(57) Procédé de déroulement automatique d’un processus de dressage pour un objet à dresser, tel que des tôles, des feuillards, des profilés et des tuyaux, et en particulier pour un objet de type fil ou de type à fils multiples, dans un appareil ou une machine à dresser doté d’au moins un rouleau à dresser réglable à l’aide d’un actionneur. Selon la présente invention, un modèle de simulation d’un processus de dressage à effectuer et un programme de simulation de processus sont élaborés, ce programme donnant en direct les paramètres de réglage du (des) rouleau(x) de dressage réglable(s). Lors du processus de dressage, des modifications des données concernant le produit, en particulier les propriétés du matériau et/ou les dimensions de l’objet, qui influencent le déroulement du processus de dressage, sont enregistrées, et sur la base de ces modifications sont calculées des données permettant le réglage du (des) rouleau(x) réglable(s). Des signaux destinés au réglage automatique du (des) rouleau(x) de dressage réglable(s) à l’aide d’un ou de plusieurs actionneurs sont alors émis.

(57) The invention relates to a method for the automatic conducting of a straightening process for an object that is to be straightened, such as sheet metal, strips, sections, pipes, and in particular for wire-like or multiwire-like objects that are to be straightened, in a straightening device or a levelling machine with at least one mangle roll which can be adjusted by an actuator. In accordance with the invention, a process simulation model of a straightening process that is to be conducted, and a process simulation programme are set up, and the latter gives directly "online" the settings of the adjustable mangle roll(s). During the straightening process, changes in the product data, in particular the material characteristics and/or dimensions of the object to be straightened which influence the realization of the straightening process, are recorded, and from these, data for setting the adjustable mangle roll(s) are also calculated, and signals are emitted for the automatic setting of the adjustable mangle roll(s) by means of an actuator and/or actuators.
METHOD FOR AUTOMATIC CONDUCTING OF A STRAIGHTENING PROCESS

The invention relates to a method for the automatic conducting of a straightening process for an object that is to be straightened, such as sheet metal, strips, sections, pipes, and in particular for wire-like or multewire-like objects that are to be straightened, in a straightening device or a levelling machine with at least one mangle roll which can be adjusted by an actuator. In accordance with the invention, a process simulation model of a straightening process that is to be conducted, and a process simulation programme are set up, and the latter gives directly "online" the settings of the adjustable mangle roll(s). During the straightening process, changes in the product data, in particular the material characteristics and/or dimensions of the object to be straightened which influence the realization of the straightening process, are recorded, and from these, data for setting the adjustable mangle roll(s) are also calculated, and signals are emitted for the automatic setting of the adjustable mangle roll(s) by means of an actuator and/or actuators.

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Process for the automatic control of a straightening process
The invention relates to a process for the automatic control of a straightening process
for a material to be straightened, such as sheet metal, strips, sections, pipes and, in
particular, for wire-like or multiwire-like objects that are to be straightened, in a
straightening apparatus or a levelling machine comprising at least one straightening
roller, adjustable by way of an actuator.

In order to eliminate buckling of objects to be straightened, non-rotary roller
straightening apparatus or levelling machines are employed. Due to the level-setting of
the straightening rollers in relation to one another, disposed in two rows in a mutually
offset manner in at least one straightening plane, the objects to be straightened are
subjected to alternating bends during their passage. The quantity and magnitude of
these alternating bends should be such that the entry curvatures of the objects to be
straightened are eliminated over the entire length of the objects to be straightened.

Predetermining the number of alternating bends, the magnitude of the alternating
bends is set in practice more or less intuitively according to the experience of the
person operating the straightening apparatus by way of the level-settings of the
straightening rollers. Changing the set parameters of the individual straightening rollers
is in this context performed by visual contact with the exiting material to be straightened
until satisfactory straightness is attained.

From Guericke W., "Simulation of the Wire Straightening Process" Wire Industry,
Volume 63, No. 752, 01 August 1996, modelling and simulation of wire straightening
processes is known. Such modelling aims to discover the most ideal conditions for a
straightening process and on the basis thereof work out specifications for conducting a
straightening process. However, a specialist is required for adapting the pre-set
process cycle to the actual conditions with regard to the tolerances of the respective
objects to be straightened, which is endeavoured by adjusting the straightening rollers
and by taking measurements after interrupting the straightening process.
From DE 195 03 850 C1 a non-rotary straightening apparatus for bending machines with an integrated measuring device is known. In the straightening apparatus, in the direction in which the material is passing through, at least one material bending measuring device, in which at least one measuring path is provided for a lengthwise predetermined material section, is disposed behind at least one straightening mechanism, in which context, along the measuring path, at least one mechanical and/or electronic and/or optical sensor device is provided, determining the extent of the bend and its orientation, in which context signals are generated by the sensor device, representing the measured bend of the material section, by way of which signals an adjusting gear is adjusted accordingly.
The measuring device of the known straightening apparatus operates according to the principle of the curvature detection in terms of the Three-Point-Method, supplying correct results only for objects to be straightened, which are cut into sections, or for immobile objects to be straightened, i.e. if the objects to be straightened are free from exterior forces and moments, neglecting gravity. If the curvature of the discharged objects to be straightened is not constant over the length of the measuring path, the measuring result is furthermore influenced by the length of the measuring path.

