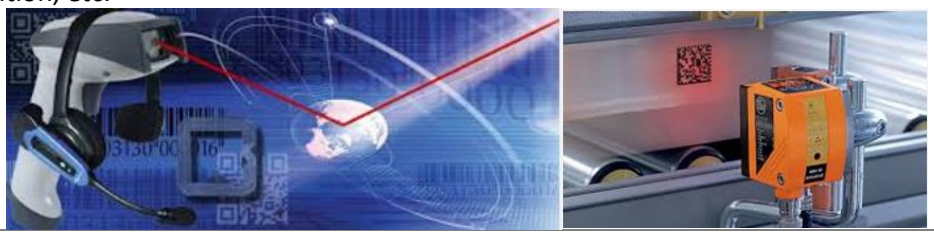
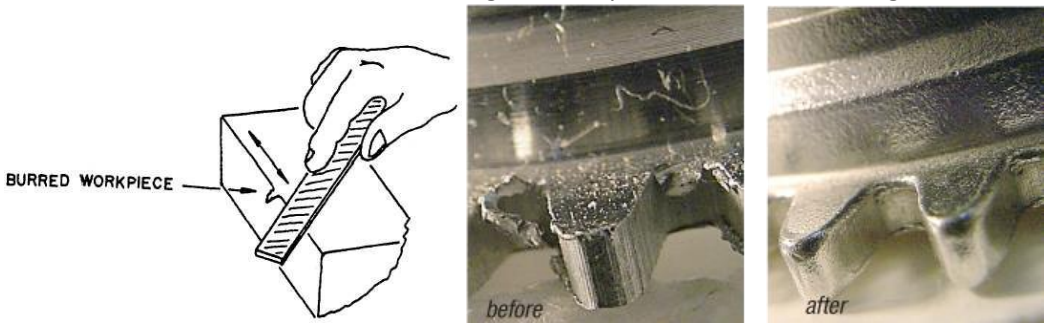
Glossary

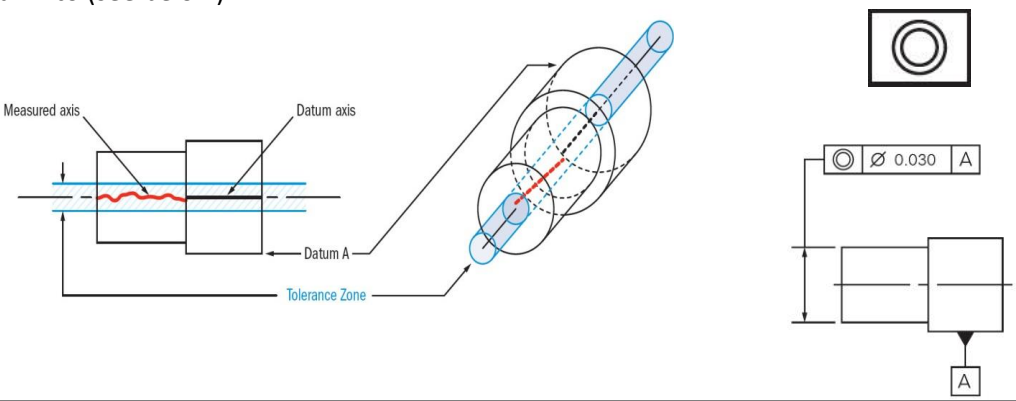
Autobinding functionality	Components of a system (e.g. control components, PLC, sensor system, software, etc.) that provide autobinding functionality can connect automatically to the main control system. Without this functionality an operator must include and set up those components manually.
Autodiscovery functionality	Automatic identification of components that provides information like component name, functionality, interfaces. No manual identification and data provision is necessary.
Automated Data Capture (ADC)	Data input without key-punching or typing. Data is captured automatically usually through the use of equipment such as barcode readers or magnetic-stripe readers, or technologies such as optical character recognition (OCR), radio frequency identification (RFID), speech recognition, etc. 
Automated Identification (AutoID)	Auto ID is a process of automatic data identification via automatic data capture (ADC) technologies. These technologies are used for the automatic detection and identification of data objects. Captured information is entered into a computer system without direct human involvement. Auto ID is usually applied to scenarios involving logistics and warehouse inventory, where the processing of many objects requires fast tracking beyond human capability and capacity.

Balancing	Unbalance exists in a rotor (rotating part) when the mass centre axis is different to its running centre axis. The running centre axis is in fact imposed by the bearings while the part mass centre axis depends on the part shape and weight distribution. Typically any machine rotor is unbalanced due to machining errors. An unbalanced rotor, when rotating, wants to revolve around its mass centre axis. Because the bearings restrict this movement, the centrifugal force, due to the unbalance, causes the rotor to vibrate. These vibrations cause wear to the bearings. It creates unnecessary noise, and, in extreme cases disintegration of the rotor itself can be experienced. It is therefore necessary to reduce the unbalance to an acceptable limit through balancing procedures. Balancing consists in (i) measuring the unbalance and (ii) correcting it. The measurement is done in dedicated machines which record the accelerations on the bearings, while the correction is done by adding some material (car tyre weights) or removing some material (drilling or milling - jet engine shafts)
Big data	Big data refers to an amount of data that is too big (volume), too complex (complexity), available in real-time (velocity) or too unstructured in order to be handled by manual or conventional data processing tools and algorithms. It is often used in the context of industry 4.0 and cloud computing, as these concepts allow the quick acquisition of a huge amount of data in real-time from different data sources like software tools, machine controls or sensor systems. Big data always requires special treatment and pre-processing so that the relevant information is extracted. The extracted knowledge can then be used for optimization, monitoring or control tasks.
Bottle boring	In machining, boring is the process of enlarging a hole that has already been drilled (or cast), by means of a single-point cutting tool (or of a boring head containing several such tools). Boring can be viewed as the internal-diameter counterpart to turning, which cuts

	external diameters. Bottle boring is the machining process for obtaining non cylindrical internal features (with a bottle like shape).  The tool design allows for the expansion or retraction of the cutter when actuated from rear end; this can be used to produce the required internal profile in the work piece. Bottle boring tools are developed for specific internal profiles of components. The initial internal profile is larger than the tool entry and exit diameter; the operation requires the use of CNC controls to program the various coordinates for the required profile.
Burr	A burr is a raised edge or small piece of material remaining attached to a workpiece after a machining operation (grinding, drilling, milling, turning, etc). It is usually an unwanted piece of material and is removed with a deburring tool in a process called deburring.  Example and effects of deburring

Causal Loop Diagram (CLD)	The complex dynamics of the interactions among quality, production logistics and maintenance requires considerable effort to be modelled and understood. This activity is important to identify and explain the many existing trade-offs. The literature includes models developed to capture and explain the dynamics of this interaction. Among these, a very powerful set of tools is business and system dynamics Causal Loop Diagrams (CLD). These tools have been proposed for modelling complex interactions between quantitative and qualitative variables in a number of complex business management problems. The main goal of these models is to identify all possible interactions among variables and decisions in order to support the definition and implementation of continuous improvement programs that do not fail to meet the goals due to unexpected interactions. Understanding the relevant interactions then makes it possible to avoid local improvements that deteriorate the global performance due to neglected impacts. CLD charts are diagrams in which the relevant variables of a problem are listed and connected by directed arrows. In this format, A pointing at B with a positive arrow means that, given that everything else is fixed, an increase of variable A causes B to increase more than it would normally. A pointing at B with a negative arrow means that, given that everything else is fixed, an increase of variable A causes B to decrease more than it would normally. Only direct and easily explicable cause-effect connections have to be reported. CLD are very powerful tools for finding existing control loops in complex, multidisciplinary and dynamic contexts and in making them explicit. Although they have been widely used for consulting activities and for policy making, state-of-the-art CLD models do not focus on the production system design and operational levels

