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AUTOMATICALLY OPERABLE MANUFACTURING PLANT

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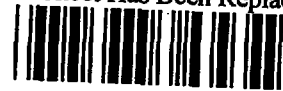
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The present invention refers to an automatically operable manufacturing plant, comprising a plurality of machining cells, a management system for work pieces including storage appliances, transporting appliances and handling appliances, and a data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

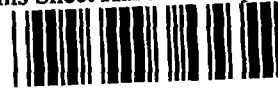
In the manufacturing plant according to the patent document Nr. EP-A2-0 364 138, there is provided for the control of the manufacturing process an information flow system with several data networks in a hierarchic structure. These data networks serve for exchanging program data between a central processing 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

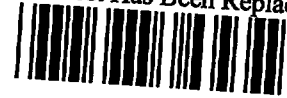


lots. Particularly, it is the object of the invention to improve the identification system. Moreover, the information system should be in a position to transmit also other information, e.g. control information for the manufacture.

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.

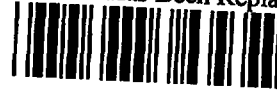
An important prerequisite for a trouble free operation of the manufacturing plant according to the invention is the safety of the data exchange. Considering the often rough conditions in the region of the machining cells with the disturbing influences of heat, oil, metal chips and cooling fluids, it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



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



AUTOMATICALLY OPERABLE MANUFACTURING PLANT

ABSTRACT

The automatic manufacturing plant comprises a plurality of machining cells, a management system for the work pieces including storage appliances for storing the work pieces, transporting appliances for transporting the work pieces and handling appliances for manipulating the work pieces, and a data handling and exchange system for controlling the operations of the manufacturing plant. The data handling and exchange system comprises 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 transporting control data between the central processing unit and the transporting appliances. Further, there is provided a second internal data handling and exchange network for the exchange of data between the storage appliances, the transporting appliances and the handling appliances. The work pieces are mounted on pallets which comprise memory modules 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. The data contained in the memory modules are processed by the second internal data handling and exchange network.

This manufacturing plant is suited for a fully automated flexible manufacturing thanks to the improved information system.

