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AUTOMATICALLY OPERABLE MANUFACTURING PLANT

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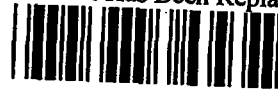
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The present invention refers to an automatically operable manufacturing plant, comprising a plurality of machining cells, a management system for work pieces including storage appliances, transporting appliances and handling appliances, and a data handling and exchange system adapted to control the manufacturing plant.

Particularly, the present invention refers to an automatically operable manufacturing plant, comprising numerically controlled machining tools, control units each individually assigned to the machining tools, tools for the complete machining of work pieces, magazines for storing the tools and work pieces, handling apparatuses assigned to the machining tools for feeding work pieces to the machining tools and for exchanging the tools of the machining tools, and at least one measuring station adapted to prealign the work pieces and tools, respectively, and to examine the condition of the work pieces and tools, respectively.

Such manufacturing plants are known with all the components typical for such plants, for example from the patent documents Nr. EP-A2-0 364 138 and Nr. DE-A1-37 20 157, in which also different solutions for the control of the manufacturing process are indicated.

In the manufacturing plant according to the patent document Nr. EP-A2-0 364 138, there is provided for the control of the manufacturing process an information flow system with several data networks in a hierarchic structure. These data networks serve for exchanging program data between a central processing unit and the control units of the machining units as well as the control units of the material transport system. Such an information flow system, in which all control programs are handled in a central processing unit, has different disadvantages.



First, the installation of machining programs in the central processing unit as a preparation for the automatic manufacturing is quite complicated, particularly if many different work pieces in small lots have to be manufactured. Second, each interruption of the manufacturing process requires a modification or adaptation of the control program in the central processing unit. Such modifications always require a certain amount of time with the result that the production process is interrupted for a shorter or longer period.

A manufacturing plant which is improved in this respect is disclosed in the patent document Nr. DE-A1-37 20 157. In the solution described therein, the central processing unit serves but for the control of those processes which are required for the operation of the automatic manufacturing plant. Particularly, the central processing unit does not provide any machining programs and no instructions about the order of machining. Rather, to each work piece to be machined is fixedly assigned a data memory unit which, amongst else, contains the appropriate machining program. This program is read into the control unit of a machining tool as soon as the work piece is transmitted to the machining station. The disadvantage of such a information flow system is that for the above mentioned purpose quite bulky data memory units must be provided on each work piece and on each pallet bearing a work piece, respectively. In order to provide for a friction less operation, it is moreover imperative that all machining stations of a manufacturing plant make use of a uniform operating system, because a translation of the voluminous data protocols would be too complicated.

It is an object of the present invention to provide, in connection with the monitoring and the control of the manufacturing operation of such a manufacturing plant, a powerful system for the flow of information between the different parts and units of the plant and the work pieces and tools, which renders possible in a relative simple manner a flexible, particularly order-related manufacture of many work pieces in relatively small



lots. Particularly, it is the object of the invention to improve the identification system. Moreover, the information system should be in a position to transmit also other information, e.g. control information for the manufacture.

This object can be met by the fact that the data handling and exchange system comprises two separate data networks, i.e. a first external data handling and exchange network with a central data processing unit for the exchange of operation control data between the central data processing unit and the machining cells and for the exchange of transportation control data between the central processing unit and the transporting appliances, and a second internal data handling and exchange network for exchanging data between the storage appliances, the transporting appliances and the handling appliances. Memory modules are fixedly assigned to the work pieces to be machined and contain data for the identification of the work piece to be machined, destination data for the transport of the work pieces to be machined, and data for fetching machine programs used for the machining of the work piece to be machined whereby the data contained in the memory modules are processed by the aforementioned second internal data handling and exchange network.

Thus, with the provisions according to the invention, the data compound in the entire information network of the machining and manufacturing plant can be tied together without a gap.

