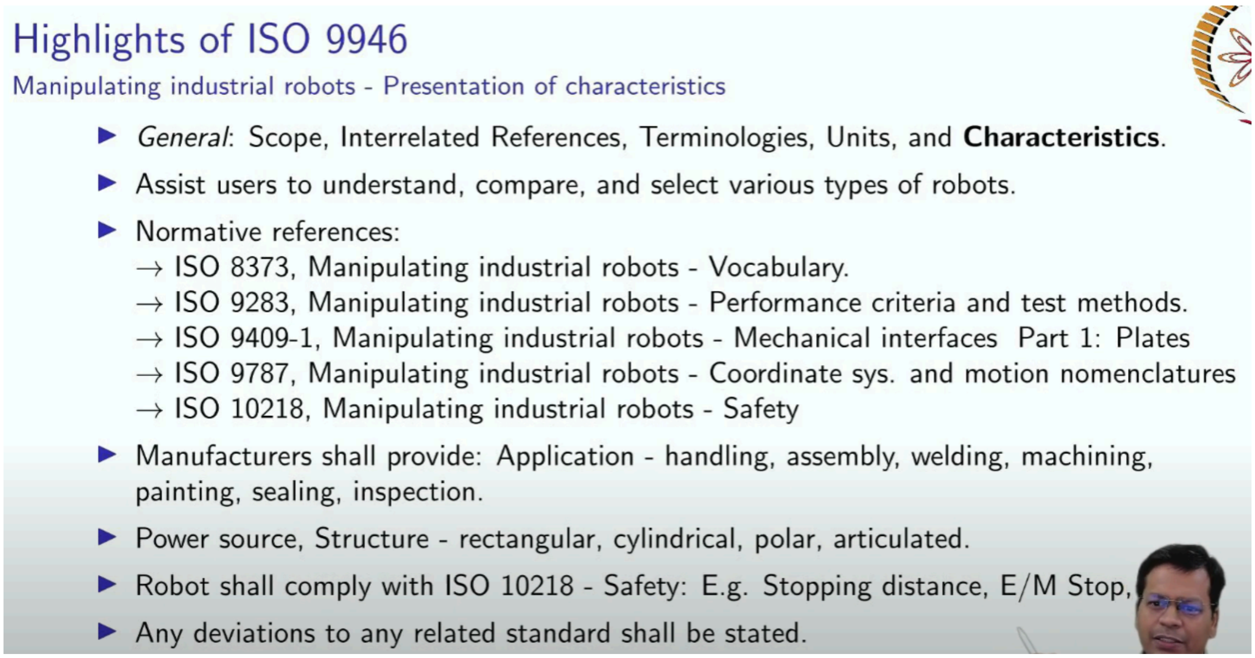


Welcome back. So, in the last class, we covered robot anatomy, where we saw different parts of the robot that actually make up a robot. You saw the 6 Degrees of Freedom industrial robot with different actuators which were there. Right, overall, it was a 6-degree-of-freedom robot. It had a gripper, it has a controller, a controller with an emergency stop switch, and some IO board with some safety features in it. Right, and it has sufficiently long wires.

Then, you saw it had a teach pendant with again some special features which were there. So you see, that was the robot all about. Is it all that makes a robot? Just having hardware does not suffice to be qualified for being an industrial robot. So what goes inside, there are many other features which are there.

So, that is what we are going to discuss as a part of the module introduction. Today, I will be discussing some technical features of industrial robots that actually characterise this type of robot—got it? So yes, and what all standards are there, which actually is very, very important when you say yes I am going to buy this robot. So, what features should you look for? Let us say you want to compare two different robots that you have to care and then you want to compare them on some specific features. So yes, today we will talk about all those steps.

So, let us start. So today, I will be discussing the highlights of the international standard ISO 9946, which is manipulating industrial robot's presentation of characteristics. It is the standard which actually defines different technical parameters which are to be there in a technical specificity which the manufacturer provides. Then I will discuss some of those characteristics in detail how they are defined, how they are defined, how we should go for, let us say if it is an emergency stop switch, how it should look like, where it should be located and many, many other things that we will be discussing.



So, let us start with highlights of industrial robots. So yes, this standard basically is a standard that says manipulating industrial robots, presentation of characteristics. In general, if somebody is very, very novice, any standard which is of this kind normally explains the scope of this standard at the beginning of this document, right? Interrelated references, basically, interrelated references, without which without defining those references, you cannot fully define this particular ISO as well. One of them may be the vocabulary of industrial robots; without understanding the different vocabularies of industrial robots, you cannot define ISO 9946 or many other similar ISO standards. So, there are various terminologies, which are their units that this ISO standard will be following and finally the characteristics, some unique characteristics which are necessary to define this type of industrial robot, right? So, I will be talking one by one on each of them, ok? So, it assists this type of standard basically assists an end user, a customer, maybe a power plant user, maybe a manufacturing plant who is going to use this type of robot or maybe simple academicians like me who use it for general purposes for teaching and other for welding and some training, some special kind of thing. So, in order to understand what this robot is going to give me, right? If I buy this what all features will I be getting out of it, right? I will be able to compare why this robot, why not some other robot, got it? So, if you have two-three similar robots in hand, which one suits my particular application well, right? So, I have to compare, or anybody has to compare for any specific application, even if it is for teaching. If not anything, at least the cost is there. That is something which is definitely beyond standards but beyond anything which is defined in a standard, but yes, it is to be compared as well. So yes, and then select various types of robots based on them, right? So, normative references are there without which this particular ISO is not completely manipulating Industrial Robot Vocabulary is a common industrial standard, ISO standard A83738 is, ok? So, that defines various vocabulary that is commonly used in manipulating industrial robots.

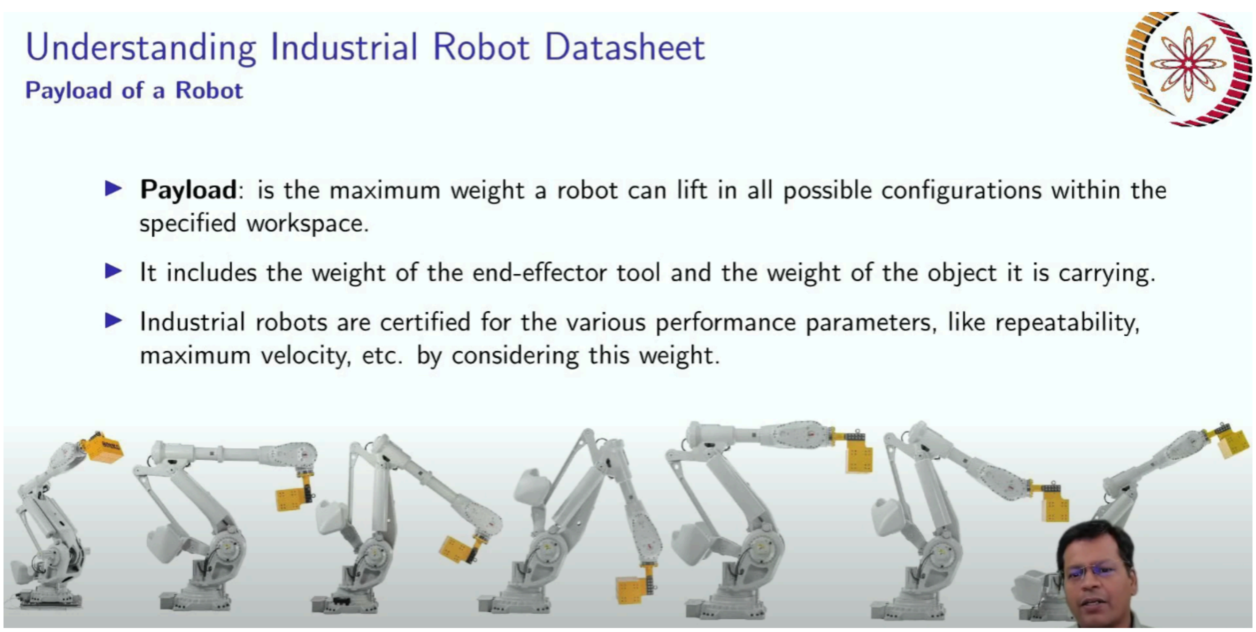
What manipulating industrial robot is, basically, any robot that is able to manipulate an object in an industry which can pick and place parts from one place to another, right? While doing so, it can even drag an electrode over a surface and do some welding work. That also is a manipulating robot, yes. So all that finds its place in this. So another very important one is Manipulating Industrial Robot Performance Criteria and Test Methods. If I say my robot is repeatable, let us say it has a repeatability of 0.1 mm, so how is it tested? Those specific test techniques are covered in this ISO 9283, and if you say my robot can carry so much payload, all those how to define a payload and these special definitions are covered in this type of ISO standard.