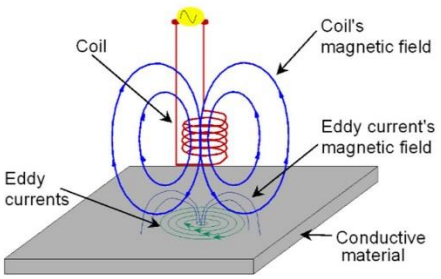
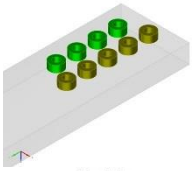
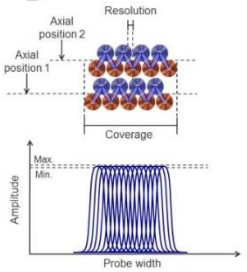
	but rather try to see the problem more generally from a managerial point of view.
CCD scanner	Charged-couple Device (CCD) scanners are similar to digital cameras, consisting of tightly packed rows of light receptors that can detect variations in light intensity and frequency. These devices have very fast scan rates but limited read ranges (less than 3 inches) compared to a laser or image scanners. CCD scanners are also lower cost than other scanner types making them a great choice for point-of-sale and lower volume scanning applications where distance reading is not a concern. 
Control	Control is a generic term that can have different meanings: • Open loop control: a system or machine is provided with set-points without receiving feedback; it cannot react to unknown disturbances. • Closed loop control: based on sensor feedback a system or machine is provided with corresponding set-points. The controller can react to unknown disturbances and correct them. Examples of controllers are: PID, MPC, fuzzy control, robust control, h infinity control, etc. • Machine control: this is a software or hardware component that manipulates the behaviour of a system or machine (PLC, CNC)
Distributed control	Distributed control means that a system (machine, production system, etc.) has several local control units instead of one central control system. This concept is similar to agent based systems in information technologies. Distributed control systems require communication between the local controllers and rules for cooperation.
Logistics control	Logistics control or logistics management is part of the supply chain management. It plans, implements, and controls the efficient, effective forward, and reverse flow and storage of goods, services, and related information between the point of origin (supplier) and the point of consumption (customer) in order to meet customer's requirements.
Multivariate Statistical Process Control (MSPC)	Multivariate data analysis is an advanced statistical approach, which identifies all of the critical variables and underlying patterns in a data set. It also shows the relationships between variables and how they impact on each other. Multivariate Statistical Process Control (MSPC) applies these methods to process and manufacturing data. MSPC simplifies the job of process operators by showing all process variables, including relationships which cannot be detected with univariate statistics, on just one or two control charts.
Production control	Production control is the activity of monitoring and controlling any particular production or operation. It operates on a higher level than process control, which is focused on one specific process of the production system.
Quality control	Quality control is the overall concept for monitoring and adjusting quality of products or services. More specific quality control strategies are: Six Sigma (6σ), Statistical quality control (SQC), Statistical process control (SPC), etc.
Statistical Process Control (SPC)	SPC is a quality control method using statistical methods. The results of SPC are displayed in control charts. SPC is one specific six-sigma tool, which is applied to reduce or eliminate process waste in a production system. However, it does not correct deviations that already occurred.
Statistical Quality Control (SQC)	Synonym for SPC (see above)
Communication level	
Device-to-device	This term is often used in the context of communication architectures. Device-to-device communication means that two or more device (e.g. control systems) communicate via a

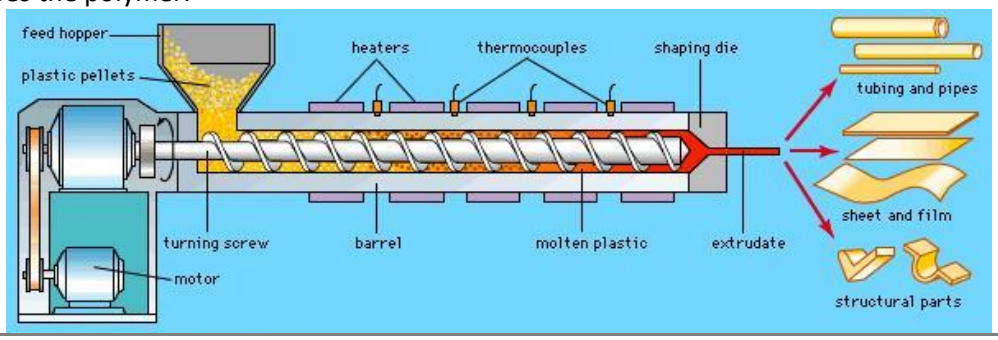
	specific communication protocol.
IT	Information technology (IT) is the application of computers and internet to store, retrieve, transmit, and manipulate data or information in the context of a business or other enterprise.
Field level	In the typical automation pyramid following layers are present from high to low level: enterprise, plant, process and field. The field level contains process signals and other inputs and outputs linked by a field bus (network at field level).
Concentricity error	Concentricity, sometimes called coaxially, is a tolerance that controls the central axis of the referenced feature, to a datum axis. The axes for the datum and referenced feature are derived from the median points of the part or feature. Concentricity is a very complex feature because it relies on measurements from a derived axis. Concentricity associated tolerance zone is a 3-Dimensional cylindrical zone that is defined by a datum axis where all the derived median points of a referenced circular feature must fall into (see below). 
Coordinate Measurement Machine (CMM)	A coordinate measuring machine (CMM) is a device for measuring the physical geometrical characteristics of an object. This machine may be manually controlled by an operator or it may be computer controlled. Measurements are defined by a probe attached to the third moving axis of this machine. Probes are mainly mechanical (contact measurement) but can also be optical, laser, or white light, among others. A machine which takes readings in six degrees of freedom and displays these readings in mathematical form is known as a CMM. Coordinate-measuring machines include three main components: • The main structure which includes three axes of motion. • Probing system • Data collection and reduction system - typically includes a machine controller, desktop computer and application software. 
Correction	To be intended as “defect correction”. Action implemented with the goal of restoring a defective product into a conforming state.
Correlation	Modern multi-stage manufacturing processes typically involve processing and assembly stages whose output quality is significantly affected by the output quality of preceding stages in the system. In multi-stage manufacturing processes, understanding how a defect generated in a specific process stage propagates to the next process stages and what effect

