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(54) **Method and system for controlling a moulding plant**

(57) System for controlling a moulding plant, said plant comprising at least one press (2) having a plurality of work stations (5,6), each of which carries out the processing of at least one piece (P). The system comprises a plurality of force sensors (S) each associated with a work station (5,6) of said plurality of stations (5,6), an electronic instrument (8) for measuring and controlling the plant connected to said sensors (S) and an electronic processing unit (9) connected to said instrument (8).

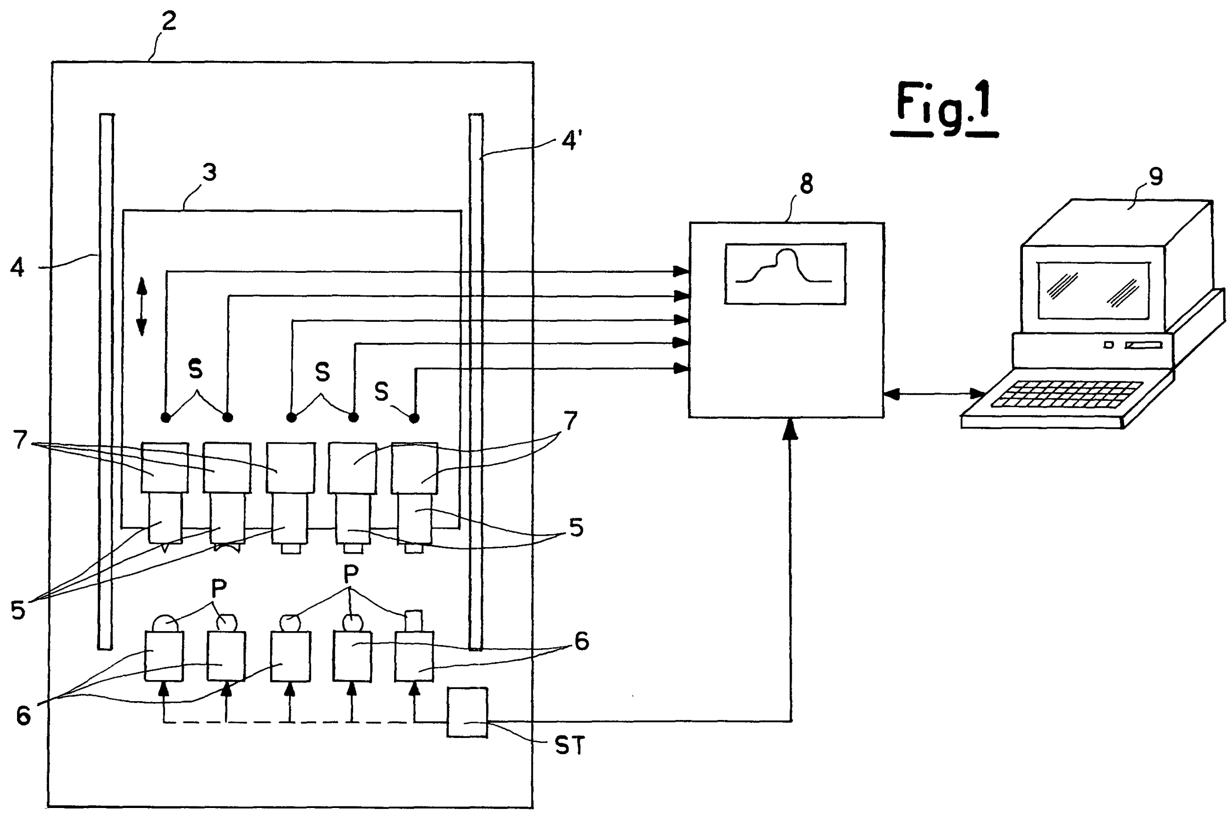

Fig.1

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Description

[0001] The present invention concerns a method and system for controlling a moulding plant.

[0002] In particular, the present invention refers to a method and system for controlling a moulding plant formed from a plurality of work stations in each of which indirect measurement sensors of physical magnitudes, for example forces, are arranged.

[0003] The measurement of the forces applied, amongst the supervision methods of a production process that uses them for moulding, extrusion or shearing processes, has established itself for its ability to detect and in many cases prevent problems of failure of the plant, and also for being able, in certain conditions, to discover defects in the product of a size just big enough to be highlighted by an accurate quality control.