This particular standard basically covers all of them. So, ISO 9409 is for manipulating industrial robots, again, mechanical interfaces. Let us say this robot has a flange and now I want to fit up a gripper on top of it, ok? So, if at all there is a gripper, that should fit on top of your end effector flange. So both the flanges should have the same dimension so that you can fit different screws on top of it without any failure, without any subsequent modification of your finger or a gripper or anything like that is a standard which precisely defines the placement of a flange on top of a robot so that any further attachments can be added very easily. So, mechanical interfaces are basically defined in 9409. We will talk about this even more in detail when we will talk about interfaces in detail.

ISO 9787, which again defines the coordinate systems, motion, and nomenclature, right? These special terminologies are explained in this particular ISO standard, and that is very, very important to define ISO 9946 as well as definitely safety. It is ISO 10218 manipulating industrial robot safety. Safety is a subset of almost all the industrial standards, so that is mostly part of each chapter of any ISO standard; in every part of a technical manual, you will find specific safety standards mentioned. So yes, manufacturers are bound to provide. If they are providing a robot, selling a robot, if they have to sell the robot to the international platform, definitely they shall provide all this. They have to qualify for ISO 9946, which says they have to provide an application where this, what is the intention, why you have made this robot first of all, where you have planned this robot to go for, let us say is this robot fit for painting, rendering, assembly, what so what is the probable application, where do you seek this robot to go, right? So, thus that should be defined by the manufacturer in its manual also.

Sometimes robot's name itself says, let us say, KUKA KR 5 ARC robot, the name itself says ARC, so mostly, although it can do pick and place if you put a gripper on top of it, but it is designed mostly to do ARC welding applications. Sometimes the name says so, sometimes it is detailed in the datasheet also, yes, so and the power source, Power Source means it is electrically actuated robot or hydraulically or a pneumatic one, we will discuss them in classification as well. So yes, power source is a very, very important parameter which is to be defined also. So, the structure of the robot, whether it is a gantry type of robot, a cylindrical robot, a polar coordinated system robot or a standard articulated arm robot, is very, very common in history. So, these are some of the very very special things which I will not be covering very much in detail now. Definitely, I will be covering different sections of this module, which is the classification of industrial robots.

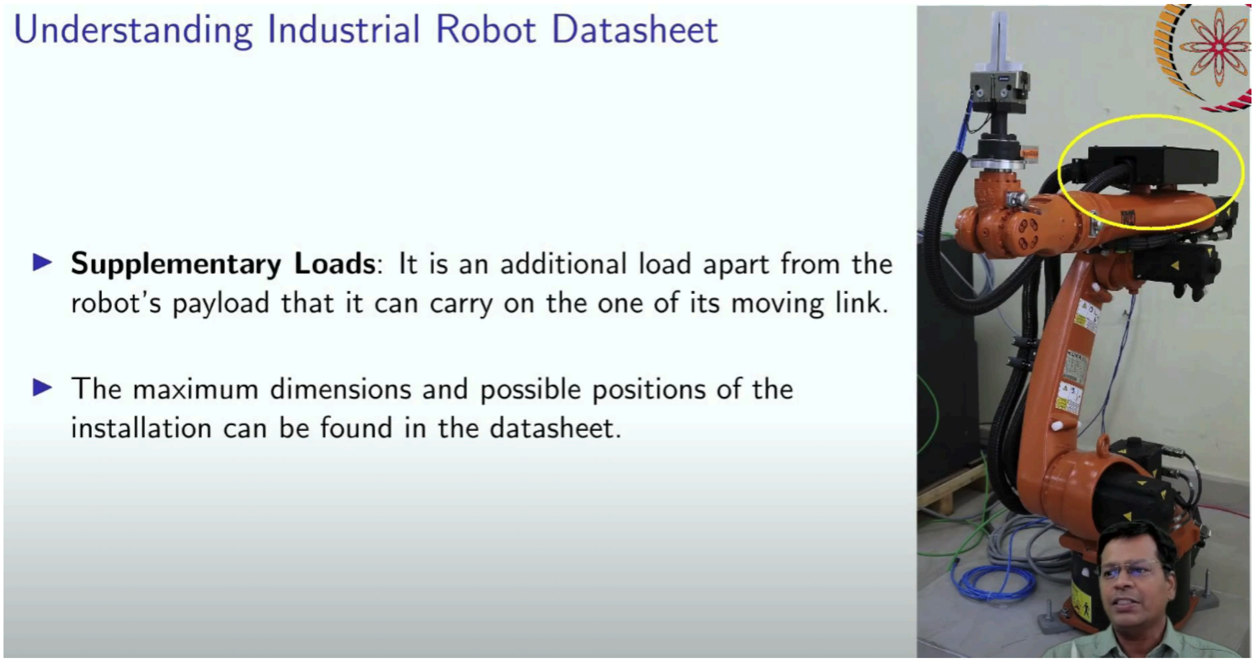
So now, the robot cell also complies with ISO 10218, which is the safety standard that is defined here also, ok, that is defined very much over here, you can see, yes, so that also defines a stopping distance. Let us say if at all you have applied a break, yes, how far it will further go, how much it is going to overshoot, stopping distance is given, emergency stops, which is their requirement, and various other safety factors are defined in this ISO 10218. So now, any deviation, if at all, is there from the related standard also needs to be stated by the manufacturer of the robot in their technical specification sheet. So, this is all given in your standard ISO 9946. Let us now start defining one by one different special parameters which are always there in a robot's technical specification sheet, and that is what anybody will seek, those are known as characteristics of the robot that basically characterises the industrial robot.



