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(54) **METHOD AND MACHINE SYSTEM FOR CONTROLLING AN INDUSTRIAL OPERATION**
VERFAHREN UND MASCHINENSYSTEM ZUR STEUERUNG EINES INDUSTRIELLEN BETRIEBS
PROCÉDÉ ET SYSTÈME DE MACHINE POUR COMMANDER UNE OPÉRATION INDUSTRIELLE

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method, an industrial machine system, a computer program product and a non-transient computer-readable medium for selecting optimum operation performance criteria for controlling an industrial machining operation, such as a sheet metal working process.

BACKGROUND ART

[0002] Industrial machine systems of today typically consist of a machine with an actuator system for providing relative motion between a machine part or operating device and a workpiece. State of the art industrial machine systems are highly specialised to perform operations like for instance beam cutting, milling, turning, drilling, boring, punching, punch pressing, press-breaking, bending, welding and assembly operations. The machine system is a substantial investment to most potential customers, in particular to smaller or medium-sized workshops, why the versatility and productivity that the machine system is to contribute with to the business is a key factor when making investment decisions.

[0003] The industrial machine systems are controlled by means of a CNC (Computerized Numerical Control) unit, an NC (Numerical Control) unit, a PLC (Programmable Logical Control) unit and/or related sensing and processing equipment that together serve to provide instructions to an actuator system to perform required movements in order to execute intended industrial operations. The machine system further comprises a machine controller, which is essentially a computer having a processor and a conventional operating system such as Windows or Linux configured to give instructions to the CNC/NC/PLC unit based on machine controller instructions, such as G-code or XML. The machine controller includes or is connected to an HMI (Human-Machine Interface), and is configured to read programs and to gather process parameters so as to yield complete instructions to the CNC/NC/PLC unit for execution by the actuator system comprised in the machine. Conventionally, both the CNC/NC/PLC unit and the machine controller are physically included in the industrial machine, and the industrial machine forms an independent and self-contained industrial machine system wherein the machine controller forms an essential and physically connected part of the machine.

[0004] A CNC system may be defined so as to comprise a machine tool, herein referred to as a machine, a part program, which is a detailed set of commands followed by the machine, and a machine controller (or machine control unit), which is a computer that stores the program and executes its commands into actions by the machine tool.

[0005] Management, control and monitoring of operations performed by an industrial machine need expertise and experience from a machine operator as well as software-based support systems to work out. To generate a program for the operation of for example manufacturing a particular metal product, the program needs to be based both on a set of predetermined principles, such as the calculation of operating sequences based on optimization techniques or shortest path principles, but also an operator's know-how of what will be the best sequence from a more practical point of view. Variables to consider and control may be related to materials properties, logistics and of course to the actual geometries, shapes, dimensions and order in which products are to be produced.

[0006] Prior art technology discloses the establishment of machining or cutting programs which are based on the principle that of single parts are produced as individual units. A wide variety of conventional production methods are used for this purpose, such as cutting, punching and/or pressing. Here, production metrics to be applied for the cutting, punching and/or pressing operation are defined in advance. Individual definitions are made for each part and applicable safety distances between adjacent parts are defined for each individual part.

[0007] More recently, the so-called common cut technology has evolved as an improvement to the more conventional cutting techniques. The underlying technique for the common cut technology is based on dividing a workpiece by cutting two adjacent parts, the parts being separated by a distance corresponding to the width of a cut of the cutting beam. Hence, careful consideration must be made, when positioning shapes to be divided from each other, to the width of a cut of the cutting beam, given the prerequisites for that particular cutting operation.

[0008] Prerequisites for a cutting operation are to be determined already in connection with initial preparation for and positioning of shapes to be separated along the cutting path. In particular for partially or fully automated processes, careful planning of a common cut machining process is crucial. To realize that common cut cannot be used first after having positioned workpieces for cutting, is too late, since the workpieces cannot be rearranged any more. To realize that common cut could not be used even later, i.e. after the cutting operation has taken place, inevitably leads to deformations and damage to the produced parts, and hence to cassation of produced items.

[0009] The above described common cut technique could also be applicable to for example punching or pressing operations, provided that the common cut technique allows parts to be separated from each other without causing damages or deformations, and does not cause the dimensions and quality of the produced item to exceed acceptable tolerances according to specification.

[0010] International patent publication WO 2011/042058 discloses a method and a system for machine cutting several parts out of a piece of material using a beam cutting technology. A set of controlling rules and variables are applied for forming a cluster of parts with free form shapes, the parts being positioned so close to each other so that only the thickness of one cut from the cutting beam is found between adjacent parts whenever the shape of the parts allows it. Another example of prior art can be found in US 2015/205289.

[0011] Since the introduction of free form shapes in cutting operations, the market has quickly realized that the technology has a potential to noticeably increase productivity in sheet metal working processes. One of the first advantages noted from free form cutting is the saving of valuable process time during cutting operations, which is one of the top priorities for competitiveness in production industry. Another advantage provided by the free form shape cutting is that it enables the shapes subjected to cutting to be arranged in a tighter pattern, thereby significantly reducing material waste, which is of benefit both from an industrial and an environmental perspective.

[0012] However, common cut technology, also when used in a way to allow for highly efficient production of free form shapes, may inevitably cause minor defects to the workpieces when in operation. Those defects are difficult to completely avoid and need to be considered, in particular for machining operations involving common cut technology. Tagged segments and/or defects that will eventually appear as a result of the machining operation are taken into account already during the initial planning of an industrial machining operation in order not to impede the overall productivity of the operation.

[0013] Machining operations of today are based on default data and theoretical parameters, which are stored locally in a database and calculated in advance of the operation. Various steps in a typical machining operation are therefore individually adjusted sequence by sequence. In view of this, a related problem that needs to be at least considered when setting up and performing an industrial machining operation is the large number of dynamic variables that may have an influence on the operation. Some of those variables may otherwise adversely affect the efficiency, precision, quality and productivity of the industrial machining operation, whether the variables are related to logistics, materials properties, production quality, presently used tooling, available tooling or operators' needs.

SUMMARY OF THE INVENTION

[0014] The present invention is defined by the attached independent claims. Other preferred embodiments may be found in the dependent claims.

[0015] The present invention discloses a computer-controlled method for selecting optimum operation performance criteria for a metal working process, said method comprising the steps of:retrieving process parameters from multiple sources relating to the metal working process,retrieving performance variables from different sources relating to the metal working process, comprising performance variable data from previous operations and/or performance variable data for subsequent operations,storing the process parameters and performance variables in a consolidated memory in association with a computer system,making the process parameters and/or performance variables available for application of optimization techniques to select optimum operation performance criteria,providing a process model that relates process parameters for the operation with performance variables for said operation,selecting at least one optimization technique and defining a function, said function comprising of process parameters,generating the function for optimization with respect to productivity by using acceptable tolerances of a product to be machined as a basis to define ranges for performance variables along with ranges for process parameters, and applying the at least one optimization technique to said function, whereby optimum operation performance criteria are determined for the process model including process parameters and performance variables to obtain a set of commands to be used for controlling the metal working process.

[0016] The optimum performance criteria calculated for the process model according to the above, result in a set of requirements which are transformed into operational instructions for controlling of an industrial machine. The control is typically executed by means of an industrial machine program, comprising a set of operational instructions that instruct an actuator system to execute machining operations.

[0017] More in detail, some of the preconditions that differentiate the present invention from traditional solutions that have been described in prior art, is the full integration of systems, machines, information related to the fourth industrial revolution (IoT) etc., but also of service providers and customers. Full integration of various sources of relevant data enables information relating to a metal working process to be retrieved even in real-time, and according to the present invention, this information may be analysed and utilized. The flexible nature of the process parameters and the performance variables, and the dynamic utilization of this information when optimising the metal working process, may lead to production results that could never be obtained using a sequential analysis or optimisation as a basis for the production planning. The flexibility in process parameters may lead to a significant reduction of waste materials and/or production time (resulting from lesser tools changes etc.) and the flexibility in performance variables may lead to a lower overall production cost, which is beneficial to both the manufacturer and the customer.

