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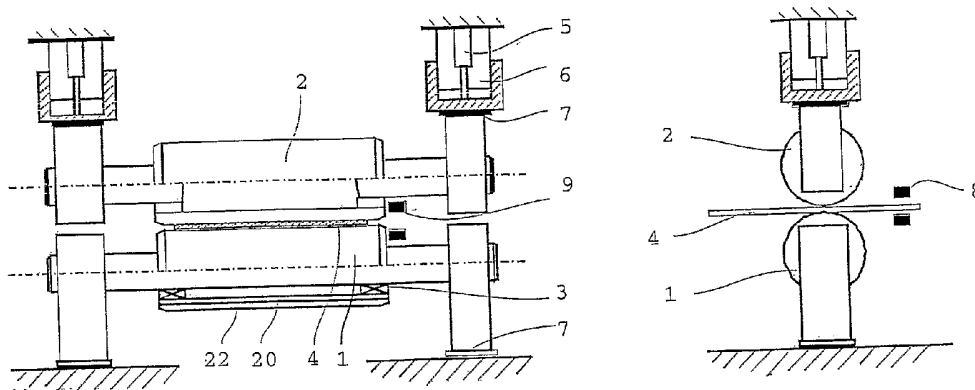
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(54) Title: METHOD OF IMPROVEMENT OF QUALITY AND RUNNABILITY OF PRODUCTION MACHINE FOR A WEB-LIKE PRODUCT



(57) Abstract: The invention relates to a method for improving the quality of a web-like product and the runnability of a production machine, such as a paper or board machine or a calender. In order to control a nip force fluctuation in operating conditions regarding a pressure load and/or a heat flux and/or a running speed, the rolls are provided with a run-out as desired by machining a desired form on the shell of a roll and/or the shaft and/or bearing components of a roll. The machining is performed in such a way that said desired form is non-circular and/or the centre of rotation of a workpiece has a trajectory as desired.

Method of improvement of quality and runnability of production machine for a weblike product

The invention relates to a method for upgrading the manufacture and maintenance of a paper machine roll for controlling the intermittent machine-directed as well as systematic cross-machine directed thickness fluctuation of paper or board and for improving the runnability as well as for cutting the maintenance costs of a paper machine by controlling the nip load by way of reducing fluctuation of a nip force resulting from geometric variations caused by unbalance, external stresses, inhomogeneous structure material, inconsistent deflections and thermal stresses, or by some other single structural systematic defect in a paper machine roll or roll assembly, such as a press section or a calender, by machining the external roll surface for a geometry which has an impact on the nip force fluctuation. Controlling the nip force refers generally to the reduction of force fluctuation. In some cases, however, it may be beneficial to establish a desired intermittent force fluctuation.

In paper making process, paper is pressed or polished by means of nip rolls which are loaded against each other (fig. 1). The press and the calender, for example, consist of two or more rolls, a stress loading system, as well as support structures. The rolls may include a heating or cooling system. The rolls establish one or more nips for passing therethrough a web-like product, such as paper, board, or a plastic strip. The web may proceed through the nip either alone or supported by a wire, a felt or a belt. One or two of the rolls is/are usually deflection compensated. The rolls may include various surface materials, such as metal, ceramics, rubber or polymer. The rolls may have a surface which is smooth or patterned, such as grooved or bored.

The function of a deflection-compensated roll or a DC-roll is to homogenize the uneven nip pressure in the axial direction of a roll caused by a pair of rolls in the paper machine. The use of a zone-controlled DC-roll also enables profiling the paper web in cross-direction (CD-direction). The deflection-compensated roll comprises a stationary shaft (21) and a roll shell (20) provided rotatably on top of it. Deflection-compensated rolls may also be heated. In a multi-nip press or calender, it is usually the outermost rolls, a so-called top roll and a bottom roll, which are deflection compensated. A typical feature with these rolls is a relatively thin-walled roll shell,

which can be deflected by means of a load applying mechanism internal of the roll. Typical load applying methods include, among others, pressurized oil and hydraulic load applying elements (23). The roll shell can be coated (22).

It is essential for a DC-roll that the shell has a wall thickness which is constant, especially in the circumferential direction. With current ultrasound-based methods, the wall thickness cannot be measured at a sufficient precision. Since the measurement is based on sound propagation time, the result does not reveal a difference between the velocity variation and propagation distance of sound. The reference surfaces of deflection-compensated rolls are machined for a circularity as perfect as possible and the roll has its bore and external surface machined in relation to this reference surface.

Rolls are often ground in paper mills in an assembled condition supported by their own end bearings. In this procedure, the rotational defects of large end bearings translate directly into variation of the roll shell thickness, which in turn causes force fluctuation in the roll nip during the process. The manufacturer's recommendation to disassemble the roll and to grind a DC-roll upon support bearings is a laborious and tedious process, but provides a better final result in terms of a required consistent wall thickness.

Deflection-compensated rolls are often used in pairs with relatively thick-walled tubular rolls (figs. 3 and 4), which are designed for example in terms of flexural rigidity for a sufficient rigidity to bear the nip load. In calenders, these tubular rolls are often heated or cooled for developing a heat flux during the process. This heat flux or thermal gradient results in the roll having an inconsistent heat distribution in radial direction. A heat flux develops even if the roll did not have a separate heating or cooling system, because the temperature of a paper machine web and, hence, that of the rolls is typically higher than temperature in the machinery hall. Thus, the heat flux from the region of roll ends is different from that taking place from the region of a roll shell, which leads to an uneven heat distribution also in axial direction.