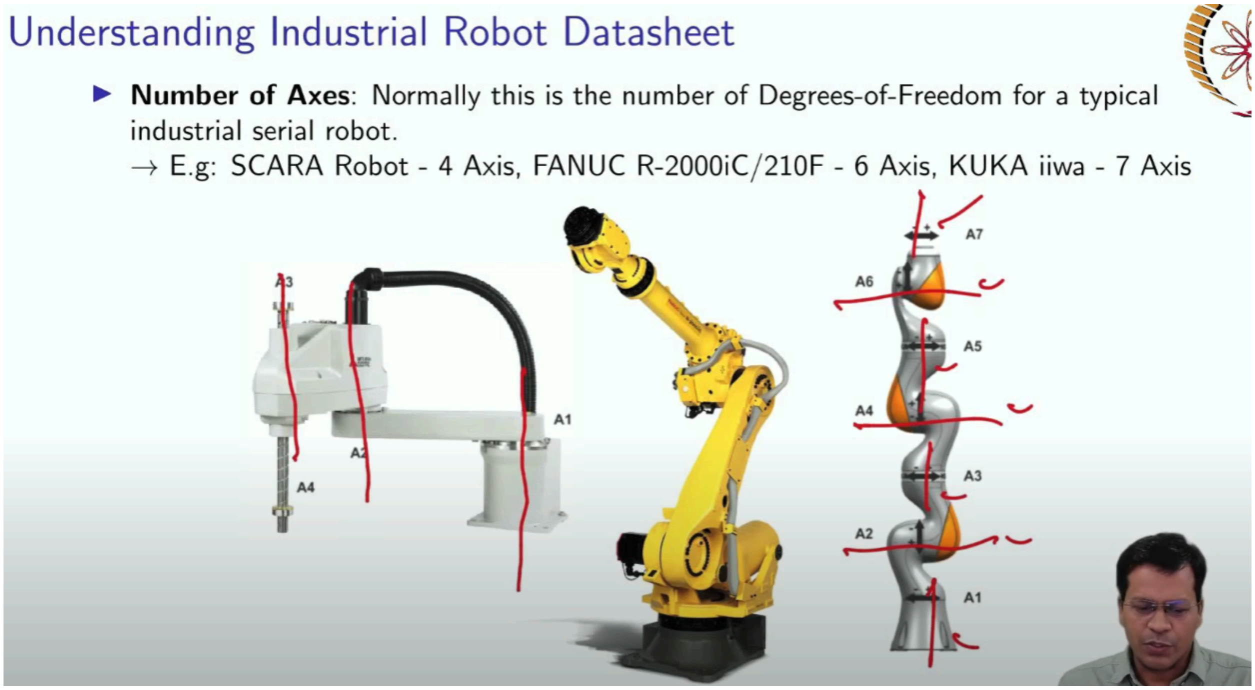
Let us start with the first one in the queue, which is the payload of a robot. It is the maximum weight that a robot can lift in all possible configurations; you see it in Figure one; the robot is something like this bending. In the second figure, you see it is a little bit down, more bending, again down, again further down, right and then it is in a different position, different position, different. There is n number of positions, so all the configuration includes a position in space and orientation in space. So, in all those configurations, the robot should be able to pick up at least this much load. It is what is the payload of the robot, got it? It includes the weight of the end-effector tool. So, when a robot comes, it comes bare-handed; the end-effector tool is not mounted on the top of the robot. So, if I say my robot can carry 12 kg of payload, i.e. my robot is a Yashkava GP12, the video which you saw in the last class. You saw it was 12 kg payload rated. Ok, that means without the gripper, it is 12 kg; the gripper itself is, let us say, 2 kg, then the final payload that it can carry is the remaining 10 kg, got it? So overall, the payload which the manufacturer specifies excludes that, so whatever payload I am going to carry also includes the payload that is your gripper itself becomes the payload for that kind of robot or any robot.

So yes, industrial robots are certified for various performance characteristics and performance parameters like repeatability. Suppose you say my robot is repeatable by 0.01 mm, so 0.01 mm, so n number of times the robot can go there without deviating more than 0.01 mm. In that case, that means that particular repeatability is defined when the robot is already carrying at least 12 kg, at least the payload which is specified in the manual ok. So that much of load it will take up, and then it is supposed to do all those acrobatics.

So, if it says I can go, let us say, at 2 meters per second, it has to carry that 12 kg or that payload capacity of the robot. Then, it should be capable of moving at 2 meters per second. If it says it can stop at so much of a stopping distance if you apply that payload brake on that robot, the robot should be stiff enough to stop immediately without further overshooting beyond the repeatable limits or whatever the limits are defined in your manual. So, there are some specific standards which are defined as per the standard; there are some special specifications also which even manufacturers are specifying in their manual. Those are proprietary standards that they are always defining, ok. So this is what is a payload.



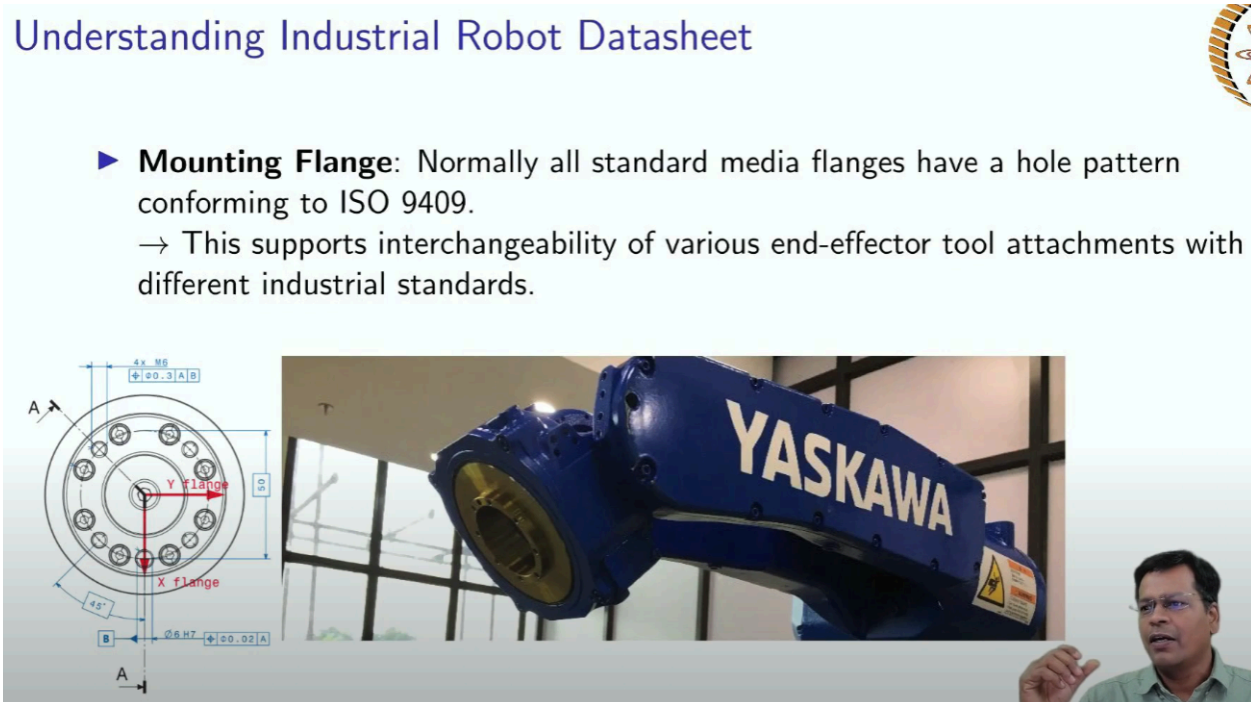
The second very important parameter is this: what you see here is one of the arms has got a load which is carried on it, so this is your base, ok then your first link, your second link and so on. So, you have further links, one of the links can carry a payload which is other than what it was carrying somewhere over here. So, this is the payload; this is the gripper other than the payload; obviously, the payload is apart from this. It is the load which is already there on the robot, so this is an additional load which can be mounted on one of the links; sometimes, for this particular robot when I used this one, this had a solenoid valve, solenoid valve that used to operate on the gripper because this is a pneumatic gripper to operate that through electrical actuation it needs a directional control valve or flow control valve which can make this gripper open and close, so that is mounted within this box. So where this box is to be mounted, this should go not very remotely at some other location, so those are sometimes mounted on top of the robot, and one of the robots is sometimes made to do that, ok. The robot controller is designed so as to take up that much uncertainty in the load in that particular arm, ok. So this is the location of this is defined, even the maximum weight that can go on top of this supplementary load, which is also defined so that location, as well as the maximum weight, is defined. It is an additional load apart from the robot's payload that it can carry in one of the links of the robot. The maximum dimensions and the possible position of the installation can be given in the, can be found in the datasheet.