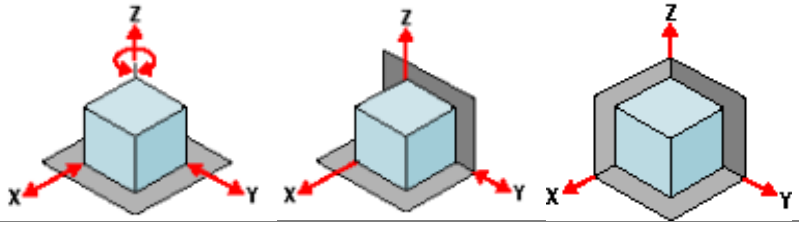
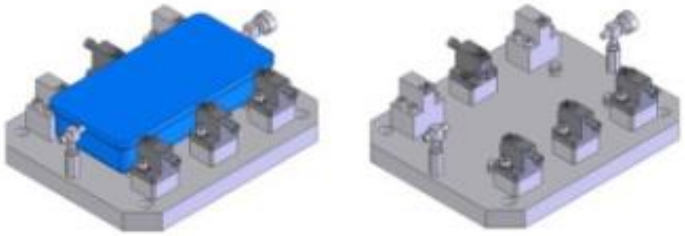
	this propagation has on the final product quality is a complex task.
Quality correlation	the quality of the product processed at a given stage is highly dependent on the quality of the output at specific upstream processes.
Failure correlation	the propagation of a defect generated in upstream processes causes machine or tool integrity problems in downstream processes, such as increased degradation and tool wear, or sudden tool breakage, or process instability.
Cyber-physical system (CPS)	Cyber-physical systems (CPS) are defined as systems integrating both computation and physical actuation capabilities. In CPSs, embedded computers and networks monitor and control physical processes, usually with feedback loops, where physical processes affect computations and vice versa. The main goal of CPSs in manufacturing is to couple the world of production and network connectivity into an "Internet of Things" to realize "Smart production" as the new approach where intelligent ICT-based machines, systems and networks are capable of independently exchanging and responding to information to manage industrial production processes.

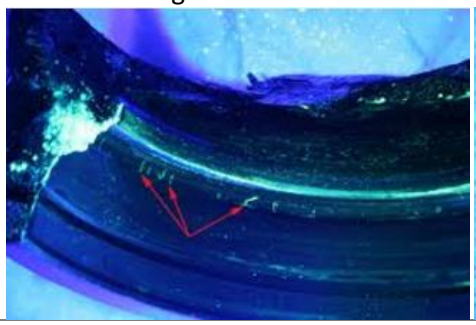
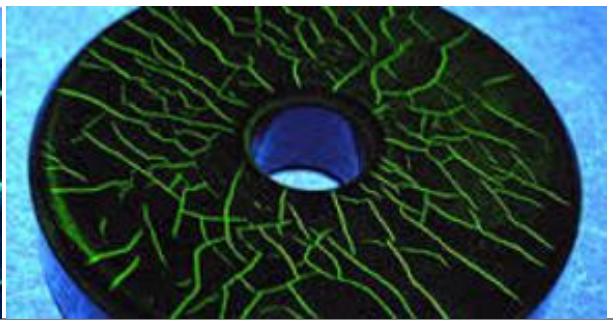
Data analysis	Data analysis is the methodology aiming to extract useful information and to infer new relevant knowledge from empirical data sets. The information delivered is often intended to support processes of decision-making or concluding remarks of a study. Data analysis is basically descriptive and relies on statistical techniques and mathematical algorithms. When data analysis involves data-based modeling for predictive purposes is often referred as machine learning. Data analysis covers the steps of data collection (e.g. through sensors), data pre-processing and data mining (e.g. arrange data, eliminate duplicated data, calculate derived values, finding correlations, handle missing values and outliers, data visualization by charts) and data modeling (e.g. calculation of descriptive statistics, learn prediction models for classification and regression, pattern recognition). Data analysis can be also referred as data, visual or predictive analytics, data science or data engineering and it usually embraces data mining, machine learning, statistics and artificial intelligence fields.
Defect	A defect is caused by a non-conforming feature (or Key Product Characteristics, KPC) that prevents the product to meet its final functional requirements. Non-conformity is due to an out-of-specification or out of tolerance dimensional, geometric or functional feature. Multiple defects can be simultaneously present on a specific manufactured item.
propagation avoidance policy	Propagation avoidance policies are proactive defect corrections/mitigation actions that are taken on semi-processed parts which are identified as potentially defective. According to the type of propagation avoidance policy, a part is traced and treated differently in the downstream stages* in order to compensate and correct the deviation from specified tolerances. These actions require the availability of a knowledge based prognosis models that are capable of calculating the ranges of downstream process parameters that can be suitable to repair the specific defect type and entity. If successfully implemented these actions will minimally interfere with the main line cycle time and do not significantly add efforts on production resources. (*downstream stages = following processes)
variation pattern	A variation pattern is a model that explains the propagation of variability in one or more key product characteristics (i.e. the diameter of a tube or a shaft) along multiple process stages. Variation patterns can be obtained by statistical or engineering methods. Of the engineering methods, SOVA (Stream of Variations Analysis) has been proposed for assembly systems and machining process-chains. This approach is based on a state-space representation of the correlation between the product deviations at consecutive process stages whose structure is driven by engineering knowledge about the processes and whose coefficients are tuned by KPC (Key Product Characteristics) measurements at the different stages. In contrast, advanced MSPC methods are based on elaborating KPCs measurements

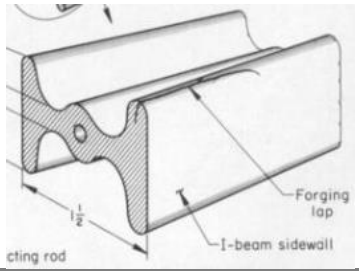
	to find the parameters of simplified multiple process statistical models. In other words, they do not a priori assume any specific structure of this correlation.
Diagnosis	In a manufacturing chain, diagnosis refers to identifying the causes which have resulted into a fault or anomaly (in a machine, part…) compared to the normal operation conditions. Process/machine/chain diagnosis is often done through data analysis techniques.

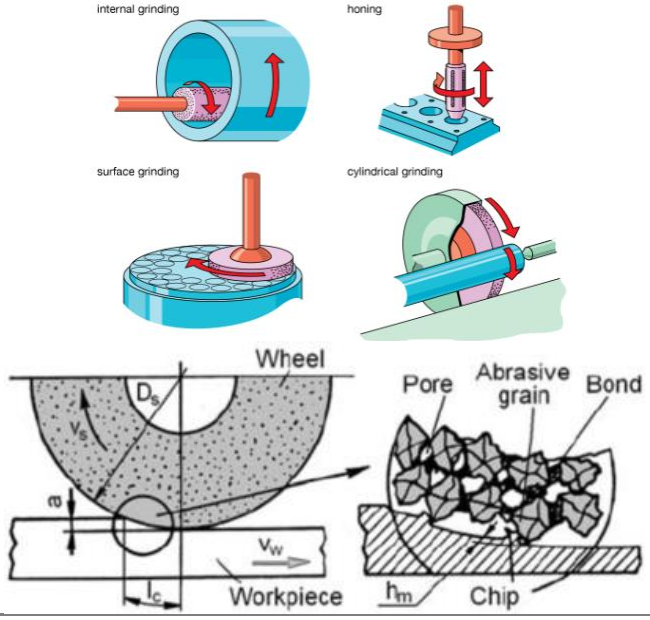
Eddy Current Array	The eddy current technology is used for detecting cracks in complex metallic parts. In a standard eddy current test, a circular coil carrying current is placed in proximity to the test specimen (which must be electrically conductive). An alternating current in the coil generates a changing magnetic field which interacts with the test specimen and generates eddy currents. Variations in the phase and magnitude of these eddy currents can be monitored using a second 'receiver' coil, or by measuring changes to the current flowing in the primary 'excitation' coil. The presence of metallurgical changes like cracks in the material will cause a change in eddy current and a corresponding change in the phase and amplitude of the measured current. In the last years, a new technology called Eddy Current Array (ECA) is gaining interest for the detection of surface and sub-surface defects. This technique is susceptible of being automated and allows saving time, greatly enhancing the inspection capabilities. The ECA technology is based on numerous eddy current coils that are positioned next to each other in the same probe assembly. In the probe, each eddy current coil generates a signal with an amplitude and phase that depends on the analyzed structure. This technology is used to build flexible sensors that allow full inspection of complex geometries and it can be readily automated, enabling to have detailed, extensive records of each inspection done.    
Enterprise Service Bus (ESB)	The ESB is a software architecture model used for designing and implementing communication between mutually interacting software applications in a service-oriented architecture (SOA – see below). A lightweight framework shall replace the ESB in ForZDM.
ERP	With Enterprise Resource Planning (ERP) is usually indicated a type of business-management software—a suite of integrated modules consisting essentially in a database — that an organization can use to collect, store, manage and interpret data from many business activities (product planning, purchase, manufacturing or service delivery, marketing and sales, inventory management, shipping and payment, finance, human resources).
EtherCAT protocol	Ethernet for Control Automation Technology (EtherCAT) is an Ethernet-based real-time fieldbus system invented by the enterprise «Beckhoff Automation».
Extrusion screw	The extrusion screw is the mechanical apparatus that transfers the polymeric granules from the input hopper(s) to the extrusion die. During its rotation, the screw generates a translational motion that transports the granules. Moreover, it increases the temperature.