Heating systems for thermal rolls exist in a variety of forms, both internal and external. Internal heating systems are based on a thermal effect carried by a heated

fluid, such as water, steam or oil, which effect is conveyed by way of a roll shell to a paper web. The fluid can also be used for cooling the roll. A hot fluid can be supplied into the bore of a tubular roll (fig. 3), from which the thermal energy proceeds to the roll shell. The bore is often provided with a displacement sleeve (14), which retains the fluid close to the roll shell's internal surface and thereby enhances the transfer of heat to the roll shell. A hot fluid can also be supplied by way of ducts drilled in the axial direction of the roll inside the roll shell (fig. 4) for an enhanced heat transfer to the roll's external surface. The roll shell comprises a plurality of such ducts around its circumference, typically organized in such a way that the supply of hot oil occurs from the same end of the roll as the discharge of the oil. The ducts are often equally spaced in circumferential direction and, for example, the oil supply and return ducts are arranged such that for one oil supply duct (15) there is/are one or two oil return ducts (16), or for two oil supply ducts there is one oil return duct.

The ducts are provided inside the roll shell in the proximity of the roll surface. The distance is limited by the thicknesses of material layers making up the roll shell. The roll surface layer, in the order of 10 mm, is made of hard and wear-resistant white cast iron (10). The roll shell core, about 50 mm inward from the surface, is made of tougher grey cast iron (12). Between these is a layer of mottled iron, i.e. a white and grey cast iron mixing layer (11). The duct is often drilled in the layer of grey cast iron as producing a straight passage within the mixing layer is difficult.

External heating systems include, among others, various top fans, induction heaters and IR-radiation based heaters. External heating systems have also been used for adjusting the cross-directed profile (CD) of paper by heating a roll locally in cross-direction, over a narrow area, zone by zone, whereby the roll diameter increases and the roll's CD profile changes. This has an impact on paper by way of two different mechanisms: thermal expansion of a local hot zone produces a higher zone-by-zone nip force; on the other hand, a higher roll temperature has an impact on the calendering property of paper. The effects of these mechanisms are inconsistent with each other and, thus, the qualities of paper, such as gloss, smoothness and thickness, cannot always optimized simultaneously. By a method of the invention, the demand for zone-by-zone heating can be reduced and thermal profiling can be focused on the fine profile adjustment.

Wearing of the roll end sections is often a major problem. One possible reason is a change in the ideal camber during the course of running, and a so-called oxbow effect. The end sections of a roll present a heat flux which is different from what occurs in the middle section of the roll, some thermal effect escaping out by way of the roll end plates with the result that the end section of a roll shell develops a heat distribution different from that of its middle section. The resulting unequal thermal expansion in various sections of a roll thus leads to a CD profile defect during the course of running.

The systematic defects of a roll shell include, among others, wall thickness variation in a roll shell, variations in shell material, such as variations regarding hardness, strength, elasticity and thermal expansion coefficients, as well as variations regarding flexibility and wall thickness and thermal expansion coefficients in the material properties of a possible roll coating. All the above-mentioned defects provide a combined effect which causes a roll run-out in operating conditions and thereby a force fluctuation in the roll nip.

The geometry of rolls manufactured from an inhomogeneous material changes as a function of temperature. Generally, an elevated temperature leads a roll bending, which causes force fluctuation in the nip. Roll manufacturers are familiar with this phenomenon, yet resources for its elimination are limited. In addition, the shell of paper-web heating, peripherically bored thermal rolls develops a circumferentially periodic heat distribution and respectively, as a result of thermal expansion, an undulated circularity profile. The transfer of heat effect from a high-speed rotating roll to the surroundings and to the paper makes it difficult to predict the phenomenon, nor is the problem eliminated for example by grinding a roll when it is hot. Heretofore, the elimination of problems caused by the rolls have been attempted by tightening precision in manufacturing. By means of traditional machine shop tolerances, the operation of rolls in running conditions cannot be substantially improved, because the inaccuracy in machining represents a very small portion of the total defect. It is also known that the run-out of rolls affects the quality variations of paper and the runnability of a paper machine.

The rolls cause various problems in a paper machine, regarding runnability, quality and service life. Rotational errors and structural defects of a roll constitute a source

of geometric error in running conditions and dynamic misalignment of the nip, causing a nip force fluctuation which falls into step with the rotation of a roll or the rolls. The run-out and geometric errors have been determined with measurements from a paper web and rolls, as well as in production both with a nip closed and with a nip open. The problems multiply with the increase of speed, temperature, stress load and web width. The roll temperatures are presently as high as 250°C and the trend is towards ever increasing temperatures.

It is recognized that the roll run-out is encouraged by at least the following defects in bearing assembly: a non-circularity of the shaft, a non-circularity and thickness variation of the bearing bush, as well as a non-circularity of the bearing installation in deflection-compensated rolls, either in combinations or individually.

Nip rolls present a so-called barring problem, which causes noise, web breaks, damage to bearings and degrades rolls to angularity. A significant number of impulses originate from geometric errors in rolls during process.