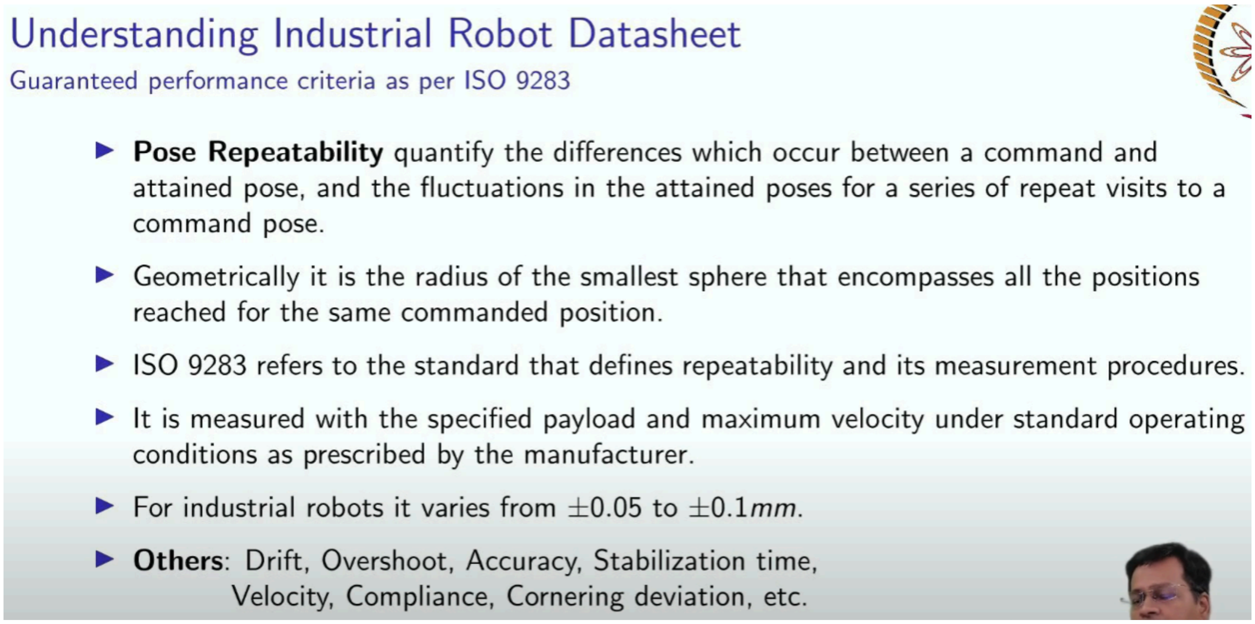
Now, Robot axes; so, what you see here is basically three different kinds of robot, and each one of them has a different number of axes. It is basically the number of degrees of freedom for a typical industrial serial robot. So, we will talk about degrees of freedom very much in detail when we discuss the kinematics of the robot. For now, at least for the serial robot arm, normally number of independent joints it has becomes the number of axes for the robot, and that is the degree of freedom for that particular robot. That is, in general, not always true, but yes, that should be the case normally. As long as you do not have two different axes in the same axis, the same direction, ok same, they should both the axis should not be collinear; let us say unless that is the case that is this is normally true.

So, SCARA is the first of them; let us say this is one robot where A1 is the first axis, A2 is the second axis, and A3 is the third axis, so all 3 are rotation kind, ok these are rotational axes, one of them is prismatic axis so A4 spindle can go up and down, ok this spindle can go up and down also, got it. So this is a 4-degree-of-freedom robot when you have three rotational axes, and one of them can go up and down, so that is SCARA. We will do forward and inverse kinematics of this also. So, this is the number of axes.

Another one over here that you see is 6 degrees of freedom robot that is an articulated arm robot that is the FANUC R-2000iC/210F robot; it has a 2000 kg payload capacity or more, so that is just a series name, which FANUC names it like this, so, that is a robot which is 6 degrees of freedom articulated arm. Next, one is 7 degrees of freedom KUKA iiwa is a seven-axis robot. The first one is like A1, next like A2, A3, A4, A5, A6 and finally A7; so, A2, A3, A4, A5, A6, A7, so seven different axes are there, and it can go in a straight line vertically upward so all the axis can be coaxial, it can become it is designed like that, so this is the number of axes that is to be defined by the manufacturer in their manual also. So yes, that is the number of axes.

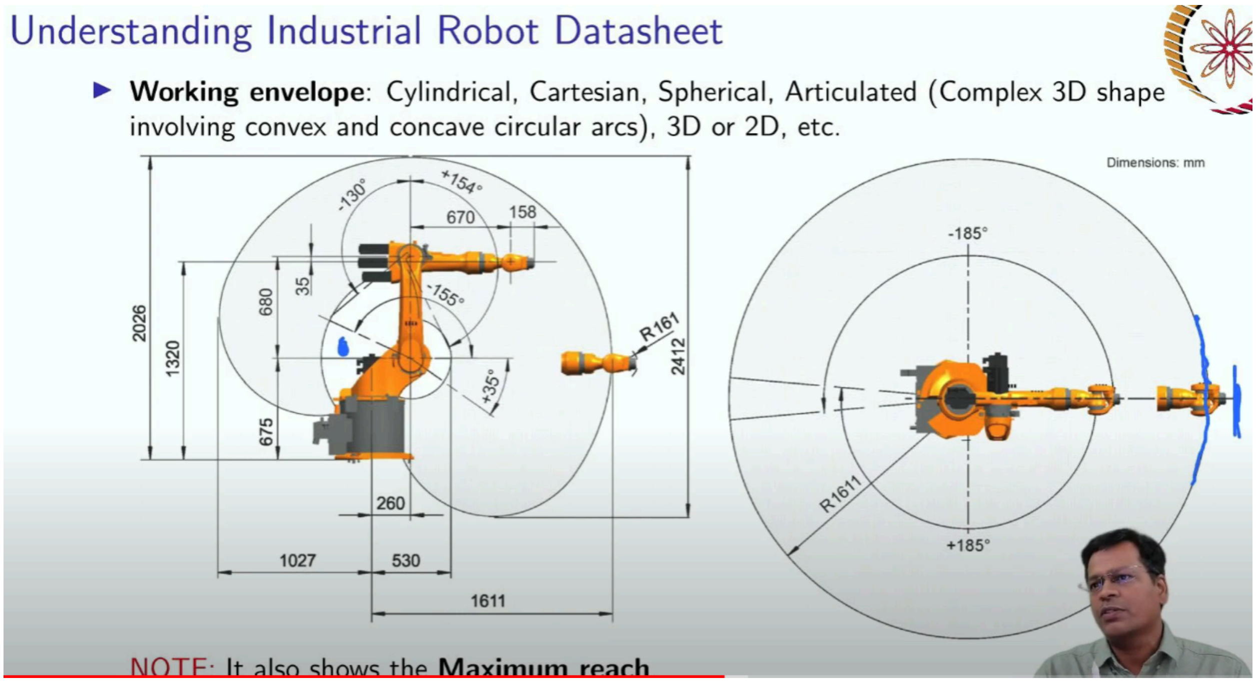


Now, this is ISO 9409 that I was talking about earlier. So, it is normally a standard media flange. Media Flange means where you have to attach that is the end effector flange of the robot is this one, ok this one where my gripper has to be fitted, ok I showed you fitting a gripper when I was demonstrating industrial serial robot in my lab in your first anatomy class, ok so I made a two-fingered gripper fitting on top of this, ok so this is the flange where you see it has different holes, different holes over here, ok so on which you can screw your gripper, ok. This is the standard which is defined by ISO 9409, so why is this so important? Because this particular supports the interchangeability of various end effector tools. Let us say today you have a two-fingered gripper, and tomorrow you may have a spot welding gun that can be fitted on top of it, so each one of them, although they have a different shape after the flange, the flange should be such that it should fit on top of this particular flange, ok. So interchangeability is possible, ok so they have to follow all these standards, especially ISO 9409, while defining that they cannot have a proprietary standard for the flange so that only Yaskawa can design a two-fingered gripper which will go on top of it so that you can pick up a Jimmer, you can fit up ATI SCHUNK tool changer, you can fit even Janatics or any other make two-fingered gripper on top of this. So you got my point what I am trying to say.