[0004] In most cases, the measurement is of the indirect type, in the sense that the sensor measures an effect of the force that is the object of measurement, given that just a part of the magnitude that one wishes to measure passes onto it.

[0005] When the force to be measured is just one, with a suitable selection of the capturing element and of its position, the "indirect" sensor measures a value proportional to the one that one wishes to control, since the parts of the machine involved are well within the elastic limits: the proportionality factor can in turn be worked out experimentally, if necessary.

[0006] This is the case, for example, of metal moulding presses having a single matrix, even if with many phases, because, indeed, one force is applied at a time, that then distributes in the body of the machine in a complex manner, but coming from a single point of origin.

[0007] In the case of more complex machines, like for example progressive presses, the piece that is processed undergoes different deformations in various work stations.

[0008] The Applicant has observed that by inserting a sensor, necessarily of the indirect type, at each work station, it is crossed by the lines of force coming from all of the stations and, in particular, if the processing in a station requires weaker forces than the forces necessary for the processing of the other stations, the part of the force that needs to be measured is polluted by the mechanically interfering components generated in the other stations.

[0009] Generalising the example, in a rigid system in which there are n points of application of forces that can be applied simultaneously (work stations), the use of indirect sensors, even if applied individually near to each of these points, only allows those forces that are of a substantial size or that can be isolated from the other forces with specific methods to be controlled with sufficient approximation.

[0010] The Applicant has found that by carrying out a calibration step of the plant, in which known forces are applied in each station and force values are simultaneously detected by sensors associated with each station, a matrix of values can be obtained, able to be used in normal operating conditions of the plant, to calculate the real forces to which each work station is subjected starting from the values of the detections of the sensors carried out at predetermined time intervals. In such a way, the force values calculated for each work station take into account the interference of the mechanically interfering components generated in the other work stations. Indeed, the calculation carried out foresees that the real force applied to each work station is obtained from the force detections in all of the other work stations.

[0011] A first aspect of the present invention concerns a method for controlling a moulding plant according to claim 1.

[0012] A further aspect of the present invention concerns a system for controlling a moulding plant according to claim 5.

[0013] The characteristics and the advantages of the method and system according to the present invention shall become clearer from the following description, given as an example and not for limiting purposes, of an embodiment of the invention with reference to the attached figure 1 that represents a block diagram of the control system according to the present invention, for exemplifying purposes applied to a moulding plant.

[0014] With reference to the quoted figure, the moulding plant comprises a press body 2 on which a trolley 3 is arranged that can slide, through moving devices (not illustrated), inside a pair of guides 4 and 4'. Said trolley comprises a plurality of work stations preferably adjacent to each other, each comprising a punch 5 suitable for compressing metal pieces P to be shaped. The pieces are arranged on a plurality of matrices 6 associated with the press body, in a position in front of said punches and aligned with them.

[0015] Said stations also each comprise an adjustment wedge 7, associated with each punch suitable for adjusting the position of the punch along its axis, to suitably establish the distance between the punch and the relative matrix when they are at their closest (trolley as far forward as possible, at the "top dead centre").

[0016] The advance of the trolley in the direction of the matrices allows the punches to mould the pieces P arranged on the matrices themselves. At the end of the deformation of the pieces the trolley pulls back and the moulded pieces are picked up by suitable pick-up devices, for example mechanical pincers, and are taken to the next stations, in which further processing is carried out. The production of a piece requires n machine cycles, if n is the number of stations; by machine cycle we mean the time between one mould and the next, which also coincides with the time for the transfer of the pieces each from one station to the next.

[0017] The control system of such a plant according to the present invention comprises a plurality of force sensors

S, each associated with a work station, suitable for measuring the force exerted by the punches themselves. The strain exerted by the processing in each station necessarily crosses said wedges, and consequently the sensors are preferably arranged in a position close to them. Such sensors are preferably of the piezoelectric type and are suitable for carrying out an indirect measurement of the stress; the electric signal generated by the sensors is by close approximation proportional to the force developed, the proportionality factor of which, however, is *a priori* unknown.

[0018] The system also comprises an electronic instrument 8 for measuring and controlling the plant, which communicates with an electronic processing unit 9, for example a personal computer.

[0019] The system also comprises a gauged calibration sensor ST that can be inserted into the position of each matrix, one they have been removed from the press plane. Such a calibration sensor can be connected to the electronic measurement instrument. As an alternative to using a sensor ST that can move from one matrix to the other so that just one station is engaged at a time and the force passes totally on it, if the machine allows it, a fixed sensor can be used that detects the overall force applied to the machine, and the machine can be forced in other ways to work one station at a time.