Paper machine fabrics, such as felts and wires, are subject to barring which causes intermittent thickness variation and alters the dewatering ability thereof, thereby reducing the service life of felts and wires. Attempts have been made to discourage the barring effect by developing a so-called felt cocking system, which is based on the principle of sliding the fabric in running direction, such that a cross-felt extending barring mark caused by the vibration of a pair of nip rolls arrives next time at the nip in an oblique position, thus slowing down the barring effect. Attempts to slow down barring has led to the development of new types of paper machine fabric materials, such as urethane-based felts. A method of the invention is capable of reducing remarkably the machine-directed force fluctuation caused by nip rolls in the nip, thus slowing down also the barring effect of the felt. An advantage of the method over other efforts is that the method is capable of reducing the original cause of barring instead of just discouraging the progress of barring.

It is prior knowledge that the circularity error and run-out of a cylindrical workpiece, such as a paper machine roll, can be reduced by moving a working tool, such as a grinding wheel or a lathe tool, as a function of the workpiece's rotational angle and

longitudinal axis, such that the distance of a tool from the centre of rotation of a workpiece is maintained substantially constant or as desired in the direction of the longitudinal axis. The working control system can be used for correcting not only a misalignment error but also a circularity error in a roll, thereby controlling the entire roll with regard to its 3D geometry. In paper and steel industry, this machining method is generally referred to as 3D machining. The respective grinding method is referred to as 3D grinding and the turning method as 3D turning.

It is prior knowledge that the true roundness profile of rolls in a grinding machine can be measured by means of a multi-point measurement, such as a four-point measurement.

It is known that the control system has enabled the machining of cylindrical workpieces, such as paper machine rolls, for a precision which is at a substantially higher level than the mechanical precision of a working machine itself.

It is also prior known that the rolls can be machined to become non-circular and/or arcuate and/or otherwise contrary to traditional machine shop practice in order to improve their operation at the running speed of a paper machine with respect to traditionally machined rolls.

It is prior known that the periodic contact pressure fluctuation of rolls can be reduced by means of a non-circular cross-section geometry, said geometry being created by 3D machining.

A method of the invention can be used for identifying phenomena with a substantial effect on the behaviour of nip rolls, such as the 3d geometry of a roll in operating conditions.

It is prior knowledge that the run-out and circularity of a roll can be measured in operating conditions directly from the roll shell. The measurement has been conducted by applying prior known multi-sensor methods (multi-point methods), effected for example by methods as described in patents FI934059, FI94801 or FI96448. These measurements are based on a rigid measuring frame, said measuring frame being provided with sensors measuring the run-out of a surface,

such that the relative angle of the sensors with respect to various measuring points and the centre of a roll is known. However, the use of such a rigid measuring frame in a paper mill is problematic, because quite often there is no location on the paper machine suitable for mounting the measuring frame accurately and with a sufficient stability or there is no room in the machine that could be used for measuring frames based on fixed sensor angles.

In this specification, the term test geometry method is used in reference to:

Measuring a nip force fluctuation caused by a known run-out in roll geometry and/or a thickness fluctuation in an end product, such as paper or board. Machining rolls for a known geometry and/or run-out profile, followed by measuring the force fluctuation and/or thickness fluctuation caused by said rolls. Calculating the magnitude of a known variation and determining a desired real geometry, for example by vector calculation. The method is analogous for example to a balancing test mass method with the exception that the calculation must be performed by including one or more vector components of geometry and/or run-out falling into step with the rotation of a roll.

A method of the invention is used for measuring systematic defects in operating conditions, either a) by compensating for the combined effect thereof on a nip force fluctuation or b) by measuring separately a fluctuation caused by a single systematic defect and adding it to the total fluctuation to be compensated for.

The invention has its objective accomplished on the basis of the characterizing features set forth in the appended claims. A few embodiments of the invention will now be described in more detail with reference to the accompanying drawings.

Example of embodiment 1.

A thermal distribution $T(r, \theta, x)$ in a roll shell (2) shown in fig. 2, as a function of radius r , angle θ and roll length x , has a significant impact on a geometry $R(\theta, T)$ of thermal rolls. Optimization of the geometry for operating conditions calls for an assessment of the roll shell thermal distribution by means of a heat transfer model. In this case, it is necessary to know e.g. a thermal power P_{IN} going in a central bore

(13) of the roll or in a duct (15) drilled in its shell and an outcoming thermal power P_{OUT} i.e. a volume flow Q , a density ρ , specific heat capacity c of the oil, a temperature T_{IN} of the ingoing oil and a temperature T_{OUT} of the oil in a discharge duct (16), a coefficient of heat transfer h , and a temperature T_S and/or a temperature distribution $T_S(\theta, x)$ of the external shell surface to enable calculating a thermal distribution $T_S(\theta, r, x)$ across the entire shell.

Determination of a process-time roll geometry $R(v, F(\theta), T(r, \theta))$ is also performed by using a thermomechanical model for the roll, comprising the various material layers, such as white cast iron (10), grey cast iron (12), as well as an intermediate mottled mixing layer (11), whose heat conduction λ , thermal expansion α and elastic modulus E are substantially different from each other. By means of the thermal distribution $T(r, \theta)$ consistent with the first model and by varying thicknesses $(s_1 \dots s_3)$ of the material layers or a centricity $e_{1,2}$ of the internal and external roll surface, it is possible to calculate a deflection or a camber v of the thermal roll.