Yes, so then a very important parameter that defines the performance characteristics of industrial robots is ISO 9283, which also defines a parameter which is known as pose repeatability. It quantifies the differences which occur between the command position and the attained position and the fluctuations in the attained poses for a series of repeat visits to the command pose. What does it mean, basically? Geometrically, let us say you want your robot to go to a specific place. Ok, you have commanded it to go there; ok, now Robot, whenever you command it to go there, it goes here, it goes here, it goes here, so every attempt it goes somewhere near to this particular point, ok. Now, what happens is this ISO standard basically defines the radius of the smallest sphere that encompasses all the positions reached for the same commanded position, right as long I have commanded it to go to, let us say, this red one. Still, it is going to the blue one, blue one, blue one, and this is the final circle; oh, sorry, if it is in a three dimension, it has to be a sphere. Hence, this is the sphere that contains all the points, deviated points. I have commanded it to go to the red one; it goes to all the blue ok sometimes; obviously, it will go to the red one also, so the smallest sphere that can enclose all of them. Hence, it is the radius of that. Ok, there are techniques to measure it also. There are different techniques to measure this also, so that is Pose Repeatability, ok. So now ISO 9283 not only defines repeatability it also defines the measurement procedure how to measure repeatability. Ok, there is a huge set of procedures: what should be the environmental condition, what should be the maximum vibration all around, what should be the environment temperature, and what should be the payload this robot should be carrying while what should be the probe dimension, right, so each and every stuff is given in ISO 9283 when it says your robot is defined for so much so repeatability, ok so it is measured with a specified payload, right; definitely the payload is always there on top of the robot when ISO standard that repeatability is getting calculated, ok or estimated through a set of experiments maximum velocity under standard operating conditions as prescribed by the manufacturer, ok. So, if a manufacturer says the maximum velocity is 1 meter per second, repeatability should be measured by considering this velocity while doing that experiment, right? So yes, for an industrial robot, it varies somewhere between 0.05 mm, so far, what I have used to plus minus 0.1 mm. So, you can imagine how stiff these robots are? So, how are the controllers? Let us say a robot which is of 1-ton capacity or 2-ton like FANUC type of robot, which is carrying 2 tons of payload, and it is moving with 1 meter per second. So, a huge lot of momentum is there, and when you apply, to breaks your repeatability. At the same time, you command to go for a particular position; it should not overshoot beyond 0.1 mm, so you can imagine how good the controllers are for these kinds of robots. So, that is the reason these robots are hugely expensive, not just the cost to make it but also for all these testing. To make your robot qualified to undergo these kinds of tests to get these certifications done to qualify your robot to pass through tests so that you can fit well and compete well with other robots in the industry, right? That is where the cost is, ok. So this is it, and then other parameters, which are also defined in ISO 9283, is how much the drift is, over let us say I have commanded it to go to a place it has gone there, right? Ok, with certain repeatability. How long can it retain there? With changes in temperature, can it start drifting over some time? Is it stable there or not? How much was the overshoot while it was going there? How much is the accuracy, stabilisation time, what was velocity, and compliance concerning deviation? All this is defined in this ISO standard, and repeatability is one of the major factors when selecting any robot because most of the industrial tasks are highly repeatable. 24x7x365 days, it keeps on doing almost the same stuff, right? So it should not deviate over the period, so yes, that guarantee should be given by the manufacturer.

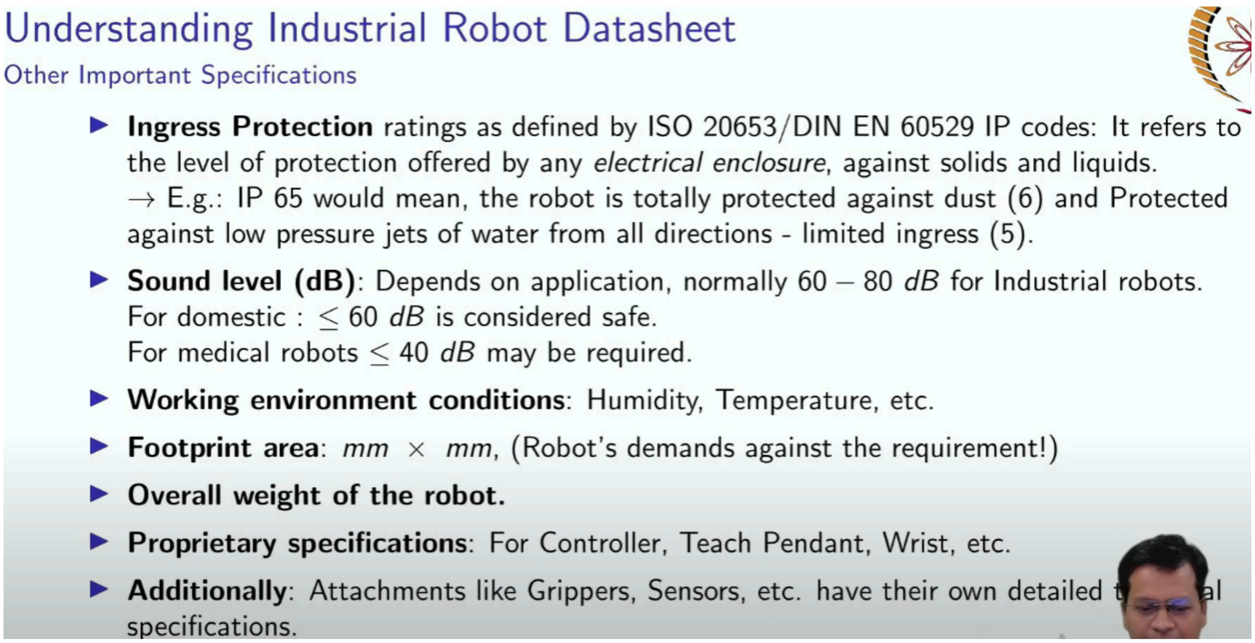
So, yes, one more very important parameter. Nowadays, at least on modern shop floors, you will find robots are not just mounted on the floor. In the video application, you also saw some of the robots mounted on the ground where it was picking huge objects and assembling the car body; one of them was hanging upside down, and it was picking the top portion of the car and putting it from the top. It can be fitted on the side walls on a rail, it can be inclined, and it can be fitted. So, the mounting position is also defined in the robot specification sheet or technical datasheet, which I say. Ok, so that is also a very, very important parameter.



And now, this is the working envelope. Ok, for the articulated arm, it looks like this. It is all the poses and all the locations where your robot can go in all possible orientations. If you can go to any XYZ, you can orient any way you want. So, it is the reason you see your tip; however can go till here, but the envelope is only till here; why? Because if you go here, you cannot orient anyhow you feel like, got it? So that is a very, very important parameter. All the locations are not included; when you say your robot can go till here, you always go till here because that becomes the working envelope of the robot, so why? Because if you can go here, yes, you can go there. That is something you can touch, but you cannot maybe hold that particular thing.

Ok, any object which is kept here, you cannot orient it in a way where you can hold it actually so that it does not form the workspace of your robot. So, this is the envelope, and that is where some excluded spaces are also the inner boundary, so this space your robot cannot go, so the workspace, which is the working envelope for your robot if it is an articulated arm robot, is something like this which is very complicated in three-dimensional space. Ok? It has an outer boundary, it has an inner boundary, and sometimes. Within space also, the robot can go singularly. So, you may not be able to program your robot for that particular region, but there are different ways you can bypass them. So, mostly your robot will include the inner boundary and the outer boundary, the whole of the boundary your robot can go. So yes, you have something, which is a cylindrical workspace for a cylindrical robot, a cartesian workspace for a gantry type of robot, spherical workspace is there for a spherical robot.

Articulated arm robots are very, very complex like this one. I have multiple convex surfaces which are there. And then you have convex surfaces like this, and then, it also shows the maximum reach where your robot can go. Again, you see, it is for maximum reach; definitely, it is the flange which is at the maximum distance that is also given, but that is not the working envelope, or the working envelope is not there that is the maximum reach where your tip can go. Sometimes, that is extended beyond by adding a gripper. You sometimes are able to reach a place which is far more than your maximum reach. So that is a working envelope.



Other important parameters are also there in the datasheet. One of the very important parameters is Ingress Protection. You are always bound by the type of application you are in. You want your robot to put it; let us say you want to do a painting job, you want to do some spray painting job. So, there is some Ingress Protection your robot should be on because your robot is mostly an industrial robot, in particular, made up of all electrical actuators; even sensors are electrical. So, IP basically defines the type of electrical enclosure, it refers to the level of protection which is offered by any enclosure which is there. If it is a motor, that enclosure is actually of this IP class - Ingress Protection class and that is defined by a standard which is known as ISO 20653, or DIN standard ingress is 6052: these are IP codes. It refers to two specific digits. The first digit is for solids, different shape sizes of the solid, and the second digit is for liquids. Let us say for example, if you say my robot is of IP 65 class, it would mean the robot is totally protected against dust. Dust comes under the sixth number. I will show you that particular table; it is this one.