[0020] The control of the production process is carried out by processing the signals received by the sensors S through the instrument 8 for measuring and controlling the plant, which compares the shapes of the waves obtained during the course of a machine cycle with the expected values based upon statistical processing of the previous cycles and decides upon the action to be carried out based upon the calculated relative deviation, for example if the deviation is greater than the predetermined minor alarm threshold, but not greater than the serious alarm threshold, the piece can be discarded, preventing it from passing to the subsequent stations; or, if the machine is not set up for discarding, an indicator light can come on and, if the error keeps repeating with a frequency greater than a predetermined limit, the machine stop is activated. If the deviation exceeds the serious alarm threshold production is stopped.

[0021] The instrument is able to carry out different actions, in general it is in any case at least able to stop the process in the case of an anomaly. Preferably, there are as many sensors as there are work stations, and a signal is supposed to be obtained from each station that describes the deformation stress developed in the relative station, as far as possible free from the interference generated by the stress on the adjacent stations, which is inevitably captured and added to the useful signal.

[0022] The controlling method according to the present invention concerns the separation of said interferences, which affect the measurement taken by the sensors S, using the measurements carried out in a calibration step.

[0023] In said calibration step the press activates without material and the wedge is adjusted that works on the station in which the calibration sensor ST is positioned replaced at the matrix 6, so as to obtained predetermined force values, coherent with the performance of the machine. Preferably, many measurements are carried out at different force levels in the position of each matrix, to simultaneously control which is the zone of linearity of the system and to intervene if anomalies are detected. In these conditions the signals obtained from all of the sensors S at the same moment in time are also read on the measuring instrument and a table of calibration force values is obtained.

[0024] Contrary to that which occurs during the course of the process, multiple samples are not taken to reconstruct a wave shape, but rather the reading of all of the sensors at the same moment in time is detected, approximately coinciding with that of maximum stress.

[0025] Therefore, in short, in the calibration step known forces, at least in the sense that the mutual relationships are known, are applied at the different application points; of course, if there were no interference it would be sufficient to apply known forces individually in the n points and each of the sensors could thus be calibrated, which in this hypothetical case are only crossed by the force that they are intended to measure. In the general situation, even applying just one force, values are detected in each of the sensors.

[0026] For the purposes of the present invention let us consider L_{ij} as the value of the signal detected on the sensor arranged on the j^{th} station when a force f_i is applied onto the i^{th} station.

[0027] Thus, for each test carried out in the calibration step applying a force, if there are n work stations, and therefore n sensors, n detections are obtained L_{i1}, L_{i2}----L_{in}.

[0028] Such a test is carried out n times applying the force f to each of the n work stations, obtaining a matrix of the detected values.

$|L_{ij}|$ with i and j that vary from 1 to n.

[0029] Assuming the hypothesis of linearity of the system and consequently applying the principle of overlapping of effects, starting from the matrix of values detected with this calibration, it is possible to construct the system,of equations that allows the value of the force applied at a certain moment in time to be obtained, during the normal operation of the plant, in each of the n points of application, knowing the readings of the sensors at the same moment in time.

[0030] If the hypothesis of linearity is not valid, it is in any case possible in certain hypotheses to reconstruct the forces from the readings, if in the calibration step sufficient data has been acquired to characterise the process under examination. Given that this analysis can be carried out before operating on the process, the time spent does not constitute an obstacle to treating complex realities. The calculation can possibly be carried out by the additional unit 9 (PC) if the capacity of the unit 8 is insufficient.

[0031] In mathematical terms, one obtains

$$\left.\begin{array}{l} L_1 = L_{11} \circ \dfrac{g_1}{f_1} + L_{21} \circ \dfrac{g_2}{f_2} + L_{31} \circ \dfrac{g_3}{f_3} + \ldots\ldots\ldots\ldots L_{n1} \circ \dfrac{g_n}{f_n} \\ L_2 = L_{12} \circ \dfrac{g_1}{f_1} + L_{22} \circ \dfrac{g_2}{f_2} + L_{32} \circ \dfrac{g_3}{f_3} + \ldots\ldots\ldots\ldots L_{n2} \circ \dfrac{g_n}{f_n} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ L_n = L_{1n} \circ \dfrac{g_1}{f_1} + L_{2n} \circ \dfrac{g_2}{f_2} + L_{3n} \circ \dfrac{g_3}{f_3} + \ldots\ldots\ldots\ldots L_{nn} \circ \dfrac{g_n}{f_n} \end{array}\right\} \quad (1)$$