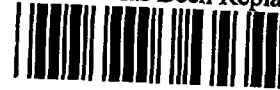
A practical solution can be seen, for instance, by the fact that the work pieces or the tool means are mounted on the pallet means individually or in groups, the pallet means comprising uniform positioning means which serve to fix the pallet means in the machining tools in an exactly predetermined position, the work pieces or tool means remaining mounted on the pallet means on their way through the manufacturing plant until the work pieces are fully finished, that the pallet of the work pieces and of the tools are provided with electronic memory modules in which data relating to the identification of the



work pieces or tools as well as data relating to the automatic machining can be stored, and that the handling means and the measuring station is provided with data processing means adapted to read the data stored in the memory modules, whereby the data processing means are communicatively interconnected with the control units of the machining stations.

According to a preferred embodiment, the manufacturing plant of the invention comprises a plurality of machining stations each containing at least one numerically controlled machining tool, with a plurality of pallet means adapted to receive work pieces to be machined or tool means for the machining of the work pieces, with a set-up station for loading the pallet means, with a plurality of transportable magazine means adapted to receive the pallet means loaded with the work pieces or tool means, with a transfer station for loading pallet means into the transportable magazine means and for unloading pallet means from the transportable magazine means, with a storing station for the transportable magazine means loaded with the pallet means, and with an automatically operating transporting means for transporting the magazine means loaded with the pallet means on a traffic network interconnecting the different stations with each other, whereby

- a) each of the machining stations comprises a handling means for transferring the pallet means between the magazine means and the machining tool;
- b) each of the machining tools comprises a control unit incorporating a first memory means for storing a plurality of machining programs;
- c) an external data handling and exchange network with a central data processing unit is provided, by means of which the control units assigned to the machining tools are connected with a central data processing unit and;



d) each pallet means comprises a memory means in which data for the identification of the work piece or tool means mounted on the pallet means and data for the machining of the work piece mounted on the pallet means are stored;

e) each pallet magazine comprising a memory means in which data for the identification of the content of the magazine and data for the transport thereof are stored;

f) an internal data handling and exchange network for exchanging data between the memory means provided on the pallet means and the memory means provided on the transportable magazine means on the one side and the different stations and the transporting means on the other side; and

g) a uniform interface means provided in each of the machining stations for interconnecting the handling means and the control unit of the machining tool, the interface means comprising means for translating the data protocol of the second internal data exchange and handling network into the data protocol of the control unit of the assigned machining tool.

The use of work piece and tool pallets incorporating uniform mechanical positioning means forms a good basis for the application of the identification system according to the invention. Thereby, particularly as far as the work piece pallets are concerned, the pallets can be adapted either to receive only one individual work piece or to receive a group of identical work pieces.

In contrary to the identification systems known in the prior art which operate with regard to the position of the work pieces and tools on the basis of a location code system, the identification system according to the invention allows the reliable identification of the work pieces and tools themselves. This fact not only substantially increases the safety against inadvertent confusions of the relation of the data and the work



pieces and tools, respectively, but renders possible a disordered storage of the work pieces and tools in the magazines.

The reliable identification of the components (work pieces and/or tools) is the basis that the individual components can be provided with additional information, particularly informative data representative for the transport destination position of the work piece and/or tool and data representative for the fetching of machining programs required for the machining of the individual work piece. Only work piece pallets and tool pallets carrying such data with them and being in a position to transmit these data to related control units render possible a fully automatic operation of a manufacturing plant incorporating a plurality of individual manufacturing and/or machining cells.

A particular advantage of the identification system according to the invention is that it is not necessary to store the machining data in the form of more or less complete control or machining programs for the machining tools required for the corresponding operation in their entirety in the memory modules of the pallets. In contrary, only data for the identification of the required control or machining program has to be stored in the memory modules of the pallets in order to call for the suitable control or machining program which is stored in a stationary memory of the control unit of the related machining tool as soon as a pallet is to be inserted into the machining tool. The result is that the size or volume of the data memory modules on the pallets can be quite small.

A particularly advantageous embodiment of the manufacturing plant according to the invention can be realized if the machining stations, the storing station, the transport vehicles and the transfer station each comprise uniform receiving means adapted to receive the transportable magazines. Thereby, the receiving means each incorporate a data processing unit with a data reading head for reading the data stored in the memory



modules provided on the transportable magazines. These data, in particular, include data representing a timetable for the pallet magazine informing about the location of the machining stations to which the pallet has to be transported and the order in which these machining stations have to be served.