	The material is gradually melted by the mechanical energy generated by turning screws and by heaters arranged along the barrel. The molten polymer is then forced into a die, which shapes the polymer. 

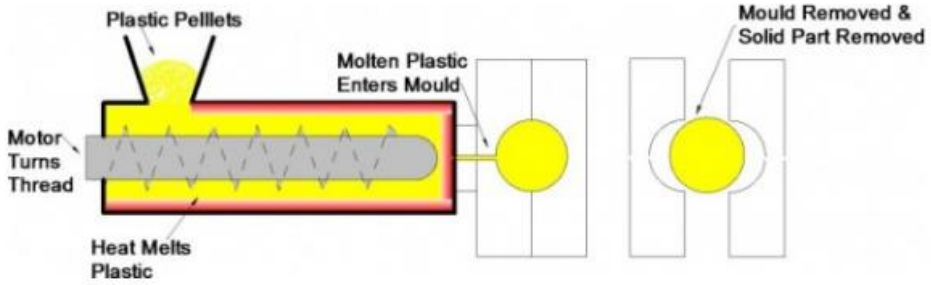
Feed-forward control for defect repair		A strategy to prevent the generation or propagation of a defect by (i) measuring the outcomes of the upstream process, (ii) providing in input these measurements to a digital model, (iii) retrieving the optimal parameter windows for the downstream correlated process, (iv) implement the adjustments to avoid the defect to be propagated or to repair a defect, if possible. It is the opposite of feedback control where the output of the downstream process is measured and the input is adjusted at the same process to avoid the defect on the next part.
Fixture		
	3-2-1 fixture	3-2-1 fixture refers to the most-common fixture design principle. First, 3 non-collinear points in the XY plane restrict translation along Z and rotation around X and Y. Second, 2 points in the YZ plane restrict translation along X and rotation around Z. Finally, 1 point in the XZ plane restricts translation along Y and the part is completely fixed. 
	6 point location fixture	6 point location fixture see 3-2-1 fixture.
	Clamping fixture	Clamping fixture is a device expected to locate accurately parts, billets, rods or similar in a fixed position into the machine and hold them tightly and securely during the manufacturing operation(s). The clamping device must also contribute to minimize unproductive operations of part loading/unloading. Often, modular concepts are used in fixture design in order to optimize costs against product design evolutions. Most designs combine commercially available and tailor-made components. Common fixing components are bolts, clamps or screws. 
Fluorescent Penetrant Inspection		Fluorescent Penetrant inspection (FPI) is a type of Non-Destructive Testing (NDT) in which a fluorescent fluid is applied to the surface of a non-porous material in order to detect defects that may compromise the integrity or quality of the part in question. Noted for its

	low cost and simple process, FPI is used widely in a variety of industries. Because of its sensitivity to such small defects, FPI is ideal for most metals which tend to have small, tight pores and smooth surfaces. Defects can vary but are typically tiny cracks caused by processes used to shape and form the metal. It is not unusual for a part to be inspected several times before it is finished (an inspection often follows each significant forming operation). Inspection steps include: • Initial cleaning: For ensuring that the surface is free of any contamination such as paint, oil, dirt, • Penetrant application: The fluorescent penetrant is applied to the surface and allowed time (Dwell Time) to seep into flaws or defects in the material • Excess penetrant removal: For ensuring that the penetrant is removed only from the surface of the material and not from inside any identified flaws • Developer application: A contrasting developer may be applied to the surface. This serves as a background against which flaws can more readily be detected. • Inspection: The inspector will use ultraviolet radiation with an intensity appropriate to the intent of the inspection operation. • Final cleaning  
FORGE software	FORGE® is commercial software for the numerical simulation of hot metal forming processes (e.g. rolling, close/open-die forging, superplastic forming). By numerical simulating the processes, outputs such as forming forces, material stresses or part geometric deviations can be estimated and the process variables (e.g. die design, forming temperature) adapted to achieve the expected outputs.
Forging	
process	Forging process is a metal forming process where a bulk material is given into shape by means of compressive forces. The bulk material is shaped with a forging hammer/die. In cold forging processes the bulk material is shaped at room temperature whereas in hot forging processes the material is previously heated up. Traditionally, parts withstanding high efforts are produced by forging since forged material feature high strength. In forged parts certain areas require further processing (e.g. machining, grinding…) in order to meet the design tolerances. Some forging application examples are aircraft landing gears, turbine shafts or automotive crankshafts. 

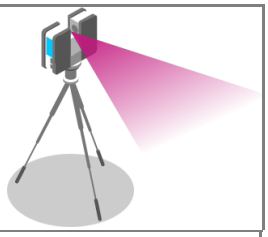
lap	Forging lap is a type of defect in forged parts appearing when the part outer surface collapses on itself. The result is a surface-to-surface contact on the outer surface extending towards the part inside. It differs from a crack since no material mix with further cracking occurs and the contact line is smooth. 

Grinding	Grinding is a cutting or chip removal process where the material is removed by using a rotating wheel made of abrasive particles and a binder. Opposite to metal removal processes using geometrically-defined cutting edges such as turning or milling, dust-type chips are produced in grinding. Depending on the surface to be ground (flat, outer cylindrical, inner cylindrical) different machine configurations are possible. Grinding delivers very smooth surfaces and accurate geometries. Thus, it is usually selected as a finishing process to make the part meet the surface finish and dimensional design tolerances. 

Hand-held batch	
HMI	The Human Machine Interface (HMI) is a hardware or software component to communicate with a machine. The HMI is an interface that is neither part of the machine nor of the human. Software HMI is the window of the software tool that is used to operate the machine. Hardware HMI can be e.g. a simple switch.
Hopper	A mechanical device of variable geometry and size that in continuous processes has the function to (i) store the inventory (material) before or after a process, and (2) load the material in the downstream process (see picture – extrusion screw). It acts as in-process buffer for material storage and to smooth the propagation of downtimes along the line
Human in the loop (HITL)	HITL systems or models require human interaction. It is often used in the context of interactive simulations. As the actions of the operator influence the system behaviour they are part of a HITL simulation in order to evaluate human interaction with the system. In ForZDM, the control system will involve also actions of the operators, which then are humans in the (control) loop.