[0032] Where L_1----L_n are the readings of the n sensors at a certain moment in time and with a certain processing and the forces g_1—g_n are the real forces to be calculated, referring to the same moment in time, f_1----f_n are the forces measured in the calibration step of the sensor ST in each work stations and L_{ij} are the parameters memorised in the calibration step. Concerning a linear system with the same number of equations and unknowns, a solution shall be found, for each force g_i, of the type:

$$g_i = b_{li} \text{ o } L_1 + b_{2i} \text{ o } L_2 + \ldots\ldots\ldots b_{ni} \text{ o } L_n \quad (2)$$

[0033] In the real system the forces, and therefore the readings, evolve with continuity in time; by carrying out a sampling with frequency suitably adapted to the band of the signals detected, a faithful representation of the process is in any case obtained. The formula resolving the system is applied to each of the samples at that moment, in this way reconstructing the complete progression of the forces applied on the punches.

[0034] The detections carried out by the sensors are suitably decoded by the electronic measuring instrument, which can also carry out mathematical calculations since it is provided with a microprocessor. Alternatively, such calculations are carried out by such an electronic processing unit connected to said measuring instrument.

[0035] In practice, the method according to the present invention introduces the concept that to correctly measure the force applied in a work station simultaneous measurements are necessary, of at least part or preferably all of them, carried out on the other work stations.

[0036] The steps of the method according to the present invention can be summarised as follows.

[0037] In the calibration step of the plant:

- detecting, through a calibration sensor arranged in place of the matrix, the values f_i of the forces exerted by the punches on each matrix and, at the same time, through the sensors associated with the punches, detecting the values L_{ij} of the forces on the punches,
- memorising a matrix of such values L_{ij} and f_i.
- Solving the system of equations (1) obtaining the coefficients b,

[0038] In normal operating conditions of the plant:

- detecting, at predetermined time intervals, the values from the sensors associated with the punches, constructing a "wave shape" with them.
- Using the coefficients b to calculate the real values of the forces on the punches, in each of the aforementioned moments in time, obtaining the real wave shape of the force applied
- Comparing such calculated values with those expected according to the statistical forecast,
- Emitting a control signal for said press according to such a comparison.

Claims

1. Method for controlling a moulding plant, said plant comprising at least one press having a plurality of work stations, each of which carries out the processing of at least one piece,

comprising the steps of

- obtaining, for each work station, the value of the force applied at predetermined time intervals during the course of each machine cycle,
- comparing, for each work station, the value of the force obtained at an i^{th} moment in time with that obtained by processing the values obtained in at least one previous cycle with statistical processes,
- adjusting the operation of the press or its possible stopping based upon the calculated relative deviation,

characterised in that for each work station, such a step of obtaining the value of the force applied at a predetermined moment in time comprises the step of calculating such a value from force detections carried out on said station and from detections carried out at the same moment in time in at least part of the other work stations.

2. Method according to claim 1, wherein said step of obtaining the value of the force applied at a predetermined moment in time comprises obtaining, in a calibration operation of the plant, a matrix of force values from the application of predetermined forces.

3. Method according to claim 2, wherein said calibration operation comprises the steps of:

- applying a predetermined force in each work station and detecting, from force sensors associated with each station, values of said forces in all of the stations of the press,
- memorising the force values detected by the sensors in such a matrix.

4. Method according to claim 3, wherein said step of calculating the force values in each work station at a predetermined moment in time comprises combining the detections carried out at said moment on the work stations, with the coefficient values worked out from said matrix obtained in the calibration operation of the plant.

5. System for controlling a moulding plant , said plant comprising at least one press having a plurality of work stations, each of which carries out the processing of at least one piece, said system comprises

- a plurality of force sensors each associated with a work station of said plurality of stations,
- an electronic instrument for measuring and controlling the plant connected to said sensors,

characterised in that for each work station at predetermined time intervals, said measuring instrument calculates the value of the force applied from force detections carried out by the sensor associated with said station and from detections carried out at the same moment in time by at least part of the other force sensors associated with the other work stations.

6. System according to claim 5, wherein said measuring and control instrument comprises a matrix of coefficients worked out from the force values obtained in a calibration step of the plant from the application of predetermined forces.