You see, dust comes in the sixth one. The earlier one is you cannot insert your hand; you cannot insert a finger, you cannot insert any pointed object. Ultimately, it is the dust. Dust is the last one, which is sixth class and protected against low-pressure jets of water from all directions; that is the second letter of the IP class. What is 5? 5 is for a jet of water from all directions.

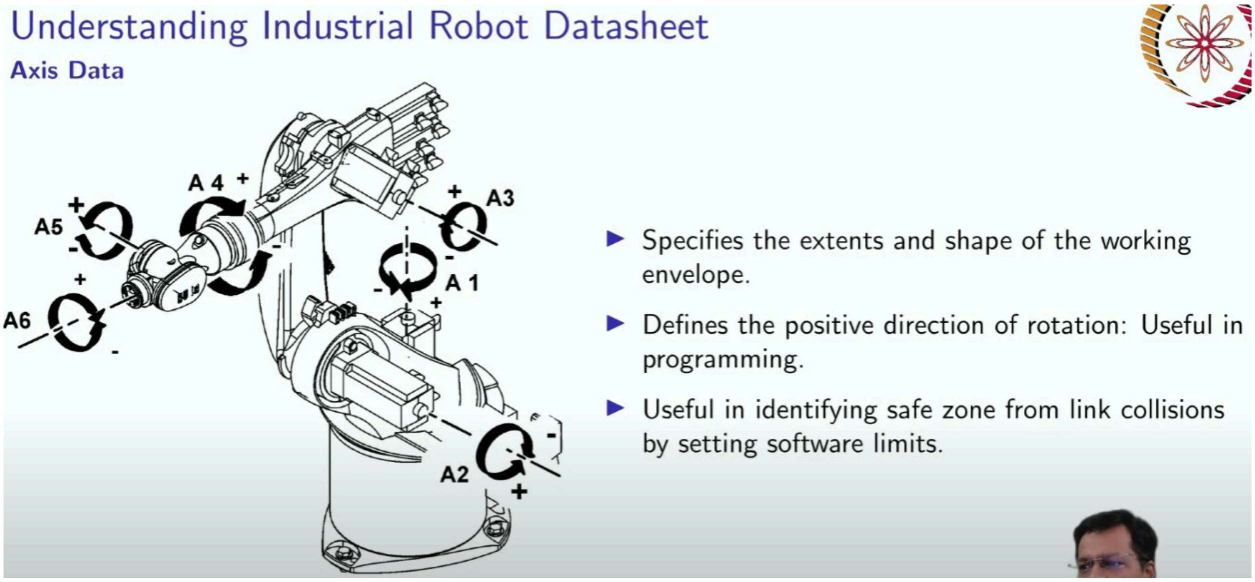
If it is more than 66, i.e. IP66, it can withstand some sort of immersion. This equipment can be immersed within the water, and further it can be immersed to a significant depth within the water. It can be a spray of water, which is in a higher-up category. So, these two letters actually define the IP code, that is, the Ingress Protection code. It is actually very much required for selecting your robot for various applications. Your environment may be very dirty. Let us say you want your application and your robot to get into the mine, definitely, it should be protected from the dust. If it is to be in an outside environment, it should handle at least low pressure jet of water from all directions because it may have to bear rainfall at times.

And then sound level. Different robots work with different sounds. Maximum sound it can generate depending on the application. Normally, for industrial robots, it lies somewhere between 60 to 80 decibels for industrial robot. It is very, very good. If you say, sometimes it is in the range of 60 to 80 decibels, but for special applications like medical and all that requires your robot to be below 40 decibels. So, there are special classes of robots that are defined by the manufacturer and are tested to give you less noise and those are suitable for that particular application, like medical and all. For domestic applications, it should be below 60 decibels. It is considered safe for humans, for if you continuously hear that type of sound for a longer amount of time, you go mad and for medical robots, less than 40 decibels.

Other parameters are working environment like humidity and temperature. So, what is the range of 0 to 70 degrees or minus 10 to plus 80 degrees Celsius? So, that becomes the range where your robot can operate. If it goes beyond, you cannot be assured that your robot will work the way it is defined by the manufacturer. Let us say I have defined it to work continuously 24x7; maybe with temperature which is existing let us say it is summer, you are going up to very high temperatures of the surroundings, plus the controller can take up even higher temperature. So, your robot may fail to give you the required performance, which is defined in the datasheet. Humidity. Sometimes in the sea weather conditions, humidity can go more than 95 percent. So, in those places, maybe your robot is not suitable to work with. Your controller and all the electronics may fail. So, that environment condition is also stated in the robot specification sheet. The footprint area is very, very important. Normally, millimetre by millimetre is mentioned in the datasheet, so that is the bare minimum space where you can mount your robot. It is the footprint. It is the robot's demands against the requirement. So, if you require a robot, if it is of 1000 kg payload, I am going to be of this much size, and you have to give me at least this much space so that I can fit in ok. So, the overall weight of the robot was the case when I was selecting at least one of my robots, which was to be mounted in a lab which was at the third floor, so I was very cautious about whether or not my ceiling was going to take up that much of load. At least the dynamic load is not mentioned in the robot datasheet. So, at least, the static load of the robot should be well known, and that is also defined in the robot data sheet. This is one of the concerns normally, let's say you are going to mount a robot on a boat that will become the robot itself will become a payload for the boat.

Let's say you are going to mount a parallel robot on top of a serial robot, so the parallel robot weight itself becomes the payload for that kind of serial robot. So weight of the robot - that is the reason it is defined. Although most of the time, they are rooted to the ground and that can take a huge amount of load. But the higher the weight of the robot, normally they have a huge inertia. But if at all they say, "I can go at 2 meters per second", all the performance characteristics are well defined, it fits your limits, and weight does not matter much.

Another parameter is proprietary. There are some proprietary specifications also, at least for the controller. Each and every part that fits on top of this robot also has many parameters, like IP, at least that is mentioned in the datasheet, sound level given, and environmental condition. So, not just the robot should handle all these conditions; even the gripper should be in this much condition. If a robot says, "I am of IP 65 class, but my gripper is not" so what is the point? Definitely ultimately, if you handle those kinds of environments, it is going to fail; at least, your gripper will fail. If your gripper fails or your tool fails, your robot has failed totally. So, each and everything that you are going to mount on this robot should qualify for that. Controller: maybe you can put it quite remotely off the robot location, but at least teach the pendant and rest gripper. These things go directly on top of the robot, and they should also qualify. So that is the reason some proprietary specifications are also given, at least for the controller, teach pendant, and rest, which is there. So, if you are going to mount this robot in an environment, at least you can ensure that your controller and teach pendant are safe, they are kept out of that environment—additionally, attachments like grippers sensor. Just now, I have said the gripper sensors and each have their own detailed technical, just see detailed technical specifications, as in the technical datasheet.



Now, I will be discussing some of the real technical datasheets. So, before that, just see one of the additional parameters which is also there, so that is the axis data. As I said, one of the ISO standards covers the number of axes. They also should specify the extent and shape of the work. If it is a prismatic one, it can travel some linear distance, that is to be given. If it is an axis plus-minus, how many degrees it can turn. The shape of this basically governs the shape of the working envelope that this robot is going to make. So that is the axis data plus and minus direction also is given. So you see, for axis A2 at least, this is the positive-negative direction, this is the positive direction. So, while programming, you should be very, very careful whether I am rotating in a plus or minus direction, clockwise or counterclockwise, for each of the directions, each of the axes, the direction is also mentioned; and how many, let us say, if it is a last tool it can turn for, let us say three turns or four turns, or maybe an infinite number of turns it can do, so that also is given. So, that is very, very important. So, it defines the positive direction, is useful in programming mostly, and is useful in identifying the safe zone from the link collision. So, one can define the software limits on these axes. One of the axes, let us say, if it moves by this much angle, is going to cause some collision somewhere in the working environment. So, you can definitely make sure by putting the software limits in the robot teach pendant or somewhere which manufacturer allows, you would not allow your robot to go beyond that. So that you can be very sure that, yes, even if I go away, my robot is pretty safe. It is not going to collide anyway.

Discussion: Industrial Robot Datasheet, Template Specification sheet

So, I will now discuss some of the robot datasheets, and I will show you one of the template datasheets also.