[0018] By means of the present invention, significant advantages and benefits will be achievable in relation to prior art technology some of which will be mentioned below. The dynamic nature of variables that may have influence and effect the efficiency and productivity of the industrial machining operation, whether the variables are related to logistics, materials properties, tooling availability or operators' needs can be taken into consideration.

[0019] The present invention uses information retrieved from multiple sources, and stores such information in a way that it is made available for use in connection with subsequent machining operations. By means of the retrieved information, the invention makes it possible to design and make available new or additional tools or tool geometries as required by the specific machining operation that is to be executed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Various embodiments and examples related to the present invention will now be described with reference to the appended drawing, in which:

Figure 1 is a flow chart that depicts an optimisation of an operational sequence of an industrial machine system by monitoring, controlling and adjusting the sequence.

Figure 2 graphically illustrates an industrial machine system according to one embodiment.

Figure 3 displays another embodiment of an industrial machine system according to the invention.

DETAILED DESCRIPTION

[0021] The present invention relates to identification of part geometries, generation of a program for controlling an industrial machine system. It also concerns configuration of an industrial machine system, in particular an industrial machine system for metal working, such as a punch press, press-break or bending machine. Combinations of punch presses and beam cutting machines are also conceivable for use, since such combinations are suitable also for milling and turning operations, besides cutting. Moreover, the invention relates to automation equipment and utilisation of process data obtained during previous machining operations, which data is used as input when planning, configuring, executing and managing a subsequent machining operation.

[0022] Both the detailed description and the drawings to which it refers are given by way of example only. Same reference numerals from different figures refer to the same element.

[0023] Sheet metal working is a generic term applicable to machining operations generally. Cutting, which is one of the comprised types of operations, is in this context to be construed as a machining operation executed by any of a variety of industrially applicable technologies, including cutting by means of technologies as laser, flames, plasma, water jet, ion, air as well as cutting by pressing, punch pressing and press-breaking. Milling, drilling and turning operations also belong to sheet metal working, provided the operations relate to machining of sheet metal.

[0024] Several properties of sheet metal materials, previous logistics operations and machining operations influence the behaviour of the material during processing. Hence products manufactured by a machine using an identical program of operation are influenced by the manner in which the processed material has been previously handled. Most of those physical properties of the material can be determined in advance of the processing, and thereafter retrieved and stored by an enterprise resource planning system. Here the data related to physical properties of the material to be processed is made available for use when planning and optimising machining operations.

[0025] Material-oriented properties that vary between subsequent operations are material quality, material compositions, size, shape and production batches that each clearly influences the result and precision achieved during a machining operation, whether it is bending, punching, cutting, milling, drilling, turning etc.

[0026] One of the mentioned influential properties is the sheet rolling direction, a variable that is dependent on the prior logistics operations of the material. The sheet rolling direction may have a significant impact on the result of a bending operation. Another property is rotation of parts and mirroring of the sheet metal, whereby rotation and mirroring of identical parts in different directions may have an influence on bending angles for otherwise identical parts. Bending angles may vary as much as by several degrees between two subsequent bending operations. The same is true for other machining operations, such as for beam cutting and punching, whereby rolling direction, part rotation and mirroring may cause tension or expansion of the material. All of the above variables are dependent on the prior logistics of the material.

[0027] The processing also influences the workpiece. During machining by means of punch pressing, the pressing operation generates marks that vary between punches of subsequent tools strokes. Another imperfection is the use of so-called micro joints when punching or pressing to fix parts with a surrounding skeleton or to fix several parts to each other.

[0028] When applying beam cutting it may be necessary to define a starting point, a so-called lead-in. Microjoints are generated by closing the cutting path which surrounds the geometry of the part. As previously mentioned, common cutting techniques and clustering of free form shapes may generate different types of marks from tangential points, different types of lead-ins and different types of micro-joints that occur between parts and the surrounding skeleton or between adjacent parts. All of the mentioned marks, lead-ins, micro joints can be seen as part defects or visual attributes. They are all departures from the original drawings, and provided their existence and positions are known in advance of a machining process, the present invention provides a way to completely avoid them and or at least to alleviate any negative influence from them. A first machine operation may have left defects and/or visual attributes, such as hardened or irregular surfaces etc., which makes it even more important for a subsequent machine operation to avoid them in order to protect applicable tooling from being damaged and thus increase its lifetime.

[0029] Segments, which are not allowed to comprise any part defects or visual attributes may be marked. This way of marring, managing and avoiding imperfections is called tagging. As a result of marking segments to be avoided, the industrial machining system will not place any lead-ins, micro joints, tangential points or other part defects or visual attributes on these segments. This allows for enhanced part quality and process reliability all through the value chain but also results in increased volumes of scrap, i.e. materials waste. Scrap is undesired and would limit the availability of techniques as common cut or clustering of free form shapes, which would otherwise be a means to enhance the productivity of industrial processes.

[0030] Tooling, i.e. a set of suitable tools for executing a bending program, or other machining program, can be chosen both manually or automatically. A commonly used method for placing the workpiece in a precise position before executing for example the bending operation is to position axes of actuators as required. Back gauge, clamping mechanisms or fixtures are used to more accurately position and support a workpiece before the bending operation is executed. All of the above machine configurations and support arrangements generate data, which is collected. Also cutting heads, nozzles, lenses and related optics equipment relating to machining operations generate data that can be collected, provided as feedback and thus taking part in an optimisation of machining operations.

[0031] Bending angles and/or back spring can be measured both manually and automatically by means of for example laser, optical, mechanics. Automation units are configured to support an operator to move the workpiece so that sequencing and bending operations can be executed. Processed parts are stacked manually and/or automatically after machining operations have been executed. Stacking is made prior to customer delivery according to a number of guiding principles, some of which are related to operational efficiency, some of which are related to logistics and some of which are related to customer needs.

[0032] The present invention relates to generation of a machining process, such as a program for punching, combinations of punching laser, milling, drilling, turning and/or bending, and takes into consideration information from the previous operation in sheet metal working. The program optimises tooling configuration, through minimising required tooling exchange from a previous operation, minimising the number of tools required and the movements of tools. The program also minimises the motions required so as to reduce cycle time, applicable for an operator and/or automated process. The effort required for an operator to move a workpiece is also considered, which means that the shortest path does not always require the least effort. With reference to figures 2 and 3, the machining program could be made directly on the machine or disconnected from the machine depending on its configuration.

[0033] Collisions between a workpiece and the machine and tooling applied, is also considered. Conceivable is to allow collisions to be simulated manually or automatically before executing the program on the machine.

[0034] Figure 1 is a flow chart that depicts an optimization of an operational sequence in an industrial machine system or a manufacturing support system, possibly remote in a central computer which is connected or at least is connectable to multiple sources of data. The system may be configured to provide support for business operations relating to design- and construction processes (including the option of parametric design), selection of material, purchasing, logistics etc., by inputting desired parameters followed by modifying and presenting the optimum performance criteria.

[0035] The sequence starts (S10) in that an operator or client either manually or automatically inputs (S20) desired parameters relating to a product to be machined or evaluated. This input of desired product parameters can be made at any location. One example is that an application (app) developed for a mobile terminal, such a so-called smartphone, is used as a tool for realizing the input of desired parameters. This app may then be provided to all stakeholders along the value chain, for example designers, purchasers, logistics professionals, manufacturing specialists etc. In a next step, the computing system according to the invention generates (S30) resulting operational data based on the desired process parameters.

[0036] In a first step (S10), the process model is provided (pre-loaded) (S20) with process parameters relating to a previous sheet metal working operation.

[0037] In a second step, identification (S30) is made of clamping mechanism, gripping configurations and tooling locked up, i.e. currently applied settings, configurations and tools in the machine.

[0038] In the next step, analysis is made of whether the current tooling configuration can be used to effect a complete machining operation of next batch for production (S40), such as a bending operation of parts for subsequent production. An evaluation is also made of whether the current tooling configuration could be improved given an available workpiece for production and its process parameters.

[0039] Based on pre-loaded information, also the product geometry is analysed, so as to determine whether an adjustment to the geometry within acceptable tolerances, would be possible to produce given the current set of tooling. Moreover, the tooling available for exchange is analysed, so as to determine whether the original or alternative product geometries, as mentioned still within acceptable tolerances, would be possible to produce given the available tooling. Based on the above information and process optimisation, it is hence determined whether to keep current tooling configuration, adjust the product geometry within tolerance boundaries or exchange at least one tool to execute the currently applicable machining operation (S50, S60, S65). Calculation is also made of the optimum tooling configuration based on tooling availability.