7. System according to claim 6, comprising a calibration sensor, able to be connected to said measuring and control instrument, able to be applied in the calibration step to each work station, suitable for calibrating said predetermined forces.

8. System according to claim 5, further comprising an electronic processing unit connected to said measuring instrument.

9. System according to claim 8, wherein said electronic processing unit is a personal computer.

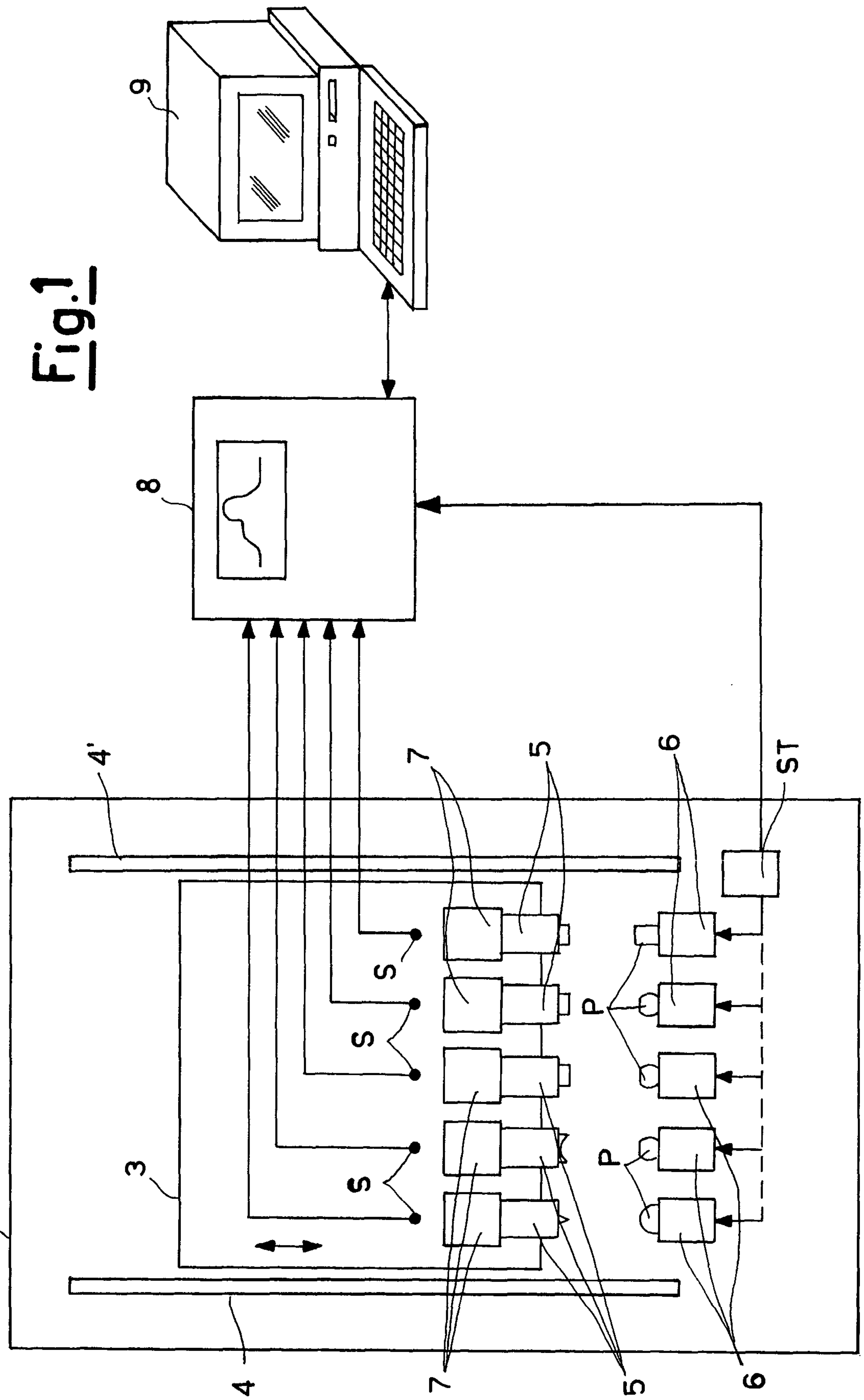

Fig.1

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EUROPEAN SEARCH REPORT

Application Number
EP 04 07 7706

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 January 2005	Barrow, J

CATEGORY OF CITED DOCUMENTS

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