The straightening process is interrupted due to the required immobilisation of the objects that are to be straightened. The immobilisation and renewed setting into motion affects the result of the curvature measurements and necessitates changes which have an effect on the quality of the straightening process. Checking the setting is thus only possible by renewed immobilisation of the straightening apparatus, i.e. continuous monitoring and adjusting while the objects to be straightened are moving or during straightening, is not possible.

It is the object of the invention to provide a process which virtually permits an immediate, automatic adaptation of the setting to continuously measured data of the respective objects to be straightened of at least one straightening roller of a straightening apparatus or a levelling machine without interruption the straightening process.

This object is attained by a process having the characteristics of claim 1. Advantageous embodiments of the invention are apparent from the subsidiary claims.

To summarise, the invention, including advantageous embodiments, is based on the principle of modelling the straightening process, which is to be automated, in a preparatory phase, using mathematical-physical laws, setting up a simulation programme and performing a calculus of parameters by means of the simulation programme with varying product data, in particular of the material characteristics and/or
the dimensions of the objects to be straightened. This phase may be considered as "offline". Due to product and/or process data being measured continuously during the straightening process, i.e. without immobilising the objects to be straightened, the adjustment of the straightening apparatus or the levelling machine, required in order to attain the desired product quality, is performed very quickly "online", integrating the results of the calculus of parameters. The change of the setting is performed objectively and in a determined manner. The measured product and/or process data are also used in order to check the set up model as well as the simulation programme and to change them, if necessary. Objectivity replaces subjective experience, judgement by the eye of the person operating the straightening apparatus or levelling machine. This not only simplifies the process, performing it automatically, but it also enhances the quality.

In the following the invention is elucidated in more detail with reference to two diagrams.

Diagram 1 illustrates an embodiment of the automatic process control according to the invention.

During the preparatory phase I a process simulation programme A, by way of which the straightening process to be automated can be imitated in a virtual manner, is set up and utilised. In the process simulation programme A machine data B, technological sequence data C of the intended straightening process, material data D of the objects to be straightened and the desired quality S (straightness or evenness, residual stress state via the cross-section of the objects to be straightened, material characteristics, e.g. a desired apparent yield point and/or influence on the distinct yield point) of the straightened objects are entered.

The process simulation programme A is subject to a calculus of parameters F, in which parameters, for example the geometrical dimensions and/or the yield point of the objects to be straightened vary. Preferably, those parameters, to the change of which the straightening apparatus or the levelling machine E is supposed to react automatically, are varied. Parameters are to be adjusted to the specificity of the respective straightening process and/or of the straightening apparatus or the levelling
machine E. The results of the calculus of parameters F are product and/or process data and the target parameters required for automation, i.e. the required level-setting(s) of straightening roller(s) in order to attain the desired quality. All calculation results of the calculus of parameters F are stored in a database in the form of reference matrices G.

In the realisation phase II a process calculation model J is provided, referring back to the reference matrices G and therefore to the correlations between the influencing variables and the target variables of the straightening process, set up in the preparatory phase I and performing, as a function of the recorded production data O, the reference matrices selection K and the appropriate recall from the overriding material flow or the material tracking system (MTS) P. The process calculation model J realises on this basis and in consideration of product and/or process data M, determined in a measuring technical manner, the calculation and emission of the target parameters, i.e. the desired level-setting values L by means of assessment statistics methods. For the basic automation N these target parameters correspond to the desired values Sw. The momentary set values lw are compared to the desired values Sw, in which case the deviations are utilised to adjust both values. The product and/or process data M, determined in a measurement-technical manner, are filed in the database H in processed form Q. They may contribute to an optimisation R of the process simulation model and of the process simulation programme A in a subsequent preparatory phase.