Figure 1

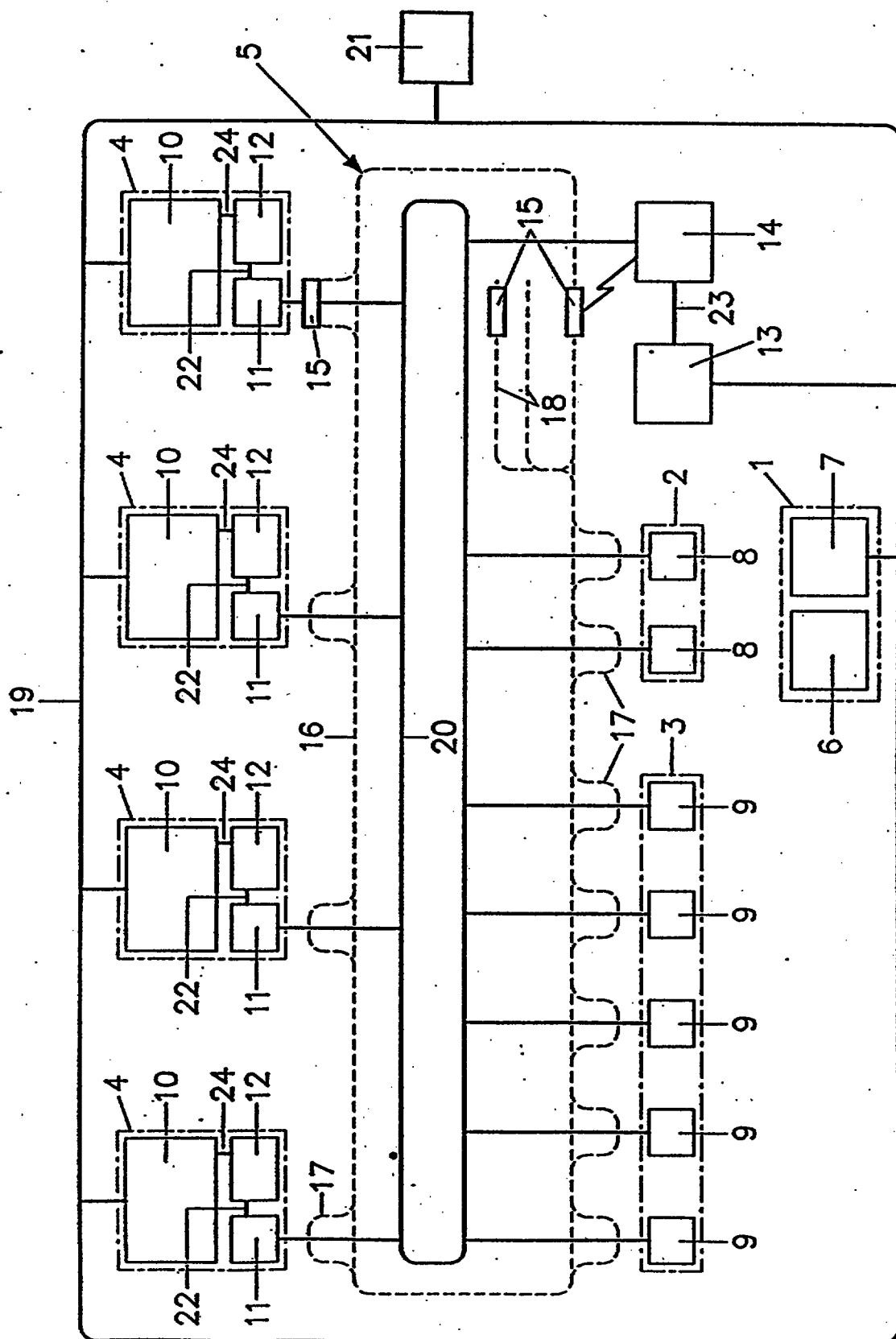


FIG. 1

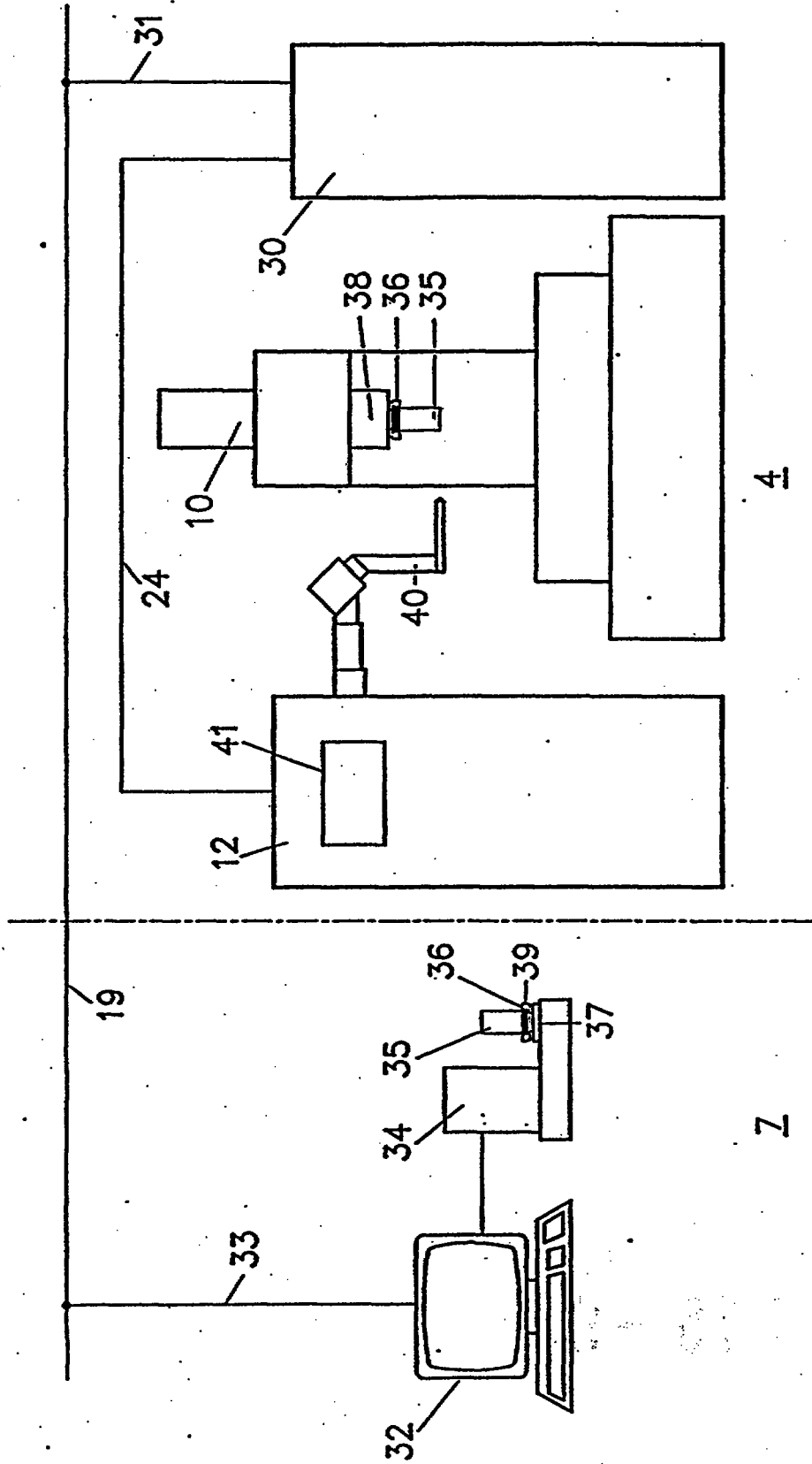


FIG. 2

AUTOMATIC MANUFACTURING SYSTEM

The present invention relates to an automatic production plant according to the preamble of Patent Claim 1.

Such production plants are known per se together
5 with all the components typical of such plants, for example from the documents EP-A-0 364 138 and DE-A-37 20 157, in which various solutions for controlling the production cycle are also specified.

10 An information flow system having a plurality of hierarchically structured data networks is provided in the production plant according to document EP-A-0 364 138 for the purpose of controlling the production cycle. These data networks serve to exchange programme data between a central computer and the control units of the
15 processing devices and the control units of the material flow system. Such an information flow system, in which all the control programmes are managed in a central computer, has various disadvantages. Firstly, it is a quite complicated matter to set up processing programmes
20 on a central computer as a preparation for automatic production, in particular concerning the production of many different workpieces in small batch sizes. Secondly, any disturbance in the production cycle requires the control programme on the central computer to be adapted or changed. However, such changes are always attended by
25 a certain time outlay, and this can lead in each case to a more or less extended interruption in production.

A production plant improved in this connection is shown by the document DE-A-37 20 157. In the solution
30 described here, the central computer serves only to control those processes which are necessary for operating the automatic production plant. In particular, the central computer supplies no processing programmes and no instructions concerning the processing sequence. Rather,
35 each workpiece to be processed is permanently assigned a data memory which contains, inter alia, the respective processing programme. The latter is read into the control device of a production station when the workpiece is transferred onto the latter. The disadvantage of such an