In a method of the invention, a roll roundness profile $R(\theta)$ is calculated in separate run-out measurements from the roll surface by shifting or sliding a sensor S_1 (28) and/or sensors to measuring positions S_2 (29), S_3 (30), S_4 (31) and S_n (32) in circumferentially of the roll at desired sensor angles $\theta_{2..n}$ with respect to the first position. The sensor for measuring a run-out may comprise contacting and/or non-contacting acceleration, speed and/or acceleration sensors. The measurement can also be conducted as a continuous measurement by sliding a sensor circumferentially of the roll and by measuring continuously the sensor's inclination angle. The measurement analysis is performed by using for example algorithms based on the weighting coefficients of multi-point methods. A specific feature in the measuring method is that every measuring angle used in algorithm is measured with an inclination angle measuring sensor, such as for example an acceleration sensor measuring the direction of a gravitational force or an inclination sensor or a gyroscope or combinations thereof. The method is based on working out the run-out components falling in step with rotation of a roll, for example by calculating the synchronized time domain average of a run-out signal. An objective of the invention is to work out a geometry existing in the running conditions of a roll, which

geometry changes as a result of rotating speed and/or external stresses and/or internal stresses and/or thermal stress. An advantage of the method over currently used circularity measuring methods is that the measurement can be readily implemented even in cramped conditions, since no continuous void roll surface is needed between the measuring points as the measurement can be performed for example on either side of a nip roll (25) or some other obstacle, such as for example a service platform (26) or frame structures (27).

A method of the invention can also be used for detecting various modes of vibration, such as modes of deflection and shell vibration, when the measurement is conducted concurrently from several cross-sections of a roll shell. Once the amplitude and phase data of run-out measurements is available, the measurements can be analysed for the present mode of vibration.

In a method of the invention, the run-out and circularity of a thermal roll is measured at an open-nip equalized temperature, whereby thermal power is supplied to the roll, but such power only escapes to surrounding air instead of being transferred to paper. In a method of the invention, the run-out of a roll is also measured during normal production by opening the nip momentarily. Hence, the heat distribution of a thermal roll is consistent with ordinary production conditions. These two measurements enable discovering a disparity in the dynamic behaviour of a roll in various thermal stress conditions. Naturally, the measurement of a roll in operating conditions does not always call for a measurement from several various directions and/or a determination of the roll's circularity, but the compensation for a run-out of the rolls can be effected by using results obtained from just run-out measurements.

The thicknesses of structural material layers in a thermal roll are identified by means of an optimizing algorithm to comply with measuring results obtained at an open-nip equalized running temperature. The structure is also calculated with a heat distribution existing in a thermal roll during production, and the calculated run-out is compared with a corresponding measurement during process. This enables calculating the run-out of a thermal roll in running conditions with a heat distribution existing explicitly during the course of running. The result is used according to the invention in working out a control graph for 3D grinding.

Example of embodiment 2.

In view of optimizing an operation-time geometry for a roll and determining a work control curve for 3D machining, the factors causing nip force fluctuation are categorized for individual error sources, each of which will be worked out separately.

A dynamic roll deflection resulting from running speed and unbalance can be measured from a cold roll either in a paper machine, on a grinding machine or on a balancing machine. A force fluctuation resulting from the dynamic roll deflection and an anti-deflection support reaction resulting from a nip contact will be accounted for and the measured deflection line is used for working out, for example by means of an analytical or finite-element model, a control graph No. 1 for 3D grinding.

A camber resulting from thermal stress can be measured for example as a run-out measurement by the method of embodiment 1, for example while production process is running in a paper machine. Provided this way is a control graph No. 2 correcting a heat-effected camber, as the stopping of deflection in the nip contact is accounted for in calculation.

The determination of control graphs 1 and 2 can also be conducted by heating a roll for example in a balancing machine and by measuring a roll deflection caused by temperature. A balancing machine may also be used for measuring a heat-cambered roll for its dynamic deflection and bearing forces.

The 3D geometric error resulting from faulty rotation of the bearing assembly at the time of grinding is measured on a roll grinding machine by means of a circularity measuring device and fed into the work control system as a control graph No. 3.

Because the heating oil ducts (15, 16) of a thermal roll are disposed in the proximity of the roll shell surface, the roll shell will be more elastic at the ducts than at a land between the ducts. This variation of elasticity in response to a stress is a vibration impulse falling in synchronization with the number of ducts and thereby a nip-force fluctuation instigating factor in the loaded condition of a paper machine at the time of running. In a method of the invention, the proportion of this

phenomenon of a run-out appearing on the wavelength of the heating oil ducts will be worked out mathematically for example by means of a Finite Element Method (FEM) and/or by measuring a run-out of the roll surface for example from the opposite side of the nip at two or more different nip load levels at a constant temperature. In the event that the change of a nip load appears as a measurable change of run-out in the spacing of heating oil ducts, it will be possible to determine the stress-responsive elasticity of the heating ducts caused by a nip force fluctuation. The nip force fluctuation resulting from the elasticity of heating oil ducts in a roll shell can be minimized by a geometric compensation $x(\phi)$ according to a known formula $F = k \cdot x$, wherein an objective is to standardize the force F when the elasticity of a roll shell varies as a function $k(\phi)$ of the roll's angle of rotation. The determined geometry $x(\phi)$ is used for the determination of a control graph No. 4.