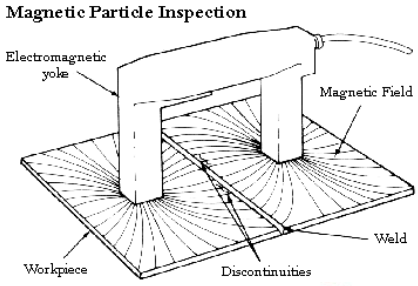
Information Sharing Platform (ISP)	The information sharing platform (ISP) is a software tool for efficiently collecting, distributing, processing, compressing and storing a considerable amount of data gathered in real-time and in asynchronous manner from distributed sensor networks. The ISP supports further data analysis for modelling and decision support purposes, thus it may be integrated with multiple big data analytics tools.
Injection molding	Injection molding is a plastic forming process where material under the form of pellets or granules is fed into a rotating auger falling down into a tube. A heater heat ups the tube and when the required temperature is reached a motor makes the screw inside the tube rotate. Pellets melt and travel along the tube up to the mold where an air jet pushes the molten material against the walls. When cooled down it keeps the shape of the cavity. Many plastic parts such as bottle caps, car dashboards or packaging are produced by injection molding. 
In-line rework	In-line rework means that a defective workpiece is corrected using the same machine (in-line). In contrast to this, a workpiece can be repaired or scrapped outside the line using different machines or human operators.

Key Performance Indicator (KPI)	Key performance indicators (KPI) are a set of quantifiable measures that a company uses to measure and evaluate its performance over time. These metrics are used to determine a company's progress in achieving its strategic and operational goals. Typical KPIs in manufacturing companies are Actual Production Cost, Actual Production Time, Units Manufactured, Number of Units Unfinished, Production losses, First time through, Manufacturing cost per Unit, On-time orders, On-time shipping etc
Knowledge-based method	A knowledge-based method aims at investigating and analysing the relevance of partially known correlating process parameters, by proving or rejecting hypotheses generated by user's knowledge of the process.

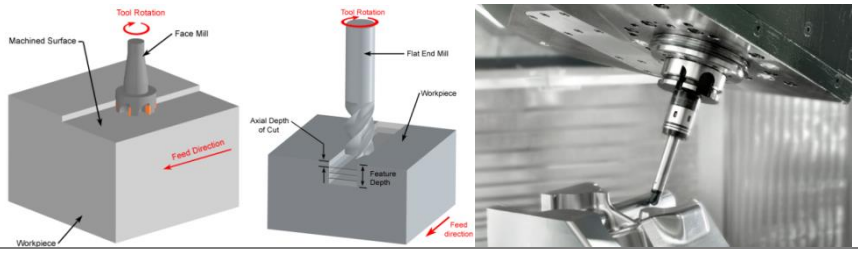
Laser scanner	Laser Scanners are non-contact devices used to gather 3D digital data from a variety of objects. A beam of light passes over the object while a camera mounted inside the scanner records the position of the laser. This 3D data is then transferred to the computer and the image is "drawn" in 3D on the screen. 
Lead time	A lead time is the latency between the initiation and execution of a process. Lead time is made of: • Order Lead Time: Time from customer order received to customer order delivered. • Order Handling Time: Time from customer order received to sales order created. • Manufacturing Lead Time: Time from sales order created to production finished (ready for delivery). • Production Lead Time: Time from start of physical production of first submodule/part to production finished (ready for delivery). • Delivery Lead Time: Time from production finished to customer order delivered.

Learning-based method	The learning-based method investigates and analyses the relevance of partially known correlating process parameters, directly from the analysis of the data without any significant user's supervision, with an emergent bottom-up approach (i.e. artificial intelligence, machine learning).
Lumen	The lumen (symbol: lm) is the SI derived unit of luminous flux, a measure of the total quantity of visible light emitted by a source. Luminous flux differs from power (radiant flux) in that radiant flux includes all electromagnetic waves emitted, while luminous flux is weighted according to a model of the human eye's sensitivity to various wavelengths. Lumens are related to lux in that one lux is one lumen per square meter. The lumen is defined in relation to the candela as 1 lm = 1 cd·sr. A full sphere has a solid angle of 4π steradians, so a light source that uniformly radiates one candela in all directions has a total luminous flux of 1 cd × 4π sr = 4π cd·sr ≈ 12.57 lumens

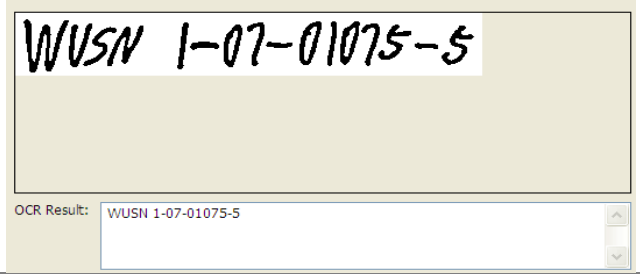
Machine state	A machine state is a condition of the machine of relevance for the specific problem under analysis. A state is identified by one or more variables, called state variables, which uniquely describe the state and the behaviour of the machine in that specific state. The dynamics of the machine from an initial state into a destination state is called state-transition. Typical machine states for a metal cutting machine are active, inactive, cutting, in alarm etc.
Machining	Machining is the broad term used to describe removal of material from a workpiece, it covers several processes, which are usually divided into the following categories: • Cutting: generally involving single-point or multipoint cutting tools, each with a clearly defined geometry. • Abrasive processes, such as grinding. • Nontraditional machining processes, utilizing electrical, chemical, and optimal sources of energy. The three principal machining processes are classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planing, boring, broaching and sawing. • Turning operations are operations that rotate the workpiece as the primary method of moving metal against the cutting tool. Lathes are the principal machine tool used in turning. • Milling operations are operations in which the cutting tool rotates to bring cutting edges to bear against the workpiece. Milling machines are the principal machine tool used in milling. • Drilling operations are operations in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the workpiece. Drilling operations are done primarily in drill presses but sometimes on lathes or mills.
Machining process compensation	Inaccuracies in workpiece location lead to errors in position and orientation of machined features on the workpiece, and strongly affect the assemblability and the quality of the product. The three major types of error are geometric, thermal and cutting-force induced errors. Error compensation basically involves a study of the various sources of error in the machine tool and a method to compensate for the same. Since the accuracy of a machine tool is affected by the overall effect of the various error sources mentioned earlier, the error compensation system should take into consideration the interaction between these sources rather than consider each error in isolation. The technique of error compensation can broadly be classified into two major fields of activity namely static and dynamic error compensation. While static error compensation deals with the identification and correction of the basic machine errors, dynamic error