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information flow system consists in that the said aim requires quite extensive data memories on each workpiece or on each pallet carrying a workpiece. In order to permit smooth operation in this way, it is virtually
5 unavoidable, furthermore, for all the production stations or the production plant to operate using a standard operating system, since it would be too cumbersome to convert the extensive data protocols in each case.

It is the object of the invention to provide in
10 conjunction with monitoring and controlling the production cycle of such a production plant a powerful system for the flow of information between the different plant units and the workpieces or tools, which permits in a comparatively simple way a flexible, in particular job-
15 centred production with many different workpieces in small batch sizes. The aim is also to provide an improved identification system. Furthermore, the information system is to be suitable for transmitting other items of information as well, for example those controlling
20 production, by way of the identification paths.

In accordance with the invention, this object is achieved by means of a production plant which has the features specified in the characterizing part of Patent Claim 1.

25 The data combination can be closed without a gap in the entire information network of the production plant by means of the measures according to the invention.

A practical solution is obtained, for example, by virtue of the fact that the workpieces and the tools for
30 use in the processing devices and at the measuring station are mounted individually or in groups on standard pallets which can be clamped in the correct position into the processing devices and on which the workpieces remain on their path through the production plant until com-
35 pletely processed, that the pallets of the workpieces and those of the tools are provided with electronic data memories in which data for identifying the workpieces or tools and data for controlling the automatic production cycle can be stored, that the handling devices and the

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measuring station are equipped with data processing units suitable for reading the stored data, and that the data processing unit is connected to the respectively assigned control units of the processing devices in a communicating fashion.