[0040] Based on pre-loaded information, it is further determined whether to exchange and/or adjust the back gauge, clamping mechanism and/or fixture (S70), either manually or automatically.

[0041] Based on pre-loaded information, calculate whether to exchange and/or adjust gripping tools that position parts for machining (S90) and for suitably also for a subsequent stacking of produced parts. Calculation of the optimum gripping tools is used as a basis for a recommendation of manual adjustments and/or exchanges, which are presented to an operator. Alternatively, partly or fully automatic adjustments and/or exchanges may be executed by the machine with little or no active involvement of an operator.

[0042] The determination of whether the current machine configuration enables production of an item according to its process parameters (S40) also includes determination of other enabling requirements besides the tooling configuration. Examples of the requirements may be missing spare parts, missing tooling, need for maintenance, material quality, shape, dimension and/or material of a part to be manufactured. Process parameters and performance variables relating to the requirements are stored in the computer system, the computing system and/or a central computer which is connected or at least is connectable to a plurality of sources of data, and in connection with the machine. The requirements relating to a process to be executed may be responded to by issuance of a purchase order or operator recommendation. Such a purchase order may be issued automatically, i.e. without direct involvement of an operator, or as a recommendation presented to an operator, who is to execute the order accordingly. In case a production process results in products outside of the tolerance limitations, a supplementary production order may be placed without direct operator involvement so as to meet customer demands on quality and precision in the delivery.

[0043] Parts are identified before the machining operation by using any known identification method, such as computer vision or other image capturing technology, to identify geometries, defects and/or engraved, marked or other visual attributes of parts to be machined.

[0044] Back gauge, clamping mechanism and/or fixture are configured to avoid defects and/or visual marks from the previous operations from coming in direct contact with the back gauge. This allows the workpiece to be positioned correctly and in direct contact with its support when executing bending operations. Moreover, bending pressure is adapted so as to generate correct bending angles based on data from prior operations, by means of using a bending angle measuring system which is provided with feedback from prior operations, whereby every bend produced has an angle within acceptable tolerances.

[0045] Required attributes described above, i.e. composition, batch, sheet rolling direction-rotation, part rotation, part mirroring, clustering, common cut, lead-ins, micro joints, etc. are continuously monitored. In result of detected variation of any of the attributes, process parameters, i.e. bending position, bending pressure, crowning data, angle measurement data, back spring measurement data, positions of back gauge, clamping mechanisms and fixture, tools radius compensation, tooling condition etc., are correspondingly adjusted to ensure a correct position of the workpiece and machining resulting in parts with acceptable tolerances. By crowning is here meant a technique used to compensate for deviations along a bending line.

[0046] Parts may be visually inspected after the bending operation to identify geometries in combination with defects, visual attributes, such as bending lines, bulges and/or asymmetries created by the bending operation. In result of the identified defects or visual attributes, stacking of parts may be made to avoid placing defects between parts thus affecting the symmetry of the stack.

[0047] In parallel with the generation of operational data, the computing system (or central computer), which is be connected to or at least is connectable with plural sources of data, selects (S40) at least one optimization technique to define a function, a function which comprises the desired process parameters. This is followed by generation (S50) of a function for optimization by using the desired process parameters as a basis to define ranges for performance variables along with ranges for process parameters.

[0048] The generated function for optimization is applied (S60) whereby optimum operation performance criteria can be determined for the process model including process parameters and performance variables to obtain a set of requirements to be used for controlling the metal working process.

[0049] As soon as the optimum performance criteria have been determined, the resulting operational data is compared (S70) with the optimum operation performance criteria, and in case there is a difference, and the optimum performance criteria seems to provides a performance advantage to the operator or client, the result is presented (S80) to a decision-making entity. This decision-making entity, whether being a human operator, a computerised, fully or semi-automated service layer, is allowed to modify (S90) the desired process parameters based on the presented optimum operation performance criteria for the metal working process. The decision-making entity may also be realized in the form of an application (app) for a smartphone, preferably the same or an app similar to the one mentioned in connection with the step of inputting desired parameters.

[0050] If the decision-making entity decides to modify process parameters comprised in the presented information (Yes), the proposed operational sequence is adopted by the industrial machine system. In case the decision-making system decides not to accept the proposal (No), the sequence continues in that the originally generated operational data is applied (S100). Whichever decision is made, the sequence continues to the starting point (S10) or end point (S110). Modified data may further be used in different applications such as CAD, CAM, ERP, MES, CRM, Sourcing management etc. The present invention is also applicable within areas such as purchasing and optimization of machine performance criteria, criteria which may be defined as instructions and/or a program of instructions for the control an industrial machine, such as a CNC machine tool.

[0051] Figure 2 graphically illustrates a first embodiment of the invention. The system comprises a machine 1, which may be a machine for beam cutting (2- or 3-dimensional), punching, punch pressing, press-breaking, bending, gluing, sewing, tape and fibre placement, milling, drilling, turning, routing, picking and placing and combinations of such machines. Beam cutting includes techniques such as laser, welding, friction stir welding, ultrasonic welding, flame and plasma cutting, pinning and sawing.

[0052] The machine comprises an actuator system 2 for performing an industrial operation. The actuator system comprises at least one actuator, i.e. a motor for linear or rotational movement. Typically, the actuator system is configured for performing two-dimensional or three-dimensional movements of an operational part of the machine and a workpiece relative to each other.

[0053] The actuator system is controlled by an actuator controller 3 in the form of a CNC/NC/PLC unit and/or related sensing and processing equipment. The actuator controller controls the actuator on a low level, i.e. by sending low level control commands for the actuation of the actuator system. The actuator system is connected to the actuator controller via a machine internal communication network 4, e.g. including a communication bus.

[0054] The machine optionally comprises other systems, such as a sensor system 10 for sensing various processing parameters of the machine and other controllers 11 for processors, networks, communication links or other computing devices for transmitting data and making decisions. These systems may also be connected to a machine common internal communication network 4 and to the computing system in connection with the machine, such that the machine controller is connected to the sensor system to receive sensor data. The machine controller may be further configured to remotely control the actuator system of the machine in response to the sensor data.

[0055] As an alternative configuration, the CNC/NC/PLC unit and/or related sensing and processing equipment as well as the mentioned machine controller may be physically attached to or otherwise included in the industrial machine. The industrial machine then forms an independent and self-contained industrial machine system, wherein the machine controller forms an essential and physically connected part of the machine. Both of the two alternative embodiments of industrial machine systems have their respective advantages, and for the purpose of the present invention, integrated or remote configurations of sensor system and actuator controller are both equally applicable.

[0056] The machine may also comprise a communication client 5 connected to the actuator controller 3 for establishing communication with a computing system 6 in connection with the machine, when configured according to the remote alternative. The communication client is then a functional unit which enables the machine or any sub-component of the machine to communicate with the machine controller. The computing system in connection with the machine may be a cloud-based computing system connected to the internet. A centrally arranged computer in connection with or connectable to a plurality of data sources is an alternative embodiment. The communication client 5 and the computing system in connection with the machine may be configured to establish secure communication 7 with each other over the internet, for instance by initiating encrypted communication by HTTPS/TSL or by establishing a VPN (virtual private network). Alternatively, the communication may be established over a firewall or a proxy server 8. As a further alternative, any sub-component of the machine, such as the actuator controller 3, may be configured to connect to the computing system 6 in itself, or alternatively to the mentioned central computer with access to multiple data sources, but as mentioned both remote and integrated configurations are equally applicable for this purpose.

[0057] The mentioned computing system 6 in connection with the machine comprises a machine controller 9, wherein the machine controller may be remotely connected to the machine, and wherein the machine controller may be configured to control the actuator system of the machine remotely via the actuator controller by modifying operational parameters of the actuator controller.