	compensation techniques, popularly called real-time error compensation, are generally used to correct the thermal and cutting force-induced errors.
Finish machining	Finish machining is used to complete the part and achieve the final dimension, tolerances, and surface finish. Finishing operations are carried out at low feeds and depths – feeds of 0.0125–0.04 mm/rev (0.0005–0.0015 in/rev) and depths of 0.75–2.0 mm (0.030–0.075 in) are typical. Cutting speeds are higer in finishing than in roughing.
Rough machining	Rough machining is used to remove large amount of material from the starting workpiece as rapidly as possible, i.e. with a large Material Removal Rate (MRR), in order to produce a shape close to the desired form, but leaving some material on the piece for a subsequent finishing operation. In production machining jobs, one or more roughing cuts are usually performed on the work, followed by one or two finishing cuts. Roughing operations are done at high feeds and depths – feeds of 0.4–1.25 mm/rev (0.015–0.050 in/rev) and depths of 2.5–20 mm (0.100–0.750 in) are typical, but actual values depend on the workpiece materials. Cutting speeds are lower in roughing than in finishing.
Magnetic Particle Inspection (MPI)	Magnetic particle Inspection (MPI) is a Non-Destructive Testing (NDT) process for detecting surface and slightly subsurface discontinuities in ferromagnetic materials such as iron, nickel, cobalt, and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source. The magnetic lines of force are perpendicular to the direction of the electric current, which may be either alternating current (AC) or some form of direct current (DC) (rectified AC). The presence of a surface or subsurface discontinuity in the material allows the magnetic flux to leak, since air cannot support as much magnetic field per unit volume as metals. Ferrous particles are then applied to the part. The particles may be dry or in a wet suspension. If an area of flux leakage is present, the particles will be attracted to this area. The particles will build up at the area of leakage and form what is known as an indication. The indication can then be evaluated to determine what it is, what may have caused it, and what action should be taken, if any.    A wet horizontal MPI machine (see picture - right) is the most commonly used mass-production inspection machine. The machine has a head and tail stock where the part is placed to magnetize it. In between the head and tail stock is typically an induction coil, which is used to change the orientation of the magnetic field by 90° from the head stock.

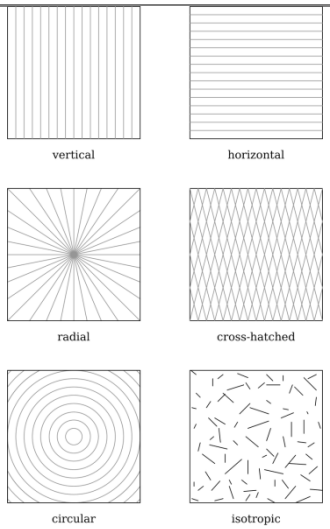
	Most of the equipment is built for a specific application.
Manufacturing	
Flow model	A flow model is an approximate representation of a discrete part manufacturing system assuming a continuous flow of parts along the different stages and buffers of the system. In the continuous flow model representation of a system, machines (stages) act as valves regulating the speed at which the material flow is processed. A buffer is a material accumulation point with a level that is increased if the input fill rate is bigger than the output drain rate, and that is decreased otherwise. Continuous flow models are preferable to discrete models as they overpass the major limitation of discrete models (machines are assumed to process part at the same cycle time, i.e. synchronous systems).
Multi-stage manufacturing systems	The manufacturing system in which production takes place conforms to a serial, multistage configuration with a different processing operation at each stage of the system
Process	Manufacturing process refers to a technology which enables to transform a raw material/semi-finished product (e.g. extrusion, forging or sheet) into a product. Manufacturing processes are often assimilated to discrete manufacturing processes which feature production of separated units in contrast with continuous processes typical in the oil, pharmaceutical or steel making industries. Some processes examples are turning, milling, grinding, extrusion, additive manufacturing technologies, deep drawing, casting… Manufacturing processes also cover assembly technologies such as welding or mechanical joining used to combine multiple inputs into one single product.
Manufacturing stage	A manufacturing stage is composed of one or more resources that implement a cluster of processes on the part in production. Is usually connected to upstream and downstream stages by a transportation module.
MES software	A manufacturing execution system (MES) is a control system for managing and monitoring work-in-process on a factory floor. An MES keeps track of all manufacturing information in real time, receiving data from robots, machine monitors and employees. Lately MES software is increasingly being integrated with enterprise resource planning (ERP) software suites. The goal of a manufacturing execution system is to improve productivity and reduce cycle-time, the total time to produce an order.
Micro-extrusion die	A micro-extrusion die is a mechanical component that provides the final shape to the extruded product of micrometric dimensions. The material is moved in the extrusion die by the action of the extrusion screw and is forced to deformation by the geometry of the die (see also extrusion screw). In the extrusion of micro-tubes, the action of a pin generates the hole and a pulling force provides the required section to the tube.
Micro-intravascular catheter	A medical device for intravascular surgery composed of a micro-tube with single of multiple lumens and single of multiple layers and an assembled moulded part for catheter manual control by the physicist.
Milling	Milling is a cutting or chip removal process where the material is removed by using a rotating cutting tool featuring usually more than one geometrically defined cutting edge. Depending on tool type, the relative movement between tool and workpiece or the volume of material being removed several operations are possible: 3/5 axis milling, side/face milling, upwards/downwards milling, slot milling. It can be performed in devoted milling machines, in machining centers, in robots or multi-tasking machines. Milling is a highly flexible manufacturing process included in the manufacturing chain of many components for the aerospace, automotive or energy sectors.

	
Modbus protocol	Modbus is a serial communications protocol that has become a standard communication protocol for programmable logic controllers (PLCs). It is a master-slave communication protocol between one master and several slaves.
Monitoring solution	Solution that supervises activities in progress to ensure they are on-course and on-schedule in meeting the objectives and performance targets. Clearly effective monitoring is critical to ensuring product quality regardless of the type of manufacturing industry. Essential components of effective monitoring solution include representative measurement and a robust representation of the obtained information, allowing appropriate action to be taken.
MQTT	Message Queue Telemetry Transport (MQTT), publish-subscribe based lightweight messaging protocol for use on top of the TCP/IP protocol for a machine-to-machine communication.
Multi-agent system (MAS)	A Multi-Agent System (MAS) is a computerized system composed of multiple interacting intelligent agents within an environment. Multi-agent systems can be used to solve problems that are difficult or impossible for an individual agent or a monolithic system to solve. Intelligence may include some methodical, functional, procedural approach, algorithmic search or reinforcement learning.
Multi-level process system	A multi-stage system is composed of more than one manufacturing stages, transportation modules to connect stages, a control and planning system and humans.

Nick defect	Nicks are small notches, grooves, chips or cuts in the metal surface and can form either ridges, uneven surfaces or burrs. 

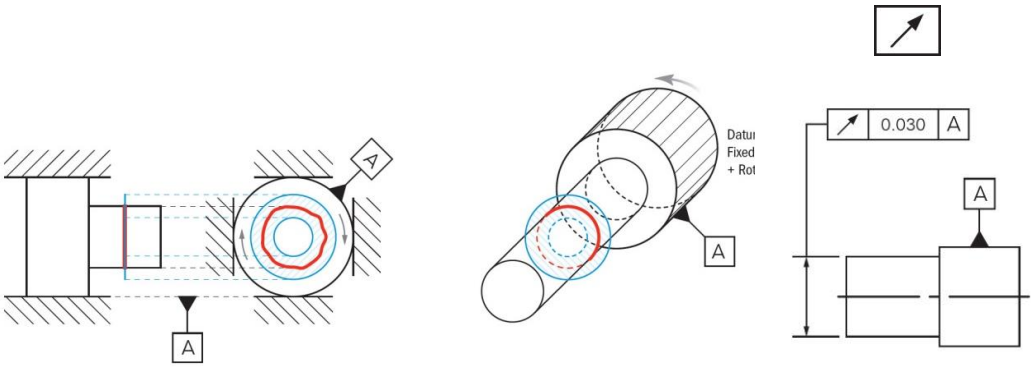
OCR	Optical Character Recognition is a technology that enables you to convert different types of documents, such as hand written paper documents, scanned documents, PDF files or images captured by a digital camera into editable and searchable data (example : hand written paper -> OCR -> word document). 