As soon as a pallet magazine has been transferred to a transport vehicle, the next transport destination can be seen from the data contained in the memory module of the related pallet magazine. This information is sent to the control unit for the transport system which ensures that the related transport vehicle loaded with a certain pallet magazine is led to a certain machining station identified by the data contained in the memory module of the pallet. As the transport system is always informed about the next transport destination position, it is no longer necessary to store complete transport programs in the transport control unit. The result is that the control of the material transportation becomes much more simple, flexible and efficient.

The data handling and exchange system according to the invention further renders possible to take measures for an alteration of the transport timetable in a simple and efficient way, e.g. in the case when a certain destination position is already occupied or out of operation and, thus, cannot be approached. Such measures can be limited to a data exchange in the internal data handling and exchange network and do not require an alteration of the program of the central processing unit. A pallet magazine which cannot reach its predetermined destination can be deviated to the storage appliance where it temporarily stays. Therefrom, it can be called at a later time upon the occurrence of a data signal which represents the fact that the previously occupied or inoperative destination is now free or in operation again.

Preferably, the pallets and the pallet magazines comprise electronic read and write data memory modules ensuring that the



data contained in the electronic data memory modules can be changed during the manufacturing or machining process, e.g. for the modification of the data to adapt them to the actual state of machining. For this purpose, the data processing units in the handling appliances and the measuring station further comprises a writing head as well as a control and analyzing unit for controlling the reading and writing process of the memory modules.

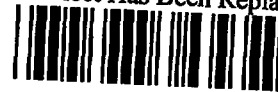
An important prerequisite for a trouble free operation of the manufacturing plant according to the invention is the safety of the data exchange. Considering the often rough conditions in the region of the machining cells with the disturbing influences of heat, oil, metal chips and cooling fluids, it is advantageous to use a system for the data exchange with touchless operation, preferably a wireless carrier frequency data exchange system.

As far as the power supply of the memory modules is concerned, it is advantageous to use non-powered memory modules whereby a system is provided for the wireless supply of power, which is required for the exchange of data between the data processing units and the memory modules, to the memory modules. Semiconductor memory modules of this kind are not expensive, relatively small and can be mounted in nearly any desired position. Preferably, an electric alternating current field is used for the transmission of energy to the electronic memory modules.

In the drawing, an embodiment of the invention is schematically shown; in the drawings:

Fig. 1 shows the overall general layout of the automatically operable manufacturing plant according to the invention; and

Fig. 2 details of a machining station and of a measuring station.



The manufacturing plant schematically shown in Fig. 1 comprises, for example, a set-up station 1 in which pallets are loaded, a transfer station 2 in which transportable pallet magazines are loaded and unloaded, a storing station 3 for pallet magazines, four machining stations 4 and a traffic network 5 interconnecting the different stations to each other.

The set-up station 1 includes a mounting station 6 in which the work pieces and the tools are mounted on pallets, as well as a measuring station 7 in which the geometrical data of the work pieces and tools mounted on the pallets are determined.

In the transfer station which comprises two bins 8 each for one pallet magazine, on the one side, arriving pallet magazines having pallets with finally machined work pieces are unloaded and, on the other side, still empty pallet magazines are loaded with pallets having work pieces to be machined or tools mounted thereon.

The storing station 3 comprises a plurality of storage bins, in the present example five storage bins 9, in which empty and/or loaded pallet magazines are temporarily stored.

In the present example, each of the machining stations 4 comprises a machining tool 10, usually in the form of a numerically controlled machining apparatus, a bin 11 for a pallet magazine and a handling and manipulating apparatus 12 for loading work pieces into the machining apparatus and for inserting and removing tools into and from, respectively, the machining apparatus.