An automatic production plant having the features of Claim 2 constitutes a preferred solution.

The use of workpiece or tool pallets which have standard mechanical positioning aids forms a favourable precondition for the application of the identification system according to the invention. The workpiece pallets involved in this case can, in particular, be ones intended for individual workpieces or ones intended for a group of similar workpieces.

By contrast with previous identification systems, which with respect to the location of the workpieces and tools operate with location coding, the workpieces and tools are themselves uniquely identifiable in the identification system according to the invention. This circumstance not only provides a better safeguard against instances of confusion when mutually assigning the data and the relevant workpieces or tools, but also permits the workpieces and tools to be deposited randomly in the relevant magazines.

The unique identification of the component (workpieces and/or tools) forms the basis for the fact that the individual components can also be given additional information, in particular target data for transporting the material and data for retrieving programmes for processing the material. Workpiece pallets and tool pallets, which carry with them appropriate data which they can transmit to the control unit if required, permit for the first time completely automatic operation of a production plant having a plurality of production stations operated as an assembly.

It is a particular advantage in this case that there is no need to store the processing data in the data memories of the workpiece pallets in the form of a more or less complete control or processing programme for the

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processing devices employed. All that is required is the presence of data for identifying the processing programmes, in order to retrieve the respectively required processing programmes stored in the control unit as soon
5 as a pallet is fed to a processing device. The storage capacity of the data memories can be correspondingly smaller.

A preferred embodiment of the production plant according to the invention consists, moreover, in that
10 the production stations, the storage device, the transport vehicles and the transfer station have standard receiving sites for the pallet magazines, there being equipped at each of these receiving sites one data processing unit with a read head for reading the data
15 stored in the data memories of the pallet magazines. These data include, in particular, a transport plan for the pallet magazine containing details relating to the production stations which are successively to be approached.

20 As soon as a pallet magazine is transferred to the transport device, the next transport destination can be read out of the data memory of this pallet magazine. This information is now relayed to the control means of the transport device, which controls a vehicle loaded
25 with the pallet magazine to the specified destination, for example to a production station. Since the transport device is always informed of the next travel destination, it is no longer necessary to input entire transport programmes into the transport control means. Controlling
30 the flow of material becomes substantially simpler and more flexible as a result.

Moreover, the information flow system according to the invention renders it possible in a simple way to take measures to change the transport plan in the case
35 when, for example, a specific destination station is occupied and therefore cannot be approached. Such measures can be restricted to an exchange of data within the internal data network, and require no change of programme on the process control computer. A pallet

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magazine which cannot reach its destination in accordance with the transport plan can be diverted into the storage device, from where it can be retrieved again at a later point in time, for example, in response to a signal which
5 announces the release of the previously occupied production station.

It is preferred to have present data memories which permit the stored data to be varied during the production operation, that is to say respectively to
10 adapt the data of a workpiece to the current state of processing, for example. For this purpose, each data processing unit can have, in addition to a read head, a write head and a control and evaluation device which controls the read cycle and the write cycle.

15 Safeguarding the transmission of data is a precondition for fault-free operation. With regard to the frequently rough operation in the field of processing devices, which have oil, chips and coolants as disturbing influences, it is advantageous to provide for data
20 transmission a system in which data are transmitted without contact, a wireless carrier frequency system being particularly well suited for this.

With regard to the power supply for the data memories, an advantageous solution is provided by virtue
25 of the fact that use is made of data memories with non-energized storage, and devices are provided by means of which the energy which the data memories require for data transmission is transmitted in a wireless fashion from the data processing unit to the respectively driven data
30 memory. Semiconductor memories of this type are cost effective and, moreover, comparatively small and easy to install overall. An inductive alternating field is advantageously provided for transmitting energy.

An exemplary embodiment of the invention is represented diagrammatically in the drawing, specifically:
35 Figure 1 shows the overall plan of the automatic production plant according to the invention; and
Figure 2 shows details of a production station and a measuring station.