OneBase software	Onebase is a database from ABF. It will be used as a basis and extended for acquiring and storing the information provided by different sensors within WP3
Overall Equipment Effectiveness (OEE)	The OEE is a measure of manufacturing line productivity that takes into account all losses, including quality, maintenance and production logistics losses. It is calculated as the product of three rates related to the aspects of Maintenance, Production and Quality: OEE = Availability x Performance x Quality Where: Availability = Run Time/Planned Production Time Performance = Net Run Time/ Run Time Quality = Good Count/ Total Count.

Part surface quality	Synonym of surface finish, surface texture or surface topography; it comprises the small local deviations of a surface from the perfectly flat ideal (a true plane). The nature of a surface is defined by the three characteristics of (i) lay, (ii) surface roughness, and (iii) waviness. Lay is the direction of the predominant surface pattern ordinarily determined by the production method used; surface roughness is a measure of the finely spaced surface irregularities while waviness is the measure of surface irregularities with a spacing greater than that of surface roughness (usually due to vibrations or deflection during machining).	 Lay
Pick-to-light	Pick-to-Light frameworks, utilize light displays to direct operators to particular stock areas. Every product location can have an individual numeric or alphanumeric showcase with a light, an acknowledgement button, and an advanced digital readout for demonstrating quantity. Different arrangements permit less or more streamlined displays to lessen the aggregate expense. In a common Pick to Light framework, the picking arrangement begins toward the start of a zone where the operator checks a bar coded address mark connected to the delivery container. The display advises the administrator which items to pick and what number of each. The operator affirms picks by means of acknowledgement buttons.	
Prevention	In a manufacturing environment, prevention is the set of periodic actions adopted for maintaining equipment under satisfactory operation conditions. This set of action is usually associated to known machine state patterns which have been previously identified through data analysis.	
Product life cycle	Includes the phases of design, manufacturing, use, maintenance and repair, collection, and disposal by end-of-life treatments.	
Production logistics	It refers to the inter-plant logistics affecting the production rate of a multistage manufacturing system.	
Prognosis	In a manufacturing environment, prognosis refers to predicting by means of a data-driven model an undesired machine operation state/condition before it occurs. The data-driven model relies on machine data which have been previously acquired.	

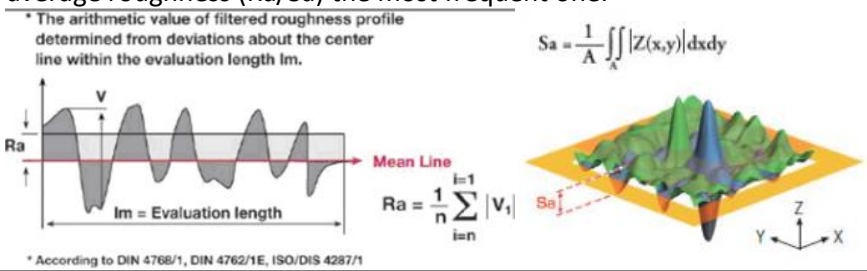
Q-DAS software	Q-DAS is a company which develops and sell statistical software packages used for quality management applications (i.e. statistical evaluation of quality information, assessment of processes and systems, process capability, six sigma statistical analysis, process optimization etc)

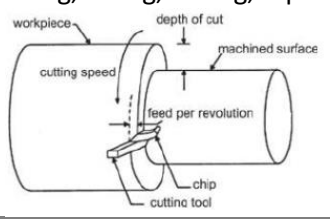
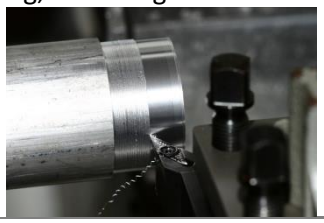
Railway axle	The circular shaft connecting two wheels to form a 'wheelset' 
Railway wheelset	A fixed formation of an axle with two wheels set at the correct gauge for the track. The wheels are pressed onto the axle and rotate with it as a unit. It is mounted into the bogie (or vehicle) frame with axleboxes. 
RF terminal	The RF terminal looks like a calculator and is easily portable. It is an extremely useful tool for inventory, whether receiving or placing orders. In fact, in addition to its complete keyboard, the RF terminal has an optical lens allowing workers to read the bar codes on products and thus ensuring correct pricing in conformity with consumer pricing laws. Employees use the RF Terminal to read the bar code on the product. Once the product has been selected the clerk only needs to count the number of remaining units. After which the clerk can do the same with another product. The RF terminal allows for the creation of different batches with detailed descriptions: origin of the product, product name, price, quantity of the product, etc.
RFID	Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source such as a battery and may operate at hundreds of meters from the RFID reader. Unlike a barcode, the tag need not be within the line of sight of the reader, so it may be embedded in the tracked object. RFID is one method for Automatic Identification and Data Capture (AIDC). For example, in the railroad industry, RFID tags mounted on locomotives and rolling stock identify the owner, identification number and type of equipment and its characteristics. This can be used with a database to identify the lading, origin, destination, etc. of the commodities being carried. 
Root cause (of defect)	Root cause (of defect) is the factor leading to an undesired event (defect) so that when it is suppressed the defect does not occur. Root Cause Analysis (RCA) refers to the methodology frequently applied in manufacturing quality and control to analyze together a defect and its potential causes attempting to identify the root cause. The final aim is to design, based on the analysis outcomes, appropriate corrective actions so that the root cause does not

	appear anymore. Different tools can be used to perform an RCA. Some examples are: Pareto analysis, 5-whys analysis, fault tree diagrams, scatter maps…
Runout error	Runout is how much one given reference feature varies with respect to another datum when the part is rotated 360° around the datum axis. It is essentially a control of a circular feature, and how much variation it has with the rotational axis. Runout can be called out on any feature that is rotated about an axis. It is essentially how much "wobble" occurs in the one part feature when referenced to another. The associated tolerance zone is a 2-Dimensional circular zone that is defined by a datum axis where all points on the called surface must fall into. The zone is a direct reference to the datum feature. Runout is the total variation that the reference surface can have, when the part is rotated around the datum's true axis. 

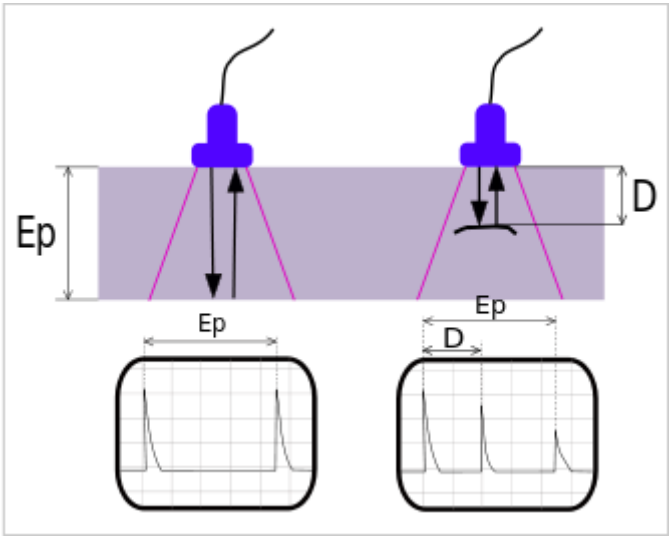
Sand blasting	Sand blasting is the operation of propelling a stream of sand (abrasive material) against a surface under high pressure to smooth a rough surface, roughen a smooth surface, shape a surface, or remove surface contaminants
Scrap	In a manufacturing process, scrap is referred as the defective parts being produced and which cannot be reworked to become an acceptable item. Thus, scrap contributes to the waste generated by the process.
Selective Assembly	Traditionally, Selective Assembly is a quality-oriented assembly method which involves the selection of components which match better together in order to realize a compliant assembly. This approach makes it possible to change a product quality problem into a system design and operation problem. More recently, direct selective assembly methods have been proposed which suggest adjustment of the target value of the feature of the coupling component after measurement of the key quality characteristics of the master component.
Sensors	A sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. Common types of sensors are used currently in every industry for monitoring or control purposes. Traditionally, typical sensors are classified as mechanical, thermal, electrical, magnetic, radiant or chemical. In addition, from a manufacturing point of view, three basic categories could be considered for structuring a sensor network. Sensors for Machine Tools and Robots, Sensors for Workpieces and Sensors for Process Monitoring.
for processes	Monitoring systems for controlling key parameters of critical processes use dedicated sensors acquiring real time information on the monitored process. Typical applications in manufacturing processes include one or more sensors applied on the machine, on the part or on the fixture, which detect a variation in one process variable (power, force, displacement, vibration, temperature etc) and provide a constant feedback to the monitoring system which is then connected to the machine control system. Each process variable is usually controlled with some thresholds and when pass the thresholds, the