The traffic network 5 is part of an automatically operated transporting installation which comprises a central transport control station 13, a remote control system 14 and a plurality of remote-controlled vehicles 15 which are disposable at the moment when they are required. In particular, the traffic network consists of a number of different, preferably rail-less



tracks along which the vehicles 15 are guided, whereby there is provided a closed loop main track 16 running along the transfer station 2, the storing station 3 and the four machining stations 4, as well as a number of separate track loops 17 running to each storage bin 8, 9 and 11. Thus, several vehicles 15 can circulate on the traffic network simultaneously without hindering each other. Further, a number of parking tracks 18 is provided for vehicles 15 not in use.

The information handling and exchange system comprises two separate data networks, namely a first external data handling and exchange network 19 and a second data handling and exchange network 20. The external data handling and exchange network 19 interconnects the control units of the numerically controlled machining tools 10 of each machining station 4 and the transport control station 13 with a central operational data processor 21 and is provided for the handling and exchange of operational control data between the operational data processor 21 and the control units of the numerically controlled machining tools 10, and for the handling and exchange of transport control data between the operational data processor 21 and the transport control station 12. The external data handling and exchange network 19 can be part of a data processing system known under the trade name "ETHERNET" to which can be connected, besides the operational data processor 21, e.g. a operational planning system.

The internal data handling and exchange network 20 interconnects the divisions of the machining and manufacturing plant which are part of the material transportation and storage systems, i.e. the storing station 2, the handling apparatuses 12 and the vehicles 15. Particularly, all storage bins 8 of the transfer station, all storage bins 9 of the storage station 3 and the storage bins 11 of the machining stations 10 as well as the remote control system 14 for controlling the vehicles 15 are interconnected to each other by means of the internal data handling and exchange network 20. For the exchange of data be-



tween the bins for the pallet magazines 11 and the handling devices 12 of the machining stations 4 on the one side and between the transport control station 13 and the remote control system 14 on the other side, there are provided data lines 22 and 23, respectively. Furthermore, in each machining station 4, the handling apparatus 12 is connected with the control unit of the machining tool 10 via an interface 24 which includes a translating circuit for the translation of the data protocol of the internal data network 20 into the data protocol of the control unit of the related machining tool 10 whereby the control unit of the machining tool 10 is connected to the external data handling and exchange network 19.

To the material to be handled, i.e. to the pallets loaded with work pieces and tools, respectively, and to the pallet magazines, certain data are fixedly related. These data comprise data for the identification of the material, destination data for the transport of the material and data for fetching machine programs used for machining the material. These data are exchanged by means of the internal data network 20. For this purpose, all pallets and all pallet magazines each comprise an electronic memory module in which the respective data are stored. In all places where the pallets rest and in all transfer locations of the pallets, data processing units are provided which are equipped with a data read head in order to read the data stored in the electronic memory modules. The handling apparatuses 12 and the measuring station 7 are equipped with data processing units which further comprise a data write head in order to write data into the electronic memory modules, e.g. data representative for the actual state of machining.

In Fig. 2, there is shown a machining station 4 (without the bin 11 for the pallet magazine) and the measuring station 7 which is part of the set-up station 1 in more detail. Corresponding parts and elements are provided with the same reference numeral as in Fig. 1.



The machining tool 10 comprises a control unit 30 which is connected to the external data network 19 via a data line 31 and connected to the handling apparatus via a data line 24. The control unit 30 is equipped with a data memory in which a plurality of machining programs is stored.

The measuring station comprises a computer terminal 32 which is connected to the external data network 19 via a data line 33. A measuring device 34 for determining the geometrical data of a work piece is connected to the computer terminal 32.

The work piece 35 is mounted on one out of a plurality of pallets 36 which are uniformly designed as far as their positioning means are concerned. Thus, the pallet 36 can be fixed in an exactly predetermined position in all locations where the work piece 35 will have to stay to be stored, measured or machined, e.g. on a support 37 of the measuring device 34 or at the clamping member 38 of the machining tool 10. The pallet 36 is provided with an electronic data memory module 39 in which are stored the data required for the identification, for the transportation and for the machining of the work piece 35.