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The production plant represented in Figure 1 comprises, for example, a preparation station 1 for fitting the pallets, a transfer station 2 for loading and unloading transportable pallet magazines, a storage station 3 for pallet magazines, four production stations 4 and a traffic network 5 which interconnects the various stations 2, 3 and 4.

The preparation station 1 contains a clamping site 6 at which the workpieces and tools are clamped on pallets, and a measuring station 7 for determining the geometrical data of the workpieces and tools clamped on the pallets.

At the transfer station 2, which has two sites 8 for one pallet magazine each, incoming pallet magazines with completely processed workpieces are unloaded, on the one hand, and empty pallet magazines are loaded with newly fitted pallets, on the other hand.

The storage station has a plurality of storage sites, in the present example five storage sites 9 for temporarily storing empty or full pallet magazines.

In the present example, each production station 4 comprises a processing device 10, generally in the form of a numerically controlled machine tool, a site 11 for a pallet magazine, and a handling device 12 for fitting the processing device 10 with workpieces and for exchanging tools.

The traffic network 5 is part of an automatic transport device which comprises a central transport control station 13, a remote-control system 14 and a plurality of remotely controlled vehicles 15 which can be optionally recalled. In detail, the traffic network 5 comprises various, preferably roll-less tracks, along which the vehicles 15 are guided, an inherently closed track 16 leading past the transfer station 2, the storage station 3 and all the production stations 4, and separate track loops 17 being laid to each magazine site 8, 9 and 11 of the various stations 2, 3 and 4, with the result that a plurality of vehicles can circulate simultaneously on the traffic network 5 without mutual hindrance.

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Furthermore, parking spurs 18 are provided for unused vehicles 15.

The information flow system has two separate data networks, specifically an external data network 19 and an internal data network 20. The external data network 19 connects the control units of the processing devices 10 of all the production stations 4 and the transport control station 13 to a central process control computer 21, and is provided for exchanging process control data between the process control computer 21 and the control units of the processing devices 10, and for exchanging transport control data between the process control computer 21 and the transport control station 13. The external data network 19 can be part of a data transmission system known under the designation of "Ethernet" to which, in addition to the process control computer, a process planning system can be connected, for example.

By contrast, the internal data network 20 interconnects the plant components belonging to the material flow system (storage station 2, handling devices 12 and vehicles 15), and to be specific all the magazine sites 8, 9 and 11 of the transfer station 2, the storage station 3 and the production stations 4 as well as the remote control system 14 for the trafficking of vehicles 15 are interconnected via this internal data network 20. Data connections 22 and 23, respectively, are present for exchanging data between the magazine sites 11 and the handling devices 12 of the production station 4, on the one hand, and between the transport control station 13 and the remote control system 14, on the other hand. Moreover, in each production station 4 the handling device 12 is connected to the control unit of the processing device 10 via a standard interface, which is indicated by the connection 24 and contains means for converting the data protocol of the internal data network 20 to the data protocol of the control unit, connected to the external data network 19, of the relevant processing device 10.

The material to be converted, that is to say the

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pallets fitted with tools or workpieces and the transportable pallet magazines are permanently assigned data for identifying the material, target data for transporting the material and data for retrieving programmes for processing the material, the internal data network 20 being intended for exchanging these data. For this purpose, all the pallets and pallet magazines have one data memory each, in which the relevant data are stored, and data processing units which are equipped with a read head for reading the stored data are present at all stopping locations of the pallet magazines and at all transfer sites of the pallets. The handling devices 12 and the measuring station 7 are assigned data processing devices which also have a write head, for the purpose of writing data into the data memories, for example data which specify the state of production.

Details of a production station 4 (without magazine site 11) and of the measuring station 7 of the preparation station 1 are represented in Figure 2, corresponding parts being provided with the same reference numerals as in Figure 1.

The processing device 10 is assigned a control unit 30 which is connected via a data line 31 to the external data network 19, and via the data line 24 to the handling device 12, and which has a data memory in which a plurality of different processing programmes are stored.

The measuring station 7 comprises a computer terminal 32, which is connected via the data line 33 to the external data network 19, and to which a measuring instrument 34 is connected for determining geometrical data.