An appropriately modified realisation phase II consists of a plurality of operators. Apart from an operator for adjusting or automatically correcting the adjusting values, an operator for the basic adjustment of the straightening apparatus or of the levelling machine immediately prior to the commencement of production as well as an operator for the recordal of the measured values are implemented. Prior to the admission of the objects to be straightened a measurement of thickness is performed, e.g. by means of laser distance sensors. The thickness value is passed on to the level-setting operator. At the same time, a value for the yield point of the object to be straightened is received, which comes either from the overriding material flow or the material tracking system P or is established by means of the yield point operator. For this purpose the yield point operator utilises the information content from a reference matrix G, selected and called up from the database H, as well as measuring results of the process magnitude, the
straightening force. The yield point determined by the yield point operator is checked for plausibility. The adjustment operator can pass the desired adjustment values to the basic automation \( N \) by way of the information on thickness and yield point of the objects to be straightened, using selected and called-up reference matrices \( G \). This means that the adjustments of the straightening roller(s), derived in this manner, take into account the respective thickness and yield point of the objects to be straightened. This allows to ensure a constant quality of the objects to be straightened, regardless of fluctuations between these two parameters.

Apart from the straightening force, the invention also permits the utilisation of other process parameters for automation and/or the reaction to fluctuations between other parameters of the objects to be straightened. For example, the curvature pattern of the objects to be straightened in a straightening apparatus or in a levelling machine can be measured and compared to a simulated curvature pattern. The comparison results allow to make detailed statements on the objects to be straightened or on the state of the straightening process. There also exists a plurality of possibilities to organise the process control, depending on the frequency of the change of the properties of the objects to be straightened, which may change, for example, from batch to batch, from one material to be straightened to the other and/or over the length of the material to be straightened.

By separating the preparatory phase I from the realisation phase II even very rapidly performed straightening processes may be automated. The automatic conducting of a straightening process as set out, is universally applicable and not time-dependant.

The embodiment illustrated in diagram 2 is denoted by units or values matching the letters according to diagram 1 and which are, therefore, not further elucidated. In this example the process simulation programme \( A \), taking into account the product and/or process data \( M \), determined in a measurement technical manner, and the recorded production data \( O \), passes on the desired values \( L \) directly to the basic automation \( N \).
Patent claims

1. Process for the automatic control of a straightening process for material to be straightened, such as sheet metal, strips, sections, pipes and, in particular, for wire-like or multiwire-like objects that are to be straightened, in a straightening apparatus or a levelling machine comprising at least one straightening roller, adjustable by way of an actuator, on the basis of which a process simulation model of a straightening process, which is to be performed, and a process simulation programme are set up, the latter predetermining directly “online” the settings of the adjustable straightening roller(s), in which context during the actual performance of the straightening process changes of the product data, in particular the material properties, having an effect on how the straightening process is conducted, and/or dimensions of the respective objects to be straightened, are recorded, data resulting therefrom are calculated for the setting of the adjustable straightening roller(s) and signals for the automatic setting of the adjustable straightening roller(s) are emitted by means of an actuator or actuators.

2. Process according to claim 1, characterised in that the process simulation model and the process simulation programme are set up in a preparatory step.

3. Process according to claim 2, characterised in that simulation calculations are carried out and that the results are entered into a process calculation model, predetermining on that basis the settings of the adjustable straightening roller(s).

4. Process according to any one of claims 1 to 3, characterised in that simulation calculations are carried out with the process simulation programme on the basis of the process simulation model, the results of which are stored and/or entered into the process calculation model.

5. Process according to any one of claims 1 to 4, characterised in that the process simulation model and the process simulation programme are optimised by the measured data recorded during the straightening process.
6. Process according to any one of claims 1 to 5, characterised in that the residual stress state is calculated by way of the cross-section of the objects to be straightened.

7. Process according to any one of claims 1 to 6, characterised in that the yield point of the respective object to be straightened is continuously determined as a function of the respective product and process data.

8. Process according to any one of claims 1 to 7, characterised in that for ferrous metals the distinct yield point (Luder's range) is calculated, reduced or eliminated.

9. Process according to any one of claims 1 to 8, characterised in that the virtual presentations of the straightening process are set up via the process simulation model and the process simulation programme, utilising data regarding the straightening apparatus or the levelling machine, the desired technological steps, the geometrical dimensions and the material properties and regarding the desired quality of the respective objects to be straightened.

10. Process according to claim 9, characterised in that the respective state of shape of the objects to be straightened, entering the straightening apparatus or the levelling machine, are recorded as geometrical magnitudes.

11. Process according to any one of claims 1 to 10, characterised in that each process simulation programme is subjected to a calculus of parameters.

12. Process according to claim 11, characterised in that at least one reference matrix is created from each process simulation programme subjected to a calculus of parameters.
Figure 2