On the basis of an incoming machining order, the suitable work piece 35 is fixed to a pallet and all required data which are specified in the order (e.g. name and number of the work piece, NC-machining program identification etc.) are written into the memory module 39 of the pallet 36 in the set-up station 1. Then, the pallet 36 with the work piece 35 is transported to the measuring station 7 where its position on the top of the pallet 36 is measured and adjusted. Particularly, the actual position of the work piece 35 on the pallet and the deviation from a predetermined reference position is measured with the help of the measuring device 34, and the measured data are stored in the memory module 39 of the pallet 36, together with the data relating to the order number, the part number of the work piece and other required data. Thereby, all these data are



fixedly related to a certain identifiable work piece with the result that inadvertent confusions are avoided.

Thereafter, the thus prepared pallet 36 is transported to the transfer station 2 (Fig. 1) where it is loaded into a certain pallet magazine. At this place, also the data memory module of the pallet magazine is loaded with the required data which serve for the identification of the content of the pallet magazine and which also contain transportation data. A vehicle 15 takes the loaded pallet magazine over and transports it either directly to a machining station 4 or temporarily to a storing station 3.

At the beginning of a machining program, the pallet magazine filled with loaded pallets is displaced to the magazine receiving place provided for this purpose in the machining station 4. The location of the magazine receiving place is such that the pallet magazine is in the range of a movable gripper arm 40 of the handling apparatus 12. The handling apparatus 12 is provided with a data processing unit 41 equipped with a data read head which preferably is located at the end of the movable gripper arm 40.

In an initial phase, the data read head of the data processing unit 41 is moved along all positions in the pallet magazine where loaded pallets are stored, reads the data contained in the memory modules 39 of the pallets 36 and stores these data in the memory of the data processing unit 41. The control unit 30 is connected to the handling apparatus 12 and can directly call for the identification of a certain work piece 35 stored in the pallet magazine. Thereafter, the handling apparatus 12 removes the required work piece 35 from the pallet magazine and inserts it, together with the related pallet 36, into the machining tool 10. The data processing unit 41 related to the handling apparatus 12 reads the data stored in the memory module 39 of the pallet 36 during the transfer of the work piece from the pallet magazine to the machining tool 10 and forwards



these data to the control unit 30. As these data also contain the machining program identification required for the machining of the related work piece 35, the control unit 30 selects the machining program required for the machining of the related work piece from the collection of machining programs contained in its memory and uses the selected machining program to control the machining tool 10.

The tools required for the machining of the work pieces 35 can be handled basically in the same way as herein before described.

After termination of the machining process, the work piece 35 is brought back into the pallet magazine and another work piece is removed from the pallet magazine to be machined according to its data contained in its memory module 39. When all the work pieces contained in a pallet magazine are machined, the pallet magazine can be transported to a further machining station for further machining of the work pieces contained in this pallet magazine, or it can be temporarily stored in one of the storage bins 9 of the storing station 3. Another possibility is to bring the pallet magazine back to the measuring station 7 or to another (not shown) measuring station where all work pieces 35 are measured again. If required, the new measuring data can be stored in the memory modules 39 provided on its pallet 36 and related to each work piece 35. Further, it is still possible to store additional data in the memory modules 39, e.g. for the further machining, processing or handling of the work piece 35.



PATENT CLAIMS

1. An manufacturing plant comprising a plurality of machining cells (4), a management system for work pieces comprising storage means, transporting means and handling means, and a data handling and exchange system adapted to control the operations of the manufacturing plant, characterized in that the data handling and exchange system comprises two separate data networks (19, 20), whereby a first external data handling and exchange network is provided for the exchange of data between a central data processing unit and the machining cells and to exchange transporting control data between the central processing unit and the transporting control means, and whereby there is provided a second internal data handling and exchange network for exchanging data between the storage means, the transporting means and the handling means, whereby memory means are fixedly assigned to the work pieces to be transported, the memory means containing data for the identification of the work piece, destination data for the transport of the work pieces and data for fetching machine programs used for the machining of the work piece to be machined, the data contained in the memory means being processed by the second internal data handling and exchange network.

2. An automatic manufacturing plant according to claim 1, characterized in that there is provided a plurality of uniform interface means each assigned to one of the machining cells, the interface means comprising means for translating differing data protocols and being connected to the first external data handling and exchange network as well as to the second internal data handling and exchange network.