The workpiece 35 is mounted on a pallet 36, which is standard with respect to the positioning means and can be clamped in the correct position at each location where the workpiece 35 stops for storage, measurement and processing, for example on a support 37 of the measuring instrument 34 and at the chuck 38 of the processing device 10. The pallet 36 is provided with a data memory

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39 in which the data required for identifying and processing the workpiece 35 are stored.

On the basis of a processing order, the workpiece 35 provided therefore is clamped onto a pallet and fed to the measuring station 7, at which the data specified in the order (such as workpiece designation, NC programme designation, etc.) are also transmitted. The workpiece 35 is preset at the measuring station 7. In this case, the measuring instrument 34 is used to establish the position of the workpiece 35 with respect to its pallet 36 or the offset of the latter with respect to the reference system assigned to the pallet 36. The measurement data are stored in the data carrier 39 located on the pallet 36, together with the abovenamed order data. The measured data are thus permanently assigned to a specific, identifiable workpiece, and instances of confusion in this regard are therefore excluded. Thereupon, the fitted pallet is passed on to the transfer station 2 (Figure 1), where it is accommodated in a pallet magazine. At this location, the data memory of the pallet magazine is also loaded with the required data, which are necessary for identifying the pallet magazine and the transport thereof. A vehicle 15 takes over the loaded pallet magazine and feeds the latter either directly to a production station 4 or, temporarily, to the storage device 3.

At the start of a production programme, the pallet magazine fitted with pallets is moved to the receiving site, provided therefor, of a production station 4 at which it can be reached by the moveable gripping arm 40 of the handling device 12. The handling device 12 is equipped with a data processing unit 41 whose read head is connected, for example, to the moveable gripping arm 40.

In an initialization run, the read head approaches all the storage positions in the pallet magazine and reads the data stored in the data memories 39 into the main memory of its data processing unit 41. The control unit 30 of the processing device 10 can now retrieve the designation of the required workpiece 35

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directly via the interface to the handling device 12, whereupon the handling device 12 fetches the relevant workpiece from the pallet magazine and feeds it to the processing device 10. During the transfer of the workpiece 35, the data processing unit 41 assigned to the handling device 12 uses a read head to read the data stored in the data memory 39, and relays them to the control unit 30, the NC programme required for processing the workpiece 35 being selected from the NC programmes stored in the control unit 30 with the aid of the NC programme designation, which is also kept, and being used to control the processing device 10.

It is possible to proceed in basically the same way with the tools required for processing the workpieces.

The workpiece 35, which is to be fed to one or more further processing devices after being processed in the processing device 10, can be put on a magazine in the interim. The workpiece 35 can, however, also firstly be conveyed again to the measuring station 7 or another measuring station, where it is measured anew and the new measurement data are read into the data memory 39 at its pallet 36. Additional data, relating to the further processing of the workpiece 35, for example, can be stored in the data memory 39 in this phase, as well.

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Patent claims

1. Automatic production plant having a plurality of production stations (4) with at least one processing device (10) which are assigned one control unit (30) each, having a material flow system for material (35) to be converted, the material flow system comprising a storage device (3), a transport device (5, 13, 14, 15) and handling devices (12), and having an information flow system for controlling the production plant, characterized in that the information flow system has two separate data networks (19, 20) specifically a first, external data network (19) for exchanging process control data between a central computer (21) and the production stations (4) and for exchanging transport control data between the central computer (21) and a transport control station (13), and a second, internal data network (20) the storage device (3) (sic), which interconnects the transport device (5, 13, 14, 15) and the handling devices (12), in that each control unit (30) assigned to a production station (4) contains a data memory for a plurality of processing programmes, and in that the material (35) to be converted is permanently assigned data for identifying the material, target data for transporting the material, and data for retrieving programmes for processing the material which are stored in the control units (30), the internal data network (20) being intended for exchanging these data, and in that the internal data network (20) is connected to the external data network (19) in the production stations (4) by standard interfaces (24), means being available at the interfaces for converting different data protocols.