[0058] The machine controller 9 is hosted in a virtual machine in the remote computing system 6. In that way the machine controller resource may be exploited in an efficient way. The machine controller may e.g. be configured to read and execute machine program code, control machine parameters, allow manual control or adjustments of machine parameters, and function as an interface to associated systems. The machine controller is connected to a HMI (Human-Machine Interface) unit 12 which may be remotely connected to the machine controller via an internet connection 13 and in another embodiment is integrated with the machine. Either way, an operator of the machine may supervise and control the operation of the machine from a remote location, e.g. connected to the internet. The HMI unit 12 and/or remote computing system 6 may be configured to require user identification of an operator, e.g. by requiring passwords or other identification means.

[0059] One alternative embodiment of the invention as illustrated in figure 2. Locally on the machine 1, an actuator system 2, comprising actuators for performing machining operations is included. An actuator controller 3 is part of or connected to the actuator system 2. The actuator controller is configured to receive instructions from the remote machine controller and execute instructions block by block in a closed loop system. Each task performed by an actuator is hence monitored and after a completed sub-operation, the actuator will perform the next sub-operation until a whole operation is completed. This means that the operation of the actuators of the machine is controlled by the actuator controller on a low level. The actuator controller typically includes a memory and a processor in order to save and execute instructions and to log data. The actuator system does not involve a conventional machine controller or HMI. The actuator system of the machine is hence dependent on receiving instructions from the remote machine controller. Once a complete set of work instructions or a defined sub-set thereof have been received and verified it may however be executed without further instructions from the machine controller. A sub-set of work instructions may be a part of a complete machine operation, but at least involves enough information for the actuator system to perform a part of a complete operation. The operation is preferably performed step by step in a closed loop system within the machine. The machine is only furnished with simple functions such as an emergency stop button and an on/off button. Other than that the machine is dependent on commands from the remote machine controller to operate.

[0060] The machine controller is physically located remote from the machine, typically in the cloud. The monitoring of an ongoing process, loading of instructions, modification of instructions and creating new instruction may only be made at the remote machine controller. Hence, the inventive machine controller corresponds to a conventional machine controller, only it is not a physical part of the machine but remote connected to the machine. The instructions monitored and controlled by the machine controller and the interconnected HMI include operational parameters such as cutting velocity, cutting depth, pressure and so on.

[0061] The machine controller is not part of the closed loop system of the actuator controller. Hence, unless new instructions are sent from the machine controller, the actuator system at the machine will conclude a fully received operation instruction without awaiting further instructions, unless specific instructions to conclude or alter the operation are received from the machine controller. Typically though, instructions are only provided for a full operation and new instruction will therefore only count for subsequent operations, not ongoing operations. This may be set as a safety arrangement but is up to the operator to decide which type of operational security should be implemented.

[0062] The machine controller is configured to send instructions, instruction per instruction, or several instructions in a batch system. Any conventional manner of sending information may be utilized. The machine controller is further configured to receive information and make decisions based on said information. For example, the machine controller may act on feedback data and make decisions and/or send new instructions based on said feedback.

[0063] The inventive system provides for a possibility of remote controlling of an industrial machine, without risking that commands are lost as a consequence of bad communication due to for instance latency in the internet connection. This is made sure e.g. because an operation is received and acknowledged in full at the actuator controller.

[0064] In order to facilitate surveillance, the machine comprises a surveillance unit 14, such as a camera, video camera or other image capturing means, for monitoring operations by the machine. The surveillance unit is connected to the remote computing system 6 via the communication client 5 and configured to provide operational information to the remote computing system. The operational information is processed and transmitted to the HMI 12.

[0065] The machine controller is configured to receive a machine program from a CAD/CAM system or by manual entry from an operator, e.g. via the HMI unit 12.

[0066] In one embodiment the remote computing system is configured to monitor an operational parameter of the machine, and disable the remote control of the actuator system of the machine by the machine controller when the operational parameter exceeds a threshold value. Such an operational parameter may be the operating time, the number of operational cycles performed by the machine etc. Thus the operational costs and the use of the machine may be controlled and limited by limiting access to the machine controller.

[0067] The remote computing system is configured to collect machine and/or production data and transfer the data to another system (not shown) for data analysis and/or optimization. The machine data may be used to e.g. optimize the supply chain (purchase, manufacturing, distribution), the demand chain (marketing, sales, service), machine maintenance or for other big data applications.

[0068] The surveillance unit may also be configured for monitoring produced items and their various properties, including their tolerances. Computer vision is another term used in the industry for this identification of properties related to geometry. By tolerances is meant material properties, such as hardness, toughness, size, shape, product geometries, such as radii, angles and dimensions, and production defects, such as, bulges, bending lines, pressure deformations and/or other visual attributes. The surveillance unit may further be connected to the computing system 6 in connection with the machine, via the communication client 5 and configured to provide operational information to the computing system.

[0069] In one embodiment the computing system in connection with the machine is configured to monitor an operational parameter of the machine, and disable the remote control of the actuator system of the machine by the machine controller when the operational parameter exceeds a threshold value. Such an operational parameter may be the operating time, the number of operational cycles performed by the machine etc.

[0070] The computing system is configured to collect machine and/or production data and transfer the data to another system for data analysis and/or optimization. This system may be an enterprise resource planning system (ERP) of manufacturing execution system (MES) of any kind. The machine data may be used to for example optimize the supply chain, i.e. purchase, manufacturing and distribution; the demand chain i.e. marketing, sales and service; and maintenance of the machine or its integrated or remote parts. Machine data may also be made available for other systems, such as big data applications designed merge data and draw conclusions based on very large amounts of information.

[0071] Figure 3 displays an alternative embodiment of an industrial machine system according to the invention. The industrial machine system differs from what is described in relation to figure 1 in that the machine does not comprise an actuator controller. The actuator controller 3' is physically disconnected to the machine and comprised in the computing system 6 in connection with the machine. The computing system is connected to the machine via one or more data lines 7, e.g. over the internet, which may be encrypted. The machine 1 comprises at least one communication client 15 for establishing communication between the machine and the computing system 6 in connection with the machine. This communication client 15 is connected to the actuator system 2 of the machine, and thus called the actuator client. The client is configured to send and receive low level communication from the actuator controller to the actuator system. Similarly, the machine may optionally comprise a sensor communication client 16 for communicating any sensor data from the sensor system 10, and any further controller clients 17 for communicating with other controllers 11 in the machine. Similar to what is shown in relation to figure 2, the communication between the machine and the computing system in connection with the machine may be the established over a firewall or a proxy server.

[0072] Below will follow examples of the present invention, intended to further elucidate the function and working principles. As has been explained in connection with the background of the invention, traditional processes of production planning in accordance with prior art are sequential to their nature. This means that information to control a sequence is collected from a local database, and the production planning is made in response to instructions emanating from locally stored information. An example of this could be 1) retrieve an order, 2) select or create at least one controlling algorithm, 3) produce a part of a certain raw material quality, and 4) form a certain component by means of bending, milling, turning, etc., 5) deliver the component to a customer according to order specifications. As mentioned, this process is sequential, and data to control the process is collected from a local database.

[0073] The present invention, as has been previously described, utilizes various sources to collect information via the mentioned central computer, such as a batch of orders including geometric drawings, a batch of material, a batch of tools and a machine's existing configuration.

[0074] Information relating to the production process according to this specification generally comes from different sources, e.g. an ERP/MES, the machine, IoT information, CAD/CAM and one or more surveillance units. The information collected by means of a central computer, which is configured as an intermediate means, that is situated in-between various end-points. The end-points are typically sources of information that may or may not influence a production process, and are comprised of for example the previously mentioned ERP/MES, the machine, IoT information, CAD/CAM and surveillance units.

[0075] The central computer may either be a general purpose computer or the computer that is configured to function as the machine control. The central computer will always be connected, or is connectable, to at least two end-points comprising data, in order to obtain information subject to optimization. That is believed to be a minimum requirement in order to carry out and fully accomplish a non-sequential optimization process on multiple variables. Several methods of optimization may be used, based on combinatorics, dynamic variation, multivariate analysis etc. Any of the methods allow for non-sequential and non-linear optimization, and are well-suited for use in complex systems with large numbers of dynamic variables.