Annexure I: Technical Specifications

Sl. No.	Specifications	Value
1.	Robot Type	Articulated Arm (Industrial)
2.	Minimum Payload	10 Kgs
3.	No. of Axis (with Brakes)	6
4.	Minimum Reach	1400 mm
5.	Pose Repeatability (ISO: 9283)	±0.08mm or Less
6.	Protection rating	IP 54 or Better
7.	Sound Level under Continuous Running	<70dB
8.	Mounting Position	Floor, Ceiling, Wall
9.	Footprint	700 mm x 700 mm
10.	Ambient Operating Temperature	5 - 45°C
11.	Humidity	Non-condensing upto 95%
12.	Weight (excluding controller)	<300 Kgs
13.	Controller	Separate

I prepared while tendering for my own robot, which I wanted to buy. I just cannot say, I want to buy Yashkava or Kuka or FANUC or any make robot, so what I can specify maximum is the specification that I want, and I can mention the ISO standard which it should qualify to do that. If it claims, "I am so much so repeatable as per ISO 9283", that qualification should be tested. And if required, they should be able to provide me with all the test certificates. So, that performance should be guaranteed based on that. So you see what all the parameters that I have just taught you. So the payload, I wanted my robot to be well almost up to 10 kg payload because I wanted my robot to be used for doing some sort of welding operation. I know the welding electrode and the attachment, and all can be fitted if it is beyond 10 kg or something. So anything beyond 10 kg should be quite good enough. I want my students to feel an actual robot, so I want it to be really tall enough to look like an industrial robot at least, so I choose it to be something around 1400mm, 6 degrees of freedom, because I want my robot to position and orient fully so that I can teach full forward and inverse kinematics. So that was the reason for me. Maybe there is some other reason for a different user of it. If it is a painting application mostly you need 6 degrees of freedom robot. But not for a pick-and-place task where a SCARA can go very well.

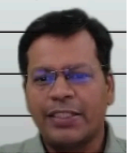
So, if I want a pick-and-place task where a SCARA can go very well, pose repeatability of 0.08 mm or less is quite good enough. Sometimes, it is more the better, like for payload, not always true, but yes, at least for payload, more is better; at least for repeatability, less is better.

But obviously, they will have a toll on the cost also. The protection rating should be IP54. But for the end-effectors, sometimes, a few robot manufacturers give you a good protection rating - IP54 for the motors and the rest of the body of the robot. But when it says it is the wrist, it is IP65 that is of higher class because it is the wrist that gets into the very much into the system. It handles the task; it should be more rugged as compared to the rest of the robot as compared to different parts of the robot, and your wrist should be stronger.

They should be sustaining more dust and more water and those things. Sound levels should be, at least for industrial robots because I was selecting, I chose it to be well below 70 decibels, and even my compressor, which was driving the pneumatic actuator, was almost around 70 decibels. So, 70 decibels is quite good enough. I can shout in my class at my students even with this much noise continuously on, so that day, while demonstrating the robot, in that recording also, you can hear the noise which was running in the background and intentionally then switched off that noise over there. So this robot, I wanted it to be fitted at least to the floor, to the ceiling, to the wall, this much capable robot, there are special features, so I wanted although I was sure I am going to mount it at least on the floor only, I am not going to mount it on the ceiling but someday who knows I can mount it on the ceiling also.

So, when I buy, it is not everyday stuff. I bought it for a footprint of 700 by 700 mm, so that was the space which I was left with. So yes, all these parameters. I know in summer, in my location, it goes up to 45 degrees so at least this much it should sustain. If it is somewhere extremely in the equatorial region, it can go beyond 50 degrees. You can specify that. Humidity is non-condensing at 95 degrees. Non-condensing 95 degrees is something very different. Normally, if it is 95 per cent humidity, it is quite ok; a robot can withstand it, but with 95 per cent humidity, if at all, it starts condensing, which may be due to the surrounding temperature or maybe the controller temperature, which is there inside it starts precipitating then what happens 95 per cent sounds very high for that. So, in that case, to withstand that, I said ok non condensing 95 per cent—total weight. Again, I am placing this robot on the second floor this time, and it was placed on a cantilever, which was, sorry it was placed on a beam which was below the ceiling. I could find out, so I wanted not to go beyond 300 kg; that is the safe limit which I could see. Although it can withstand, you are not very sure it is lower the safer, so 300 is quite safe for most of the roofs that you see. Separate controller: I don't want the controller and the robot to be mounted in the same place so that I can keep my controller, which normally has some electronic components, a little far off from my robot. So, that is the reason I want it to be separate. So, every user has their requirements. Sometimes, these are not necessary requirements, and it is not always defined in ISO standards as well, so yes, it can be on the robot, but it can be separate also.

14.	End-effector Speed	1 m/s Normal mode 2 m/s Automatic/External Mode
15.	Range: Axis 1	300°
	Range: Axis 2	250°
	Range: Axis 3	200°
	Range: Axis 4	360°
	Range: Axis 5	200°
	Range: Axis 6	360°
16.	Axis Calibration/ Mastering Facility	Automatic or through Supported Tool
17.	USB Drive for Backup	Yes
18.	Operating System	Windows/Linux/Proprietary
19.	Controller Cabinet	Open Architecture
20.	Event Logging facility	Yes
21.	Drives	AC Servo for 6 Axes
22.	Integrated Troubleshooting	Supported



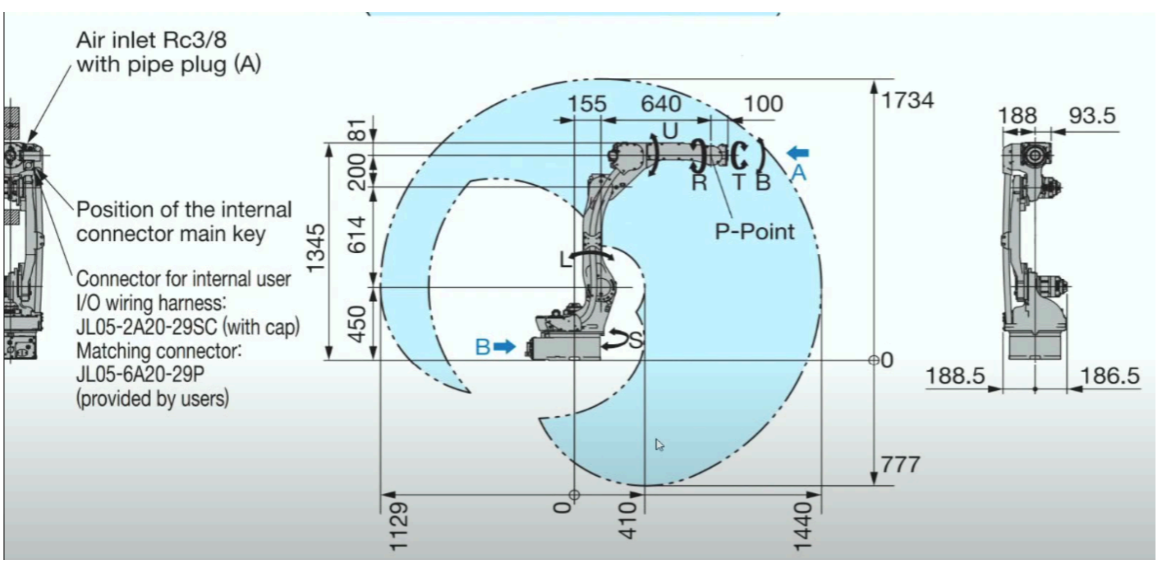
The end-effector normally should be this speed—range of the axis I have mentioned- Automatic. Operating System can be any Windows/Linux/proprietary or anything. Open Architecture is one of the very special things that I have put. My architecture should be open so that I can fit any IO cards, any input and output card, not necessarily if it is a Yashkava robot. I should be able to put only the Yashkava thing. So, the controller is of open architecture, I can put any [unintelligible], Ethercat or any sort of communication to interface with any IO system. Although it already had 16 inputs and outputs built into the system, even if you sometimes want to have some sensor which is outside the controller, you should definitely have that. Additional keyboard, mouse, display, sometimes for us at least, we are not always happy with the teach pendant.