3. An automatic manufacturing plant according to claim 1, with a plurality of machining stations each containing at least one numerically controlled machining tool, with a plurality of pallet means adapted to receive work pieces to be machined or tool means for the machining of the work pieces, with a set-up sta-



tion for loading the pallet means, with a plurality of transportable magazine means adapted to receive the pallet means loaded with the work pieces or tool means, with a transfer station for loading pallet means into the transportable magazine means and for unloading pallet means from the transportable magazine means, with a storing station for the transportable magazine means loaded with the pallet means, and with an automatically operating transporting means for transporting the magazine means loaded with the pallet means on a traffic network interconnecting the different stations with each other, characterized in that

- a) each of the machining stations comprises a handling means for transferring the pallet means between the magazine means and the machining tool;
- b) each of the machining tools comprises a control unit incorporating a first memory means for storing a plurality of machining programs;
- c) an external data handling and exchange network with a central data processing unit is provided, by means of which the control units assigned to the machining tools are connected with a central data processing unit and;
- d) each pallet means comprises a memory means in which data for the identification of the work piece or tool means mounted on the pallet means and data for the machining of the work piece mounted on the pallet means are stored;
- e) each pallet magazine comprising a memory means in which data for the identification of the content of the magazine and data for the transport thereof are stored;
- f) an internal data handling and exchange network for exchanging data between the memory means provided on the pallet means and the memory means provided on the transportable magazine



means on the one side and the different stations and the transporting means on the other side; and

g) a uniform interface means provided in each of the machining stations for interconnecting the handling means and the control unit of the machining tool, the interface means comprising means for translating the data protocol of the second internal data exchange and handling network into the data protocol of the control unit of the assigned machining tool.

4. An automatic manufacturing plant according to claim 3, characterized in that data memory means are provided which enable that data contained in the data memory means can be changed during the manufacturing process.

5. An automatic manufacturing plant according to claim 4, characterized in that each data processing unit comprises a reading head, a writing head as well as a control and analyzing unit for controlling the reading and writing process.

6. An automatic manufacturing plant according to one of the preceding claims, characterized in that there is provided a wireless carrier frequency system for the exchange of data.

7. An automatic manufacturing plant according to one of the preceding claims, characterized in that the memory means comprise non-powered memory modules and that means are provided for the wireless supply of power, which is required for the exchange of data between the data processing means and the memory means, to the memory modules.

8. An automatic manufacturing plant according to claim 7, characterized in that an inductive alternating current field is provided for the transfer of power for the memory modules.

9. An automatic manufacturing plant according to claim 3, characterized in that the work pieces or the tool means are mounted



on the pallet means individually or in groups, the pallet means comprising uniform positioning means which serve to fix the pallet means in the machining tools in an exactly predetermined position, the work pieces or tool means remaining mounted on the pallet means on their way through the manufacturing plant until the work pieces are fully finished.

10. An automatic manufacturing plant according to claim 3, characterized in that the set-up station includes a measuring station connected to the first external data handling and exchange network for determining the geometrical data of the work pieces and tool means, respectively, mounted on the pallet means, and further includes a data processing unit incorporating data reading and writing heads cooperating with the memory means provided on the pallet means.

11. An automatic manufacturing plant according to claim 3, characterized in that the automatically operating transporting means comprises transport vehicles and a central transport control station connected to the first external data handling and exchange network for controlling the movement of the vehicles.

12. An automatic manufacturing plant according to claim 3 and 11, characterized in that the machining stations, the storing station, the transport vehicles and the transfer station each comprise uniform receiving means adapted to receive the pallet magazine means, the receiving means each incorporating a data processing unit with a data reading means for reading the data stored in the memory means provided on the pallet magazine means.

13. An automatic manufacturing plant according to claim 3, characterized in that each of the handling means comprises a data processing unit incorporating a data reading and writing means cooperating with the second memory means on the pallet means, the data processing unit comprising a uniform interface means with means for translating the data protocol of the sec-

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ond internal data handling and exchange network into the data protocol of the control unit of the machining tool assigned to the control unit.