[0076] The present invention utilizes non-sequential optimization, which is a numerical process or method that is neither sequential nor linear as compared to traditional processes. Several of the steps in a production process may be subject to optimization. One example is geometry of parts to be produced, a geometry that may be modified to reduce tool changes, another example is scheduling jobs may be altered to reduce setup time provided that information is retrieved from for instance a machine, a surveillance unit and/or from IoT information sources, third and fourth examples are scheduling jobs that may be adjusted to reduce material changes, provided that information is gathered from at least two end-points, and information that can be read and reused from previous process steps, e.g. visual attributes via a surveillance unit or modification of tool combinations or the rotation of a part on its surface.

[0077] Other conceivable examples are to reconfigure machine tools, such as the back-gauge positioning, pressure, pressing position etc. or the ordering of tools, materials, maintenance, spare parts for reducing production disruptions.

[0078] One of the prerequisites to making this type of optimization is to allow retrieval of data from a variety and a plurality of sources e.g. ERP/MES, the machine and its configuration, IoT information, CAD/CAM, surveillance unit. Information is then collected in and made available from the central computer in order to allow for optimization of several separate process steps in relation to their current status, including dynamic influences that are not controllable, since being dependent circumstances on out of reach, such as updates in a management system.

[0079] The present invention may also introduces control of the so-called modifiability and customizability in various end-points (data sources), such as ERP/MES, the machine and its configuration, IoT information, CAD/CAM (both with respect to design and configuration) and at least one surveillance unit. For example, by means of the present invention, it is possible to change the materials specification as a measure to potentially reduce material and tool changes, the mandatory tolerance intervals and relevant ranges of strength and solidity. In accordance with another embodiment of the invention, it is also possible to change the product geometry/shape to minimize tool changes but still maintain tolerances from drawings or as an alternative, on which coordinates visual marks exist that can be back gauge positioned for complete avoidance. Is may also be possible to schedule jobs to reduce material/tool replacement while keeping the delivery time. This allows communication with the customer so as to possibly allow the delivery time to be a variable influencing the price of the produced item. In order to achieve those options and new opportunities, two or more end points must be able to control in a non-sequential fashion, e.g. via the machine tool, via IoT information and a database in ERP/MES to schedule orders, tools, materials change, change product geometry. For instance, an amendment to the geometry that may lead to a reduction or minimization of tool changes can be checked against any form of tolerance interval in a drawing that can be available in ERP/MES or even available at a customer or designer as a variable influencing the ration between production cost and market price.

[0080] As has become apparent based on the above, the present invention is differentiated from traditional prior art process planning by means of MES systems of production scheduling that are configured to retrieve information from a local database. Those systems may even be based on the functionality that an operator keys in data on orders and delivery, which is followed by sequential scheduling. The present invention is based on an entirely different level of optimization based on actual, even real time data, a central computer that retrieves, a computer that also in some cases may share information. The central computer is connected or connectable to two or more end points, such as ERP, MES, CAD, CAM, machine, IoT information sources, at least one CRM management system and/or surveillance unit. In addition to that, the central computer may also be connected or connectable to other providers of information relating to multiple variables influencing production, such as materials, tooling, spare parts, maintenance, design, specification or customers of parts, constructions and/or products.

Claims

1. A computer-controlled method for selecting optimum operation performance criteria for a metal working process, said method comprising the steps of:

    retrieving process parameters from multiple sources relating to the metal working process,
    retrieving performance variables from different sources relating to the metal working process, comprising performance variable data from previous operations and performance variable data for subsequent operations,
    storing the process parameters and performance variables in a consolidated memory in association with a computer system,
    making the process parameters and performance variables available for application of optimization techniques to select optimum operation performance criteria,
    providing a process model that relates process parameters for the operation with performance variables for said operation,
    selecting at least one optimization technique and defining a function, said function comprising of process parameters,
    generating the function for optimization with respect to productivity by using acceptable tolerances of a product to be machined as a basis to define ranges for performance variables along with ranges for process parameters, and
    applying the at least one optimization technique to said function, whereby optimum operation performance criteria are determined for the process model including process parameters and performance variables to obtain a set of commands to be used for controlling the metal working process.

2. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, the metal working process being any industrially applicable cutting technology based on laser, flames, plasma, water jet, ion, air, bending, pressing, punch pressing, press-breaking, milling, drilling and turning.

3. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein the metal working process relates to machining of sheet metal.

4. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein the process model is dynamically monitored and controlled in real time.

5. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein the set of requirements to be used for controlling the metal working process can be provided as recommendations to an operator or alternatively can be applied with partial or no operator involvement.

6. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, further comprising the steps of:

comparing retrieved process parameters (S20) relating to the metal working process from previous operations with a current machine configuration (S30) comprising parameters relating to tooling,
determining if the current machine configuration enables production of an item according to its process parameters (S40),
evaluating the applicability of the tooling configuration (S50), which when required, in a first optional step results in adjustments to the product geometry (S60) within acceptable tolerances, and in a second step results in adjustments to the tooling configuration (S65), and
whereby any adjustments made result in a new current machine configuration to be compared with parameters from previous operations (S30).

7. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, further comprising the steps of:

comparing retrieved process parameters (S20) relating to the metal working process from previous operations with a current machine configuration (S30) comprising parameters relating to clamping mechanism and/or gripping configuration,
determining if the current machine configuration enables production of an item according to its process parameters (S40),
evaluating the applicability of the clamping mechanism (S70), which when required results in adjustments to the clamping mechanism (S80), and/or
evaluating the applicability of the gripping configuration (S90), which when required results in adjustments to the gripping configuration (S100), and
whereby any adjustments made result in a new current machine configuration to be compared with parameters from previous operations (S30).

8. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein tools and/or produced items are embedded with electronics, software, sensors and/or network connectivity, which enables these objects to exchange data, such as process parameters and/or performance variables, with the computer system.

9. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein predefined and/or determined tolerances of produced items include any of the following performance variables:

material properties, such as hardness, toughness, size and thickness,
product geometries, such as radii, angles and dimensions, and
production defects, such as bulges, bending lines, pressure deformations and other visual attributes.

10. A method for selecting optimum operation performance criteria for a metal working process according to claim 1, wherein product geometries include data on bending curves, compensation factors and tooling preferences.

11. A method for selecting optimum operation performance criteria for a metal working process according to anyone of preceding claims, wherein the determination of whether the current machine configuration enables production of an item according to its process parameters (S40) in addition to the tooling configuration also includes determination of other enabling requirements, such as spare parts, tools, maintenance, material, shape and/or dimension, whereby corresponding process parameters and/or performance variables are stored.

12. An industrial machine system comprising:

a machine (1) comprising an actuator system (2) for performing an industrial operation,
a computing system (6) in connection with the machine, comprising a machine controller (9), and
the machine controller being adapted to carrying out the method according to anyone of claims 1-11.

13. Computer program product comprising computer program code, which when executed enables a processor in a computer to perform the method according to anyone of claims 1-11.

14. A non-transient computer-readable medium or media comprising data representing coded instruction sets configured for execution by a processor in a computer, the instructions comprising the method according to anyone of claims 1-11.

Patentansprüche

1. Computergesteuertes Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess, welches Verfahren die folgenden Schritte umfasst:

Abrufen von Prozessparametern aus einer Mehrzahl von Quellen bezogen auf den Metallbearbeitungsprozess,
Abrufen von Leistungsvariablen aus verschiedenen Quellen bezogen auf den Metallbearbeitungsprozess, umfassend leistungsvariable Daten aus vorherigen Betriebsvorgängen und leistungsvariable Daten für darauffolgende Betriebsvorgänge,
Speichern der Prozessparameter und Leistungsvariablen in einem einem Computersystem zugeordneten konsolidierten Speicher,
Zurverfügungstellung der Prozessparameter und Leistungsvariablen für die Anwendung von Optimierungstechniken zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien,
Bereitstellung eines Prozessmodells, das sich auf Prozessparameter für den Betriebsvorgang mit Leistungsvariablen für den Betriebsvorgang bezieht,
Auswählen mindestens einer Optimierungstechnik und Definieren einer Funktion, welche Funktion aus Prozessparametern besteht,
Erzeugen der Funktion für die Optimierung in Bezug auf die Leistungsfähigkeit durch die Verwendung von akzeptablen Toleranzen eines zu bearbeitenden Produkts als Grundlage für die Definition von Bereichen für Leistungsvariablen zusammen mit Bereichen für Prozessparameter, und
Anwendung der mindestens einen Optimierungstechnik auf die Funktion, wobei optimale Betriebsvorgangs-Leistungskriterien für das Produktmodell einschließlich Produktparameter und Leistungsvariablen festgelegt werden, um einen Satz von für die Steuerung des Metallbearbeitungsprozesses zu verwendenden Befehlen zu erzielen.

2. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei der Metallbearbeitungsprozess jede industriell einsetzbare Schneidtechnologie basierend auf Laser, Flammen, Plasma, Wasserstrahl, Ion, Luft, Biegen, Pressen, Lochstanzen, Pressbrechen, Fräsen, Bohren und Drehen ist.

3. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei sich der Metallbearbeitungsprozess auf die Bearbeitung eines Metallblechs bezieht.

4. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei das Prozessmodell dynamisch überwacht und in Echtzeit gesteuert wird.

5. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei der Satz von für die Steuerung des Metallbearbeitungsprozesses zu verwendenden Bedingungen als Empfehlungen für einen Betreiber bereitstellbar ist oder alternativ mit teilweiser oder keiner Einwirkung eines Betreibers anwendbar ist.

6. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, ferner umfassend die folgenden Schritte:

Vergleichen abgerufener Prozessparameter (S20) bezogen auf den Metallbearbeitungsprozess aus vorherigen Betriebsvorgängen mit einer gegenwärtigen Maschinenkonfiguration (S30) umfassend auf Werkzeugbereitstellung bezogene Parameter,
Bestimmen, ob die gegenwärtige Maschinenkonfiguration die Herstellung eines Gegenstandes gemäß deren Prozessparametern (S40) ermöglicht,
Auswerten der Anwendbarkeit der Werkzeugbereitstellungskonfiguration (S50), was bei Bedarf in einem ersten optionalen Schritt zu Anpassungen der Produktgeometrie (S60) innerhalb akzeptabler Toleranzen führt und in einem zweiten Schritt zu Anpassungen der Werkzeugbereitstellungskonfiguration (S65) führt, und
wobei jegliche vorgenommenen Anpassungen zu einer neuen gegenwärtigen, mit Parametern aus vorherigen Betriebsvorgängen (S30) zu vergleichenden Maschinenkonfiguration führen.

7. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, ferner umfassend die folgenden Schritte:

Vergleichen abgerufener Prozessparameter (S20) bezogen auf den Metallbearbeitungsprozess aus vorherigen Betriebsvorgängen mit einer gegenwärtigen Maschinenkonfiguration (S30) umfassend auf Klemmmechanismus und/oder Greifkonfiguration bezogene Parameter,
Bestimmen, ob die gegenwärtige Maschinenkonfiguration die Herstellung eines Gegenstandes gemäß deren Prozessparametern (S40) ermöglicht,
Auswerten der Anwendbarkeit des Klemmmechanismus (S70), was bei Bedarf zu Anpassungen des Klemmmechanismus (S80) führt
und/oder Auswerten der Anwendbarkeit der Greifkonfiguration (S90), was bei Bedarf zu Anpassungen der Greifkonfiguration (S100) führt, und
wobei jegliche vorgenommenen Anpassungen zu einer neuen gegenwärtigen, mit Parametern aus vorherigen Betriebsvorgängen (S30) zu vergleichenden Maschinenkonfiguration führen.

8. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei Werkzeuge und/oder hergestellte Gegenstände mit Elektronik, Software, Sensoren und/oder Netzwerkkonnektivität eingebettet sind, was diesen Objekten ermöglicht, Daten wie beispielsweise Prozessparameter und/oder Leistungsvariablen mit dem Computersystem auszutauschen.

9. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei vorgegebene und/oder bestimmte Toleranzen von hergestellten Gegenständen jede der folgenden Leistungsvariablen mit einschließen:

Materialeigenschaften wie beispielsweise Härte, Zähfestigkeit, Größe und Dicke,
Produktgeometrien wie beispielsweise Radien, Winkel und Abmessungen und
Fertigungsfehler wie beispielsweise Beulen, Biegelinien, Druckverformungen und andere visuelle Attribute.

10. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach Anspruch 1, wobei Produktgeometrien Daten über Biegekurven, Kompensationsfaktoren und Werkzeugpräferenzen beinhalten.

11. Verfahren zum Auswählen von optimalen Betriebsvorgangs-Leistungskriterien für einen Metallbearbeitungsprozess nach einem der vorhergehenden Ansprüche, wobei die Bestimmung, ob die gegenwärtige Maschinenkonfiguration die Herstellung eines Gegenstandes gemäß deren Prozessparametern (S40) zusätzlich zur Werkzeugbereitstelllung ermöglicht, ebenfalls die Bestimmung anderer Ermöglichungsbedingungen wie beispielsweise Ersatzteile, Werkzeuge, Pflege, Material, Form und/oder Abmessung umfasst, wobei entsprechende Prozessparameter und/oder Leistungsvariablen gespeichert werden.

12. Industriemaschinensystem umfassend:

eine Maschine (1) umfassend ein Aktuatorsystem (2) zur Ausführung eines industriellen Betriebsvorgangs,
ein mit der Maschine in Verbindung stehendes Rechensystem (6), umfassend eine Maschinensteuerung (9), und
welche Maschinensteuerung zur Durchführung des Verfahrens nach einem der Ansprüche 1-11 ausgelegt ist.

13. Computerprogrammprodukt umfassend einen Computerprogrammcode, der, wenn er ausgeführt wird, es einem Prozessor in einem Computer ermöglicht, das Verfahren nach einem der Ansprüche 1-11 durchzuführen.

14. Nichtflüchtiges, computerlesbares Medium oder Medien umfassend Daten, die kodierte Anweisungssätze darstellen, die zum Ausführen durch einen Prozessor in einem Computer ausgelegt sind, welche Anweisungen das Verfahren nach einem der Ansprüche 1-11 umfassen.

Revendications

1. Procédé commandé par ordinateur pour sélectionner des critères de performance de fonctionnement optimal pour un processus de travail métallique, ledit procédé comprenant les étapes consistant à :

récupérer des paramètres de processus à partir de multiples sources se rapportant au processus de travail métallique,
récupérer des variables de performance à partir de différentes sources relatives au processus de travail métallique, comprenant des données variables de performance provenant d'opérations précédentes et de données variables de performance pour des opérations ultérieures,
stocker les paramètres de processus et les variables de performance dans une mémoire consolidée en association avec un système informatique,

rendre les paramètres de processus et les variables de performance disponibles pour l'application de techniques d'optimisation pour sélectionner des critères de performance de fonctionnement optimal,

fournir un modèle de processus qui concerne des paramètres de processus pour l'opération avec des variables de performance pour ladite opération,

sélectionner au moins une technique d'optimisation et définir une fonction, ladite fonction comprenant des paramètres de processus,

générer la fonction d'optimisation par rapport à la productivité en utilisant des tolérances acceptables d'un produit à usiner en tant que base pour définir des plages pour des variables de performance conjointement avec des plages pour des paramètres de processus, et

appliquer l'au moins une technique d'optimisation à ladite fonction, par laquelle les critères de performance de fonctionnement optimal sont déterminés pour le modèle de processus comprenant des paramètres de processus et des variables de performance pour obtenir un ensemble de commandes à utiliser pour commander le processus de travail métallique.

2. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, le processus de travail métallique étant toute technologie de coupe applicable industriellement basée sur laser, flammes, plasma, jet d'eau, ion, air, courbure, pression, pression de poinçon, rupture par pression, fraisage, forage et rotation.

3. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel le processus de travail métallique concerne l'usinage de tôle.

4. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel le modèle de processus est surveillé de manière dynamique et commandé en temps réel.

5. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel l'ensemble d'exigences à utiliser pour commander le processus de travail métallique peut être fourni en tant que recommandations à un opérateur ou peut en variante être appliqué avec une implication d'opérateur partielle ou nulle.