The thermal power proceeding from the heating oil ducts (15, 16) of a thermal roll to the roll surface develops an undulated heat flux, which in turn causes an undulated geometric error, "a cookie geometry". The factor caused by this phenomenon has a wavelength which is equal to that between the heating oil ducts. The magnitude of this single error component can be determined mathematically by means of FEM and/or by measuring a roll run-out for example from the opposite side of the nip at a constant load at two or more roll temperatures, for example by the method of embodiment 1. In the event that the change of temperature has an impact on a run-out component appearing on the wavelength of the heating oil ducts, at least some of the nip force fluctuation results from a thermal expansion caused by the heating ducts. The run-out component determined like this is used for working out a control graph No. 5.

The roll is ground in a stabilized condition by supplementing the work control with the above-described control graphs 1...5, if necessary according to the magnitude of a single error. Hence, all cross-sections become circular, specifically in the paper machine's production conditions.

Example of embodiment 3.

The determination of control graphs separately for 3D machining can be conducted as described in embodiment 2, yet in such a way that a heat flux and a geometric error caused thereby may also be implemented at temperatures lower than production temperatures, provided that a temperature difference matching a production condition is established between the heating oil ducts and the external surface. A roll surface temperature, which is appropriate from the standpoint of machining, is for example the air temperature in a roll grinding workshop, whereby the machining can be performed by using a conventional cutting fluid and temperature stresses and deformations caused in the machine tool by a workpiece are insignificant. In order to conduct machining with a heat flux equal to production condition, the roll must be heated the same way as in production condition and the roll surface must be cleared, for example by means of cooling water or air, of a thermal power which is designed to match the process-time transfer of thermal power to paper and the ambience.

The roll is ground in this above-mentioned stabilized condition subjected to a thermal stress by supplementing the work control with the above-described control graphs, if necessary according to the magnitude of a single error. Thus, the roll cross-sections become circular, specifically in conditions simulating the production process of a paper machine. When the temperature of a roll after grinding equalizes to a constant temperature, the geometry of the roll's cross-section will include an undulation pattern (having typically an amplitude of 0,2...5 μm), resulting from thermal expansion and matching the spacing of oil passage ducts, and a static camber in reverse matching the dynamic deflection and the thermal stress. According to traditional machine shop tolerances, the roll may be of a poor quality, yet it becomes optimal in operating conditions.

Example of embodiment 4.

Disengagement of the shaft (21) and bearings (3) of a deflection-compensated roll's shell (20) for grinding represents a maintenance-related risk, because a significant number of unexpected machine breakdowns coincides with the first use of newly overhauled machine components. It is an established practice in paper mills to grind

DC-rolls on their own bearings, whereby particularly the roller-bearing mounted end bearings cause rotational error motion duplicating as a geometric error in the roll. It is an objective to 3D machine a roll (33) in assembled condition on its own bearings in such a way that the accomplished grinding precision matches that obtained by a system recommended by the manufacturer, in which the rotational precision at the time of grinding is achieved by supporting the roll shell by its reference surfaces (34). In the arrangement of embodiment 4, the 3D machining of a roll is based on the aspect that a reference surface (34) machined on the roll is tracked by means of any prior known measuring sensor (36), such as for example a laser or a contacting optical measuring rod. The method enables avoiding the situation that a rotational error in a roll's own bearing assembly be duplicated as a geometric error in the roll. The method is also cost effective as the roll need not be disassembled for grinding. The sensors may also be disposed in an attitude other than along the line of a grinding wheel (35), inasmuch as the angular deviation can be mathematically accounted for in the control system.

The inventive method provides a reduction in the quality variation of paper both in machine direction (MD) and in cross-direction (CD), a significant decline in vibrations along the entire papermaking line by reducing, along others, the impulses of regenerative barring vibration, a prolongation of the service life of rolls and roll coatings and, by virtue of barring being less frequent than the grinding interval, a deterrent to the barring of paper machine fabrics, thus extending the service life thereof.

Example of embodiment 5. Utilization of a test geometry method.

The inventive method can be applied as in embodiment 1, but the target geometry is determined by using a test geometry method as described above.

In a calibration run, a pair of nip rolls (1, 2) is driven, for example without paper, at a running speed generally lower than a production speed immediately after normal paper production, while the rolls are still at a normal production temperature. The sooner a calibration run is performed after finishing a process run, the more likely it is that the running-time heat flux and thereby temperature have not yet changed, thus enabling a measurement of a nip load consistent the real operating condition.

The applicable stress level can be either a real, for example average load level or alternatively two or more production load levels, whereby the inside stress levels can be interpolated and the outside ones can be extrapolated.

The force measurement can be conducted by using a stress measuring feature of load applying cylinders, such as a hydraulic pressure (5) or a displacement (6) of the cylinders, or load sensors (7) fitted in bearing housings or other structures, or special films or electric diaphragm sensors (4) intended for measuring a nip pressure.