2. Automatic production plant according to Claim 1, having a plurality of production stations (4) which have at least one numerically controlled processing device (10) each, having a plurality of pallets for being fitted with workpieces (35) and/or tools, having a preparation station (1) for fitting the pallets, a plurality of transportable pallet magazines for depositing the palletized workpieces (35) or tools, a transfer station (2)

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for loading and unloading the pallet magazines, a storage station (3) for the pallet magazines loaded with pallets (36), and an automatic transport device (5, 13, 14, 15) for transporting the loaded pallet magazines on a traffic network (5), which interconnects the different stations (2, 3, 4) characterized

5 a) in that each production station (4) has a handling device (12) for transferring the pallets (36) between a pallet magazine and a processing device (10);

10 b) in that the control units (30) of all the processing devices (10) are connected to a process control computer (21) via the external data network (19);

c) in that each pallet (36) has a data memory (39) in which there are stored data for identifying the workpiece (35) or tool clamped on the pallet (35) and data which

15 control the processing of the workpiece (35);

d) in that each pallet magazine has a data memory in which are stored data for identifying the pallet magazine and data which control the transport of the latter;

20 e) in that the internal data network (20) is provided for data transfer between the data memories (39) of the pallets (36) and pallet magazines and the different stations (2, 3, 4) and the transport device (5, 13, 14, 15); and

f) in that in each production station (4) the handling

25 device (12) is connected to the control unit (30) of the processing device (10) via in each case one standard interface (24) which contains means for converting the data protocol of the internal data network (20) to the data protocol of the control unit (30), connected to the

30 external data network (19) of the relevant processing device (10).

3. Automatic production plant according to Claim 2, characterized in that data memories (39) are provided which permit the stored data to vary during the production operation.

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4. Automatic production plant according to one of the preceding claims, characterized in that a wireless carrier frequency system is provided for reading data into and out of the data memories (39).

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5. Automatic production plant according to one of the preceding claims, characterized in that data memories with non-energized storage are used and devices are provided by means of which the energy which the data memories require for data transmission is transmitted in a wireless fashion from the data processing unit to the data memory respectively driven.

6. Automatic production plant according to Claim 5, characterized in that an inductive alternating field is provided for transmitting energy.

7. Automatic production plant according to Claim 2, characterized in that the workpieces (35) and the tools are mounted individually or in groups on pallets (36) using standard positioning means, with the result that the pallets (36) can be clamped in the correct position into the processing devices (10), the workpieces (35) remaining on the pallets (36) on their way through the production plant until completely processed.

8. Automatic production plant according to Claim 2, characterized in that the preparation station (1) is equipped with a measuring station (7), connected to the external data network (19), for determining geometrical data of the workpieces (35) or tools clamped on the pallets (36), and with a data processing unit (32) cooperating with the data memory (39) of the pallets (36), and equipped with a read-write head.

9. Automatic production plant according to Claim 2, characterized in that the transport device (5, 13, 14, 15) has a plurality of vehicles (15) which can be optionally recalled from a central transport control station (13) connected to the external data network (19).

10. Automatic production plant according to Claims 2 and 9, characterized in that the production stations (4), the storage device (3), the transport vehicles (15) and the transfer station (2) have standard receiving sites (8, 9 and 11) for the pallet magazines, there being provided at each of these receiving sites one data processing unit with a read head for reading the data stored in the data memories of the pallet magazines.

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11. Automatic production plant according to Claim 2, characterized in that the data processing unit (41) assigned to each handling unit (12) is connected to a read-write device cooperating with the data memories (39) of the pallets (36), and contains at a standard interface (24) means for converting the data protocol of the internal data network (20) to the data protocol of the control unit (30) of the relevant processing device (10).
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AUTOMATIC MANUFACTURING SYSTEM

ABSTRACT

The automatic manufacturing plant comprises a plurality of machining cells, a management system for the work pieces including storage appliances for storing the work pieces, transporting appliances for transporting the work pieces and handling appliances for manipulating the work pieces, and a data handling and exchange system for controlling the operations of the manufacturing plant. The data handling and exchange system comprises 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 transporting control data between the central processing unit and the transporting appliances. Further, there is provided a second internal data handling and exchange network for the exchange of data between the storage appliances, the transporting appliances and the handling appliances. The work pieces are mounted on pallets which comprise memory modules 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. The data contained in the memory modules are processed by the second internal data handling and exchange network.

This manufacturing plant is suited for a fully automated flexible manufacturing thanks to the improved information system.

Figure 1

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