I at least prefer having a keyboard at least so that I can conveniently key in my robot programming. Sometimes, the Mouse - easy to handle the GUI which I can see. Sometimes, an external display is very, very helpful. Industrial robots should support all these. It is not always true; industry people don't think like that. They are happy with just the keyboard, just the teach pendant, because they are used to it. It is very, very ok with this and not always. Even the teach pendant, once it is programmed, you forget about it. You need not change now and then. You should be happy with it, and they have dedicated operators who can handle things with just the teach pendant. Built-in servo drives, extension possible, three-phase neutral and earthing connection. That is important sometimes, if it is two phases 220 volt, single phase 220 volt, it is quite good enough.

25.	Software PLC	Extension possible
26.	Power Supply	3 Phase + N + E, OR 2 Phase 220V
27.	Warranty	12 Months
28.	Documentation	For Training/ Parts/ Maintenance
	Teach Pendant	
1.	Hot Pluggable	Preferable
2.	Jogging	3D/6D Joystick, Buttons
3.	Touch Display	Color
4.	Axis / IO Controls	6 Robot + 2 External + 1 Gripper
5.	Dimensions	Ergonomic
6.	Weight	<2.0 Kgs
7.	Integrated Connectivity	1 USB
8.	Additional	Emergency Stop
	Gripper	**SCHUNK, Zimmer, Festo or Equ**
1.	Description	2 Fingered - Pneumatic

Warranty: these are some special things that you can ask for. Joystick - it can or should have a joystick or some sort of buttons to make your robot go to XYZ location, orientation, and all. Weight should be, if it is a teach pendant, it should be below 2 kgs, so that you can hold it firmly in your hand. One USB connection should be there so that I can put it in my pen drive, and external offline programs I can put it in. Gripper - some standard grippers I have named here, SCHUNK, Zimmer, Festo, whatever is a two-fingered gripper that can hold 2 kgs of payload, it should be good enough. Maximum Force and Gripping Force are mentioned, Workpiece, additional there are.

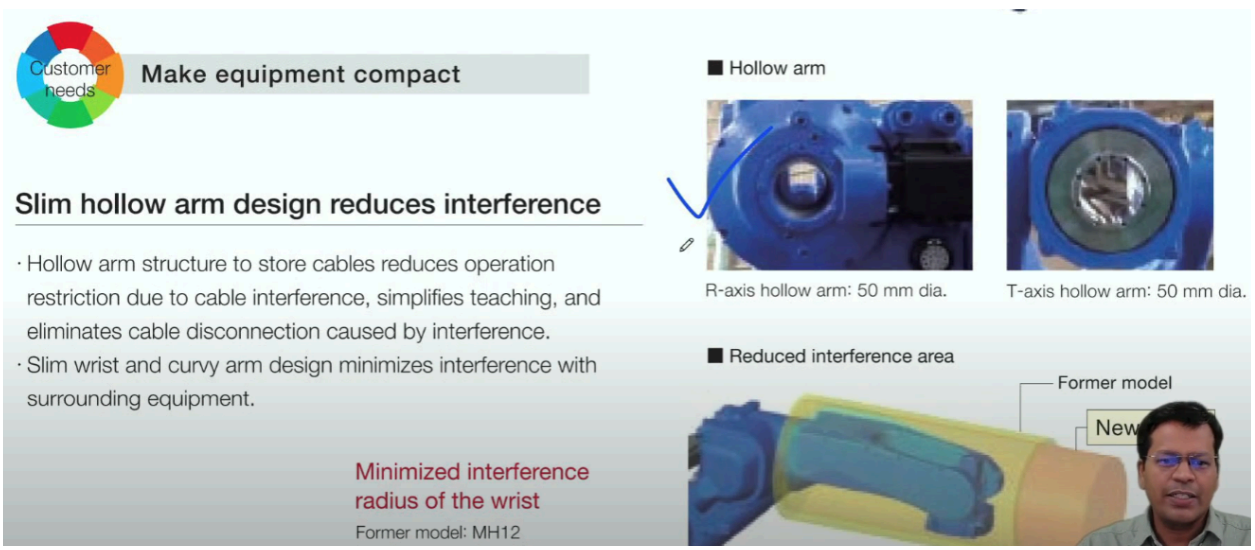
Then, there are many other things, and this is the PC which I wanted to interface so that is why it is here. So yes, this is one of the real datasheets. You can see this is for Yaskawa GP12, my robot only.



So, this is the workspace which is given in the datasheet. You see, it is the working envelope, this is the working envelope. So, this robot, this place, these are the places where it cannot go, and these are the places where it can go. You see, it is a complex shape all over, ok? It is a complex shape for the different views it is given.

So these are some of the parameters which I have just discussed. Controller, axis, you see it is here. Payload is given, the maximum load it can carry, repeatability is given, and plus-minus axis angles are given. What are the angles for each of the joints it can go to? The maximum speed of the joint is given here; allowable moments are here, and allowable moment of inertia which it can take up. The total weight of the robot is given. Weight, no, it says mass, ok, and IP67 for the wrist, you see, and IP54 for the rest of the body. It can operate from 0 to 45 degrees. The relative humidity is something around 80%. Non-condensing can take, and vibration cannot take more than this, and then these are not necessary parameters which are there but may be very very useful for some specific requirements.

It requires at least this much power electrical payload rating is given, so if you plug into the plug point, it definitely should carry. It should be capable of carrying at least this much of a load, and it can be mounted on the floor, wall, and ceiling. And it can even be tilted, ok, so these are some of the parameters.



Once you see it specifying it is a hollow arm, it is a proprietary specification which is also given. Over here (blue tick mark), it has a hollow arm, which may be required for the arc-welding robots because you have to pass through many cables from between. And if it is so, if it is hollow, the cable does not interfere.

It simplifies teaching, and not teaching my students while teaching the robot because you program a robot. While programming, you teach, and it repeats the task. So that is what is teaching. Eliminates cable disconnection if it gets entangled with some object in the surroundings; the club wire may be plugged out. In that case, it should not interfere with the working of the robot, so yes, this is one of the very important specifications.

Basic data

	KR 20-3
Number of axes	6
Number of controlled axes	6
Volume of working envelope	14.5 m³
Pose repeatability (ISO 9283)	± 0.05 mm
Weight	approx. 254 kg
Rated payload	20 kg
Maximum reach	1611 mm
Protection rating	IP65
Protection rating, in-line wrist	IP65
Sound level	< 75 dB (A)
Mounting position	Floor
Footprint	575 mm x 535 mm
Permissible angle of inclination	≤ 5 °
Default color	Moving parts: KUKA orange 2567; Base frame cover: black (RAL 9005)
Controller	KR C4
Transformation name	KR C4: KR20 3 C4 FLR ZH16 2

And then, let us say this is a KUKA robot, and I will come directly, and there are many other parameters which are given here and today's lecture I will just cover the technical things, technical data which is there.

So, this is the number of axes. Working envelope - it shows it is a meter cube; it is a volume. Repeatability: again, it says, as per this certificate, it is ISO 9283. It is 0.05 mm; its weight, so all similar parameters you see are here.

Axis, ranges, their angular velocity, this is the axis data, plus-minus, and the direction. And you see the working envelope it can go, where it can go, and the payload for a different class altogether. So this is also there, so this is for another robot which is a FANUC robot. You see, this again, and it is a similar one this time, it also shows quite a lot of details, which are not always required for anyone. But the details which are required are always there, as is specified by the ISO standard.

You see, it is a tabulated map. It is the coupling flange which I was talking about. So, it is the flange dimension, that is, the media flange, where you can fit in your gripper or any other tool to work with. Okay, so this is the flange dimension which is given. It is as per the ISO standard. It is the repeatability, and all the dimensions which I just discussed. So, you see, this is all about industrial robots and their technical specifications, which are here. So now, with this, I think I will end today's lecture. So, thanks a lot for being with me and in the next class, I will be discussing the classification of industrial robots. Why is that important, How different technical parameters are used to qualify a robot for a given class? We will discuss everything in that class. Thanks a lot! Thanks a lot for being with me. That's all.