6. Procédé commandé par ordinateur pour sélectionner des critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, comprenant les étapes consistant à :

comparer les paramètres de processus récupérés (S20) relatifs au processus de travail métallique à partir d'opérations précédentes avec une configuration de machine actuelle (S30) comprenant des paramètres relatifs à l'outillage,

déterminer si la configuration de machine actuelle permet la production d'un article en fonction de ses paramètres de processus (S40),

évaluer l'applicabilité de la configuration d'outillage (S50), qui, si nécessaire, dans une première étape facultative, aboutit à des ajustements de la géométrie de produit (S60) dans des tolérances acceptables, et dans une deuxième étape, aboutit à des ajustements de la configuration d'outillage (S65), et

tout ajustement effectué aboutissant à une nouvelle configuration de machine actuelle à comparer avec des paramètres provenant d'opérations précédentes (S30).

7. Procédé commandé par ordinateur pour sélectionner des critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, comprenant les étapes consistant à :

comparer les paramètres de processus récupérés (S20) relatifs au processus de travail métallique à partir d'opérations précédentes avec une configuration de machine actuelle (S30) comprenant des paramètres relatifs au mécanisme de serrage et / ou à la configuration de préhension,

déterminer si la configuration de machine actuelle permet la production d'un article en fonction de ses paramètres de processus (S40),

évaluer l'applicabilité du mécanisme de serrage (S70), qui, si nécessaire, aboutit à des ajustements du mécanisme de serrage (S80), et / ou évaluer l'applicabilité de la configuration de préhension (S90), qui, si nécessaire, aboutit à des ajustements de la configuration de préhension (S100), et

tout ajustement effectué aboutissant à une nouvelle configuration de machine actuelle à comparer avec des paramètres provenant d'opérations précédentes (S30).

8. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel des outils et / ou des articles produits sont intégrés à l'électronique, à un logiciel, à des capteurs et / ou à une connectivité de réseau, ce qui permet à ces objets d'échanger des données, telles que des paramètres de processus et / ou des variables de performance, avec le système informatique.

9. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel des tolérances prédéfinies et / ou déterminées d'articles produits comprennent l'une quelconque des variables de performance suivantes :

des propriétés de matériau, telles que la dureté, la ténacité, la taille et l'épaisseur,
des géométries de produit, telles que des rayons, des angles et des dimensions, et
des défauts de production, tels que des renflements, des lignes de flexion, des déformations de pression et d'autres attributs visuels.

10. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon la revendication 1, dans lequel des géométries de produit comprennent des données sur des courbes de courbure, des facteurs de compensation et des préférences d'outillage.

11. Procédé de sélection de critères de performance de fonctionnement optimal pour un processus de travail métallique selon l'une quelconque des revendications précédentes, dans lequel la détermination du fait que la configuration de machine actuelle permet la production d'un article selon ses paramètres de processus (S40) en plus de la configuration d'outillage comprend également la détermination d'autres exigences d'activation, telles que des pièces de rechange, des outils, une maintenance, un matériau, une forme et / ou une dimension, des paramètres de processus et / ou des variables de performance correspondants étant stockés.

12. Système de machine industrielle, comprenant :

une machine (1) comprenant un système d'actionneur (2) pour effectuer une opération industrielle,
un système informatique (6) en connexion avec la machine, comprenant un contrôleur de machine (9), et
le contrôleur de machine étant adapté pour mettre en oeuvre le procédé selon l'une quelconque des revendications 1 à 11.

13. Produit de programme informatique comprenant un code de programme informatique, qui, lorsqu'il est exécuté, permet à un processeur dans un ordinateur d'exécuter le procédé selon l'une quelconque des revendications 1 à 11.

14. Support ou supports lisibles par ordinateur non transitoires comprenant des données représentant des ensembles d'instructions codés configurés pour une exécution par un processeur dans un ordinateur, les instructions comprenant le procédé selon l'une quelconque des revendications 1 à 11.

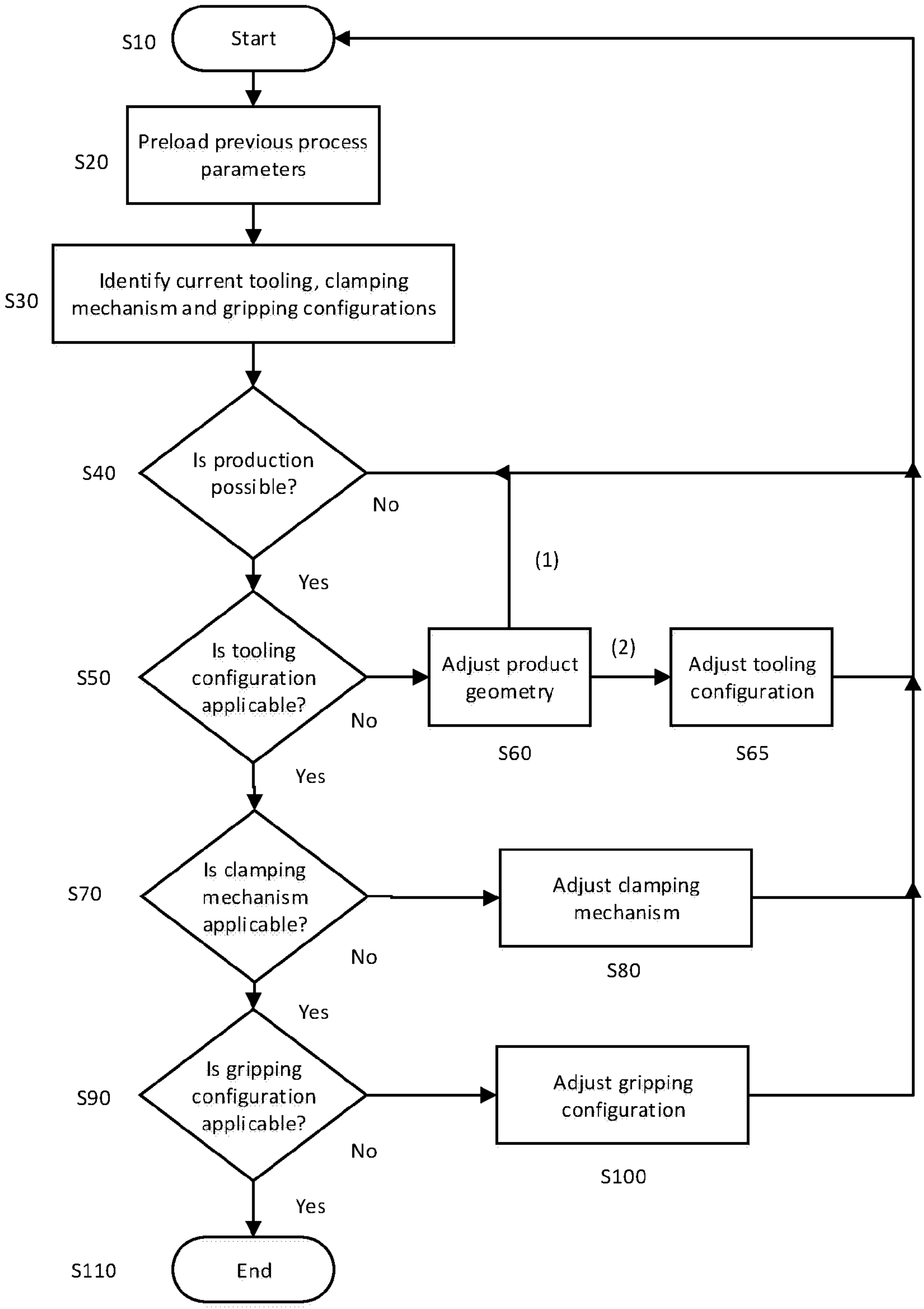
S10
Start
S20
Preload previous process parameters
S30
Identify current tooling, clamping mechanism and gripping configurations
S40
Is production possible?
No
Yes
(1)
S50
Is tooling configuration applicable?
No
Adjust product geometry
(2)
Adjust tooling configuration
S60
S65
Yes
S70
Is clamping mechanism applicable?
No
Adjust clamping mechanism
S80
Yes
S90
Is gripping configuration applicable?
No
Adjust gripping configuration
S100
Yes
S110
End