The measured and synchronized signals can be used for working out a target geometric form required for each nip roll. The multiplier for the amplitude of correction can be determined calculably by means of a mathematical model or experimentally by means of preceding measurements, a separate calibration run or a special test geometry method.

The machined geometry is made more precise over the following machining cycle by supplementing the machining geometry with a geometry consistent with a residual error measured from the nip force fluctuation and/or from the product. The measuring signals are used to determine a fluctuation caused by each roll, for example by averaging a synchronized time plane set in step with the roll and/or by means of a Fourier analysis.

The method according to embodiment 5 of the invention is used for giving nip rolls a desired run-out by machining a desired form to the roll shell. The objective is to obtain such a cross-sectional geometry and trajectory for the centre of rotation which jointly compensate for the stress and elasticity variations resulting from the structure and/or thermal expansion of a nip roll, and to thereby accomplish a more consistent quality for the end product and a better runnability for the production line.

In practice, for example, the shells of both nip rolls are machined to form a calculably determined bulge at a spot with which the undulation peak in the thickness of calendered paper can be synchronized.

Based on subsequently synchronized measuring signals, it is verified that the fluctuations of signals measured by all sensors in a pair of nip rolls have diminished, and so has the thickness variation of paper, board, or a plastic strip. The runnability and efficiency of an entire paper machine has improved, because the vibration levels of a pair of nip rolls become lower, fewer web breaks occur, and a harmonic impulse, carried along by paper as paper quality variation, such as thickness variation, for the following unit processes of papermaking, is reduced. Running speed can also be raised.

The rolls machined with a residual error correction can be used for further reducing the signal variations measured by the sensors of a pair of nip rolls and for further upgrading the quality of an end product.

The inventive method also enables a prolongation of service life for rolls and especially roll coatings.

Figure 1. shows schematically a unit process, such as a press or calender for a paper machine, comprising a deflection-compensated roll (1) and a thermal roll (2) with bearings (3) therefor. The figure shows a web-like product (4), such as paper, board, or a film or sensor used for a nip force measurement. The nip force is provided for example by way of a hydraulic cylinder load (5) external of the roll and the nip force can be measured by a cylinder pressure (6) measurement or by a load sensor (7) or by a thickness measurement (8) of the web-like product. The measurements are analysed by using synchronization sensors (9).

Figure 2. shows schematically a deflection-compensated roll structure, wherein a roll shell (20) is provided around a stationary shaft (21). The roll shell can be coated for example with polymer (22) and a pressure on the roll is provided for example by means of a hydraulic load applying element (23).

Figure 3. shows schematically one type of thermal roll structure, comprising various roll shell material layers, such as white cast iron (10), grey cast iron (12) and an intermediate mottled mixing layer (11) therebetween. The heat transfer of a heating or cooling fluid (13) can be enhanced by a displacement conduit (14).

Figure 4. shows schematically one type of thermal roll structure, comprising various roll shell material layers, such as white cast iron (10), grey cast iron (12) and an intermediate mottled mixing layer (11) therebetween. Heating or cooling for the roll is provided by means of supply ducts (15) and discharge ducts (16) drilled in the roll shell.

Figure 5. shows schematically a roll run-out measurement in paper machine operating conditions for determining, for example, a normal production-time geometry, comprising a roll (24) to be measured and, by way of example, measuring points (28...32) required by a multi-sensor method, as well as surrounding structures, such as a second roll (25), a service platform (26) and frame structures (27).

Figure 6. shows schematically 3D machining a roll (33) to a desired geometry (37) in compliance with a reference surface (14) of a desired shape prepared on the roll, comprising a grinding wheel (35) and sensors (36) measuring the reference surfaces.

Claims

1. A method for improving the quality of a web-like product and the runnability of a production machine, such as a paper or board machine or a calender, *characterized in* that, in order to control a nip force fluctuation in operating conditions regarding a pressure load and/or a heat flux and/or a running speed, the rolls are provided with a run-out as desired by machining a desired form on the shell of a roll and/or the shaft and/or bearing components of a roll, such that said desired form is non-circular and/or the centre of rotation of a workpiece has a trajectory as desired.
2. A method as set forth in claim 1, *characterized in* that improving the quality of a web-like product and the runnability of a production machine, such as a paper or board machine or a calender, refers to a reduction of intermittent machine-directed and/or systematic cross-directed quality variation, such as thickness and/or gloss and/or smoothness variation, in paper and/or board, and/or to a reduction of the effects of external stress variations and/or to a compensation for inconsistent elasticities of the structure and/or to a compensation for geometric variations resulting from thermal stresses and/or to a reduction of nip force fluctuation resulting from other single systematic structural defect in a paper machine roll or roll system in operating conditions and/or to an improvement of the runnability of a paper machine and/or to a reduction of maintenance costs.
3. A method as set forth in claim 1-2, *characterized in* that the desired form is determined in operating conditions, and/or in conditions reflecting the effects of operating conditions, by calculation and/or by measuring, wherein the operating conditions refer to a machine running speed and/or to a pressure load of nip rolls and/or to a heat flux in the rolls.
4. A method as set forth in claims 1-3, *characterized in* that the geometry of the rolls in operating conditions is measured from the roll surface in a continuous measurement and/or in separate measurements by shifting and/or sliding a sensor and/or sensors circumferentially of the roll, such that the inclination angle of every measuring signal relative to the roll is known, and the measurements can be analysed for a systematic run-out signal, falling in step with rotation of the roll, and/or run-out components, for example by averaging a synchronized time

domain and/or by means of a Fourier analysis, and such analysed run-out signals and/or run-out components are used for working out, by means of known circularity algorithms, a circularity profile for the roll and a displacement of its centre of rotation.