	monitoring system sends a feedback to the control system, which stops the machine or adapt some process parameters (i.e. feed rate, r.p.ms) until the process variable do not go back to normal values.
for production monitoring	A real time production monitoring system typically relies on machine (PLC) or sensor inputs. These systems help the company management to gather and distribute information to everyone in the shopfloor as events are happening. Real time production monitoring can help industries to achieve realistic goals, reduce downtime and increase yield. Typical applications include product tracking solutions for detecting part positions and work in progress (voice systems, RFID, OCR, pick-to-light, laser scanners, CCD scanners, hand-held batch and RF terminals, vehicle-mounted computers, and wearable computers), HMIs for acquiring operators inputs and, machine state monitoring systems (see above, machine state). The availability of all the data provided by these distributed sources, allow the management to have a constant overview of the work in progress and the potential issues.
for quality inspection of workpieces	Monitoring systems that permit to inspect one or several product features. Depending on the feature to be measured, a great variety of sensors and technologies exists in the market. For example, typical dimensional features are checked via contact probes or non contact sensors (laser, 3D cameras) while other product features can be checked via non destructive testing methods (NDT, see Magnetic particle inspection, Fluid Penetrant Inspection, Ultrasonic Testing).
Service Oriented Architecture (SOA)	A service-oriented architecture (SOA) is an architectural pattern in computer software design in which application components provide services to other components via a communications protocol, typically over a network.
Shot peening	Shot peening is a cold working process which entails impacting a surface with shot (round metallic, glass, or ceramic particles) with force sufficient to create plastic deformation; it is used to produce a compressive residual stress layer and modify mechanical properties of metals and composites. It is similar to sandblasting, except that it operates by the mechanism of plasticity rather than abrasion: each particle works as a ball-peen hammer. In practice, this means that less material is removed by the process, and less dust created compared to sand blasting.
Six Sigma production system	Six Sigma is a set of techniques and tools for process improvement. Six Sigma seeks to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, mainly empirical, statistical methods, and creates a special infrastructure of people within the organization, who are experts in these methods.
DML	Distributed Multi-Level, see distributed control
IEC 61131	IEC 61131 is an international standard for programmable logic controllers (PLC).
IEC 61499	IEC 61499 defines a generic model *for distributed control systems*; it is based on the IEC 61131 standard.
OPC UA	OPC Unified Architecture is an industrial communication protocol that can be used to acquire data from different data sources like sensor systems or machine controls (PLC). Almost every industrial machine control available on the market is able to act as OPC UA server and provide data for client applications. Therefore, OPC UA is widely spread in industrial applications.
XMPP	Extensible Messaging and Presence Protocol is a communication protocol that is widely used in information technologies, not in industrial applications. The capabilities of XMPP for industrial real-time applications is part of the research carried out in ForZDM.
Stream of Variation Analysis (SOVA)	See Variation Pattern.
Surface roughness	Surface roughness is the surface topography associated to short wavelength deviations of the part surface regarding its theoretical (design) surface. An uneven surface roughness can

	be for example due to feed marks left by the cutting tool on the part surface as well as with irregularities (e.g. cracks, notches) existing in the cutting edge portion in contact with the part. The surface roughness can be represented by a roughness profile (2D representation) or a surface (3D representation) depending on the measurement equipment being used. Roughness profiles/surfaces are usually quantified by means of normalized parameters being the average roughness (Ra/Sa) the most frequent one. 
System throughput	Also named production rate, or throughput rate, is the amount of output material the system can deliver in a given time (e.g. JPH, Job per Hours).

Turning	Turning is a cutting or chip removal manufacturing process where a non-rotating tool with a defined geometry and a single cutting edge removes material from an ax symmetric rotating part. Turning is performed basically in lathes or multi-tasking machines and depending on the tool geometry or tool path being described different operations are possible: straight turning, facing, boring, tapering, threading.  

Ultrasonic	Ultrasounds are sound waves with a frequency higher than the upper limit of the human hearing range. Sounds propagate in solids and liquids at much higher speed than air. Ultrasounds can be used to measure distances or find defects in different materials.
Ultrasonic Testing (UT)	Ultrasonic testing (UT) is a family of Non-Destructive Testing (NDT) techniques based on the propagation of ultrasonic waves in the object or material tested. In most common UT applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion. Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is used in many industries including steel and aluminum construction, metallurgy, manufacturing, aerospace, automotive and other transportation sectors. In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing. However, when ultrasonic testing is conducted with an Electromagnetic Acoustic Transducer (EMAT) the use of couplant is not required.

	 There are two methods of receiving the ultrasound waveform: reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Using the couplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces
Ultrasonic transducer	Ultrasonic transducers are transducers that convert ultrasound waves to electrical signals or vice versa. Those that both transmit and receive may also be called ultrasound transceivers; many ultrasound sensors besides being sensors are indeed transceivers because they can both sense and transmit. These devices work on a principle similar to that of transducers used in radar and sonar systems, which evaluate attributes of a target by interpreting the echoes from radio or sound waves, respectively. Active ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object.

Waste	In a manufacturing environment, waste refers to consumables which are left by a manufacturing process/chain. Examples include: metallic chips, sheet/plate coupons, spoiled/contaminated metalworking fluids, ancillary materials (e.g. fabrics and films in composite parts production), and part cleaning agents (e.g. solvents). Further to costs associated to waste, hazardous wastes (e.g. contaminated metalworking fluids) often involve expensive disposal procedures and health issues for personnel.

Zero Defect Manufacturing	It is a systematic approach aiming at reducing manufacturing defects by simultaneously addressing and controlling the following phases: • Zero defects Generation phase: At process level, the generation is the appearance of non-conformity on the manufactured workpiece. • Zero Defect Propagation phase: At process chain level, the propagation is the transmission of a defect throughout the stages of a manufacturing system.

	Zero Defect Manufacturing" is a recent paradigm aiming at going beyond traditional six-sigma approaches in highly technology intensive and strategic European manufacturing sectors through new knowledge-based approaches. «Zero Defect Manufacturing» paradigm is of key importance to manage production quality targets in advanced manufacturing industries. The implementation of this paradigm in industry requires innovative defect management and control methods, novel technologies for in-line inspection and integration of knowledge management and ICT tools for smart and sustainable decisions in complex industrial scenarios, which are not available in the market.

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