Fig. 1

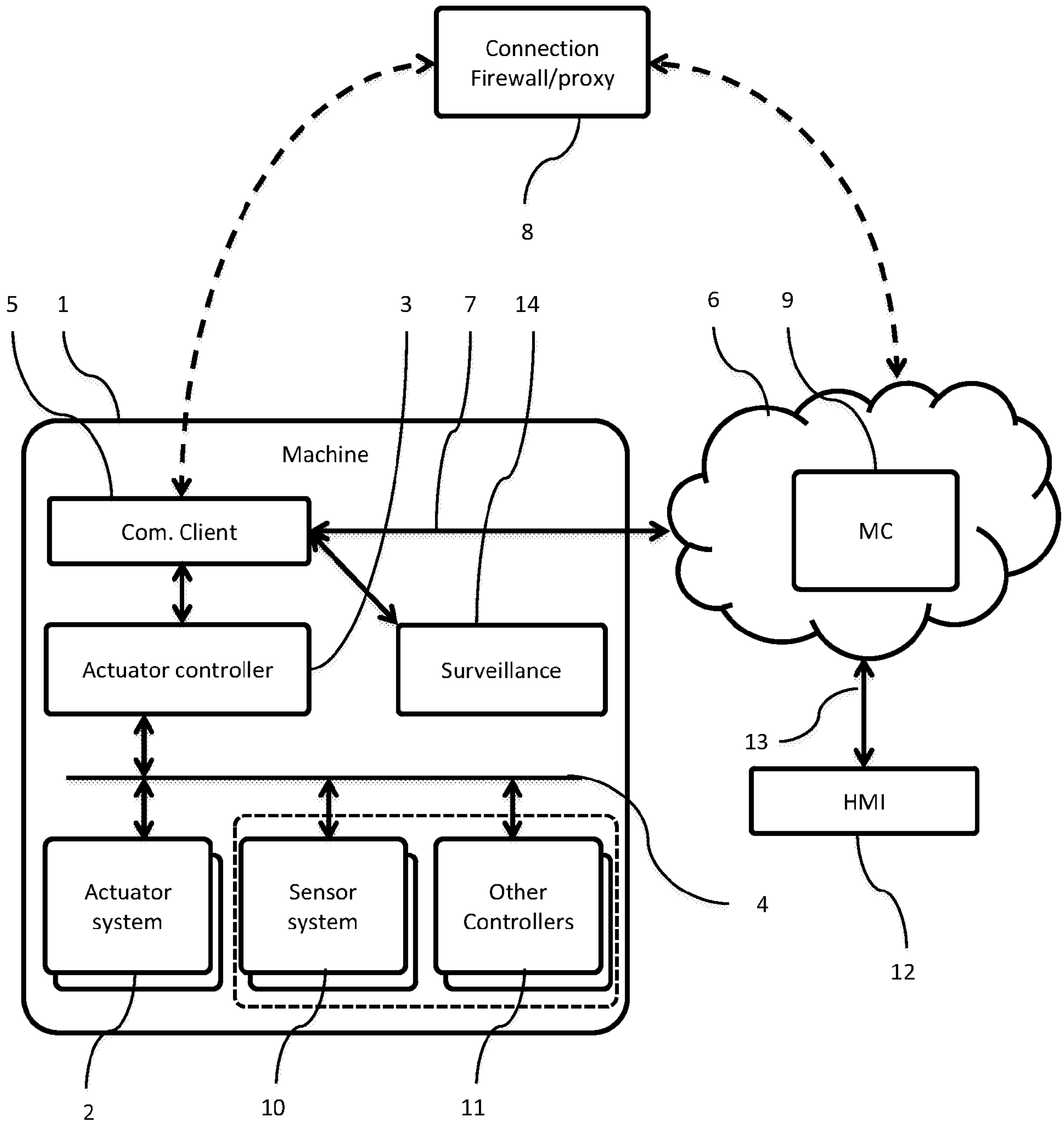
Connection
Firewall/proxy
8
5
1
3
7
14
6
9
Machine
Com. Client
MC
Actuator controller
Surveillance
13
HMI
Actuator
system
Sensor
system
Other
Controllers
4
12
2
10
11

Fig. 2

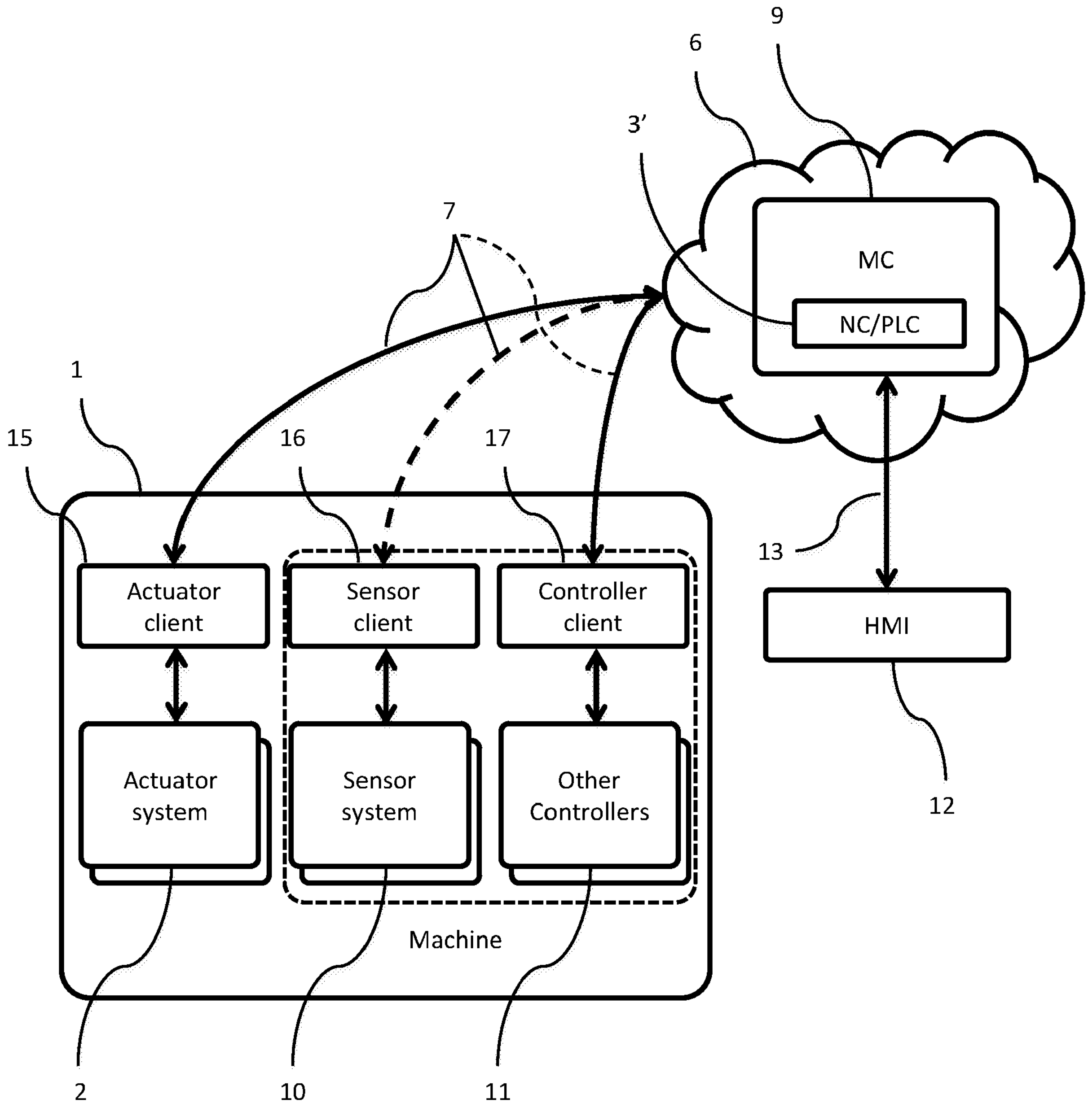
9
6
3'
7
MC
NC/PLC
1
15
16
17
13
Actuator client
Sensor client
Controller client
HMI
Actuator system
Sensor system
Other Controllers
12
Machine
2
10
11

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2011042058 A **[0010]**
- US 2015205289 A **[0010]**