5. A method as set forth in claim 1-3, characterized in that the geometry to be machined on the rolls is determined from a nip force fluctuation and/or from a pressure load fluctuation and/or from an intermittent machine-directed variation and/or a cross-directed variation, such as thickness and/or grammage variation and/or gloss variation and/or other paper quality variation, in a product, such as paper and/or board.

6. A method as set forth in claim 1-3, characterized in that the geometry to be machined on the rolls is determined separately for each single error component and, in the machining of a roll, a geometric variation resulting from a heat flux is compensated for by generating in the roll, at a temperature favourable from the standpoint of machining and a machine tool, a heat flux, which is consistent with operating conditions and which can be produced by means of internal heating/cooling and/or external cooling/heating.

7. A method as set forth in claims 1-3, characterized in that the geometry to be machined on the rolls is determined by means of a calibration run effected with rolls at operating temperature with the nip closed and without paper in the nip, such that the measuring signals, such as for example a cylinder pressure and/or a nip film and/or a diaphragm sensor reflecting a nip force, are used for determining a variation caused by each roll, for example by means of a synchronized average set in step with the roll and/or by means of a Fourier analysis, said calibration run being performed at a nip pressure applied in production and/or at one, two or more stress levels lower than a normal nip load, such that the normal nip load level is determined from the measuring results, for example by extrapolation.

8. A test geometry method for implementing a method as set forth in claims 1-3, characterized in that the target geometry for the rolls is determined experimentally, such that the nip force fluctuation caused by a known run-out

and/or the thickness variation of a product, such as paper, is measured, followed by machining the rolls for a known variation geometry and/or a variation of the run-out profile; and then a measurement is conducted regarding a force fluctuation and/or a thickness variation caused by said rolls, followed by working out the magnitude of variation, for example by vector calculation, and then by determining a real desired geometry.

9. A method as set forth in any of claims 1-7, characterized in that the geometry to be machined on the rolls is determined experimentally by means of a test geometry method as set forth in claim 8.

10. A method as set forth in claim 1-3, characterized in that the geometry to be machined on the rolls is determined by calculation, such as by means of a mathematical model, like for example a finite-element model, relating to a press and/or a calender and/or a single roll, said roll model comprising differences between at least the wall thickness variation of a roll shell and/or elasticity variation of a coating and/or material layer thickness variation of a roll shell and/or material layers of a roll shell, regarding thermal expansion and/or elastic modulus and/or thermal conductivity.

11. A method as set forth in claim 1-10, characterized in that a desired target geometry and a control graph for 3D machining are determined in conjunction with manufacture and/or maintenance by means of a reference surface prepared on the surface.

12. A method as set forth in claim 1-11, characterized in that the rolls' reference surface and/or the roll shell are machined to be circular and/or non-circular as desired by 3D machining.

13. A method as set forth in claim 1-12, characterized in that the machining of a roll for a desired form by 3D grinding in compliance with a reference surface is effected without disassembling the roll and/or the bearing assembly.

14. A method as set forth in any of claims 1-13, characterized in that the geometry determined and machined by a method as set forth in any of claims 4-10

is enhanced in terms of precision by supplementing the machining geometry with a geometry consistent with the residual error measured by a method as set forth in any of claims 4-10.

15. A method as set forth in any of claims 1-14, characterized in that the machined geometry is measured by a multi-point measurement, such as a four-point measurement.

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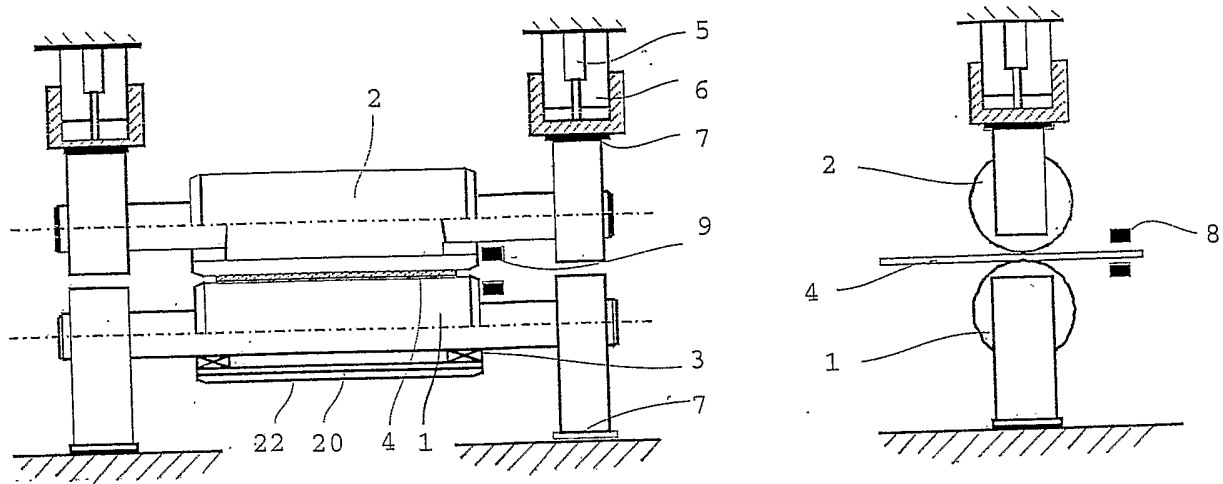


Fig. 1

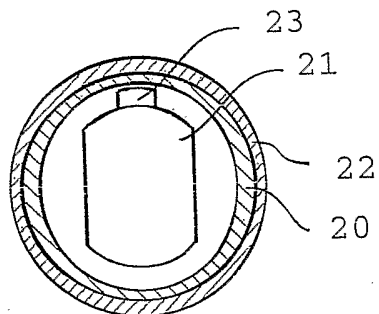


Fig. 2

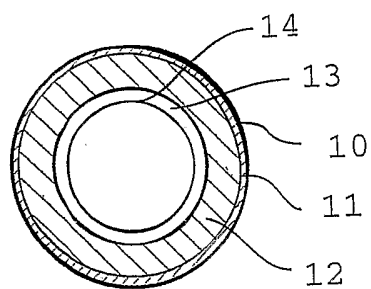


Fig. 3

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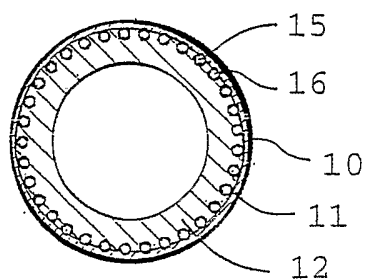


Fig. 4

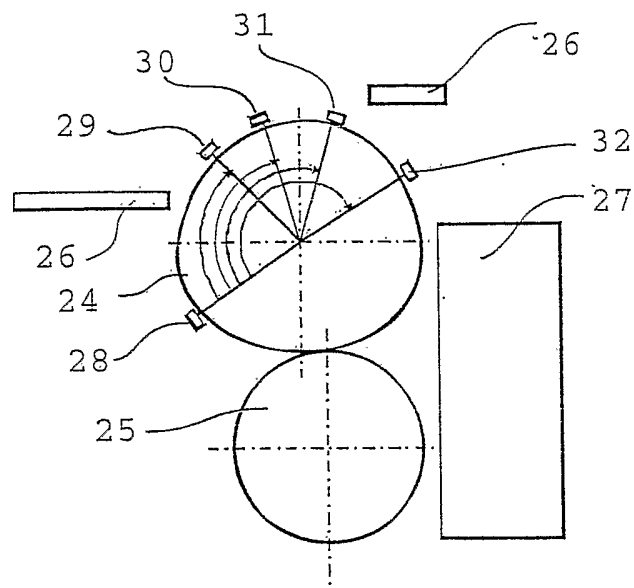


Fig. 5

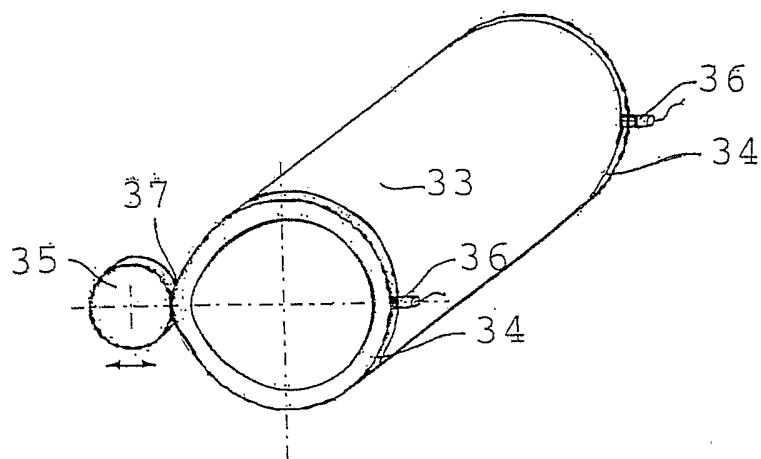


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI2006/000004

A. CLASSIFICATION OF SUBJECT MATTER		
See extra sheet		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
IPC8: F16C, D21G, D21F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
FI, SE, NO, DK classes as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPO-Internal, WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AEL/Metsko, Calendering Methods, "Calender Vibrations-Mechanical and process challenge", 27-28 October 2004, the whole document	1
X	EP 0507553 A2 (ARMCO INC) 07 October 1992 (07.10.1992), abstract; page 6, lines 31-36	1
X	FI 942567 A (KUOSMANEN PETRI et al.) 02 December 1995 (02.12.1995), abstract; page 1, paragraph 4; page 4, paragraphs 1,3,6	1
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
29 March 2006 (29.03.2006)		20 April 2006 (20.04.2006)
Name and mailing address of the ISA/FI National Board of Patents and Registration of Finland P.O. Box 1160, FI-00101 HELSINKI, Finland Facsimile No. +358 9 6939 5328		Authorized officer Pirjo Laine Telephone No. +358 9 6939 500

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2006/000004

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2006/000004

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.

F16C 13/00 (2006.01)

D21G 1/02 (2006.01)

G01B 21/20 (2006.01)