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(54) **Weaving loom with modulated drive and weaving controlling method featuring variation of the drive speed**

(57) A weaving loom and a control method therefor are disclosed, said loom comprising at least one weaving machine, a sley, weft inserting members and a main driving motor which is operated at a variable speed on the basis of predetermined textile requirements.

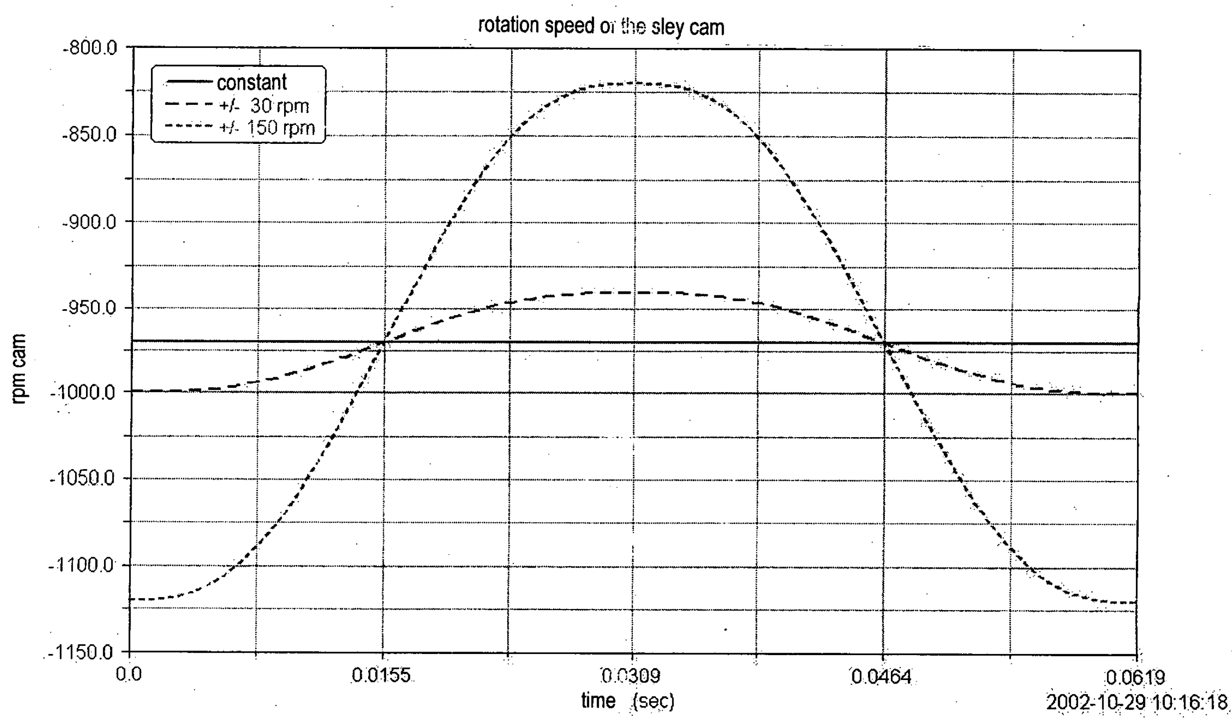

FIG.1

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Description

Field of the invention

[0001] The present invention relates to a modulated drive weaving loom and to a weaving controlling method employing said loom.

Background art

[0002] As is known, conventionally the drive system of a weaving loom comprises at least one main motor able to actuate a main shaft by means of a suitable friction clutch and a flywheel. The main shaft, in addition to transmitting motion to the main components, such as the sley and - in gripper looms - the actual grippers, drives also to secondary shafts which control other components, for example the weaving machine. Moreover, one or more auxiliary motors may be envisaged for operation of the loom at a slow speed or in reverse.

[0003] In the past, efforts have always been directed towards ensuring as uniform as possible operating speed of the loom, despite the fact that the inertia forces and resistance torques vary a number of times within the same operating cycle of the loom. For this purpose, a flywheel was used, said flywheel representing an effective mechanical system able to absorb a momentum, during the phases when the resistance torque decreases, and restore said momentum during the phases when the resistance torque increases, thereby avoiding an excessive loss of power (in particular during acceleration peaks) and a certain uniformity of operation. With this system, moreover, it was possible to use drive systems with a limited power - and therefore cost - whilst still achieving a uniform power consumption and speed of rotation of the main shaft.

[0004] Owing to the uniform rotation of the main shaft, it was possible to set in a accurate and repeatable manner the motion law of the individual components (for example, sley, dobby, grippers, etc.) by means of suitable kinematic chains, such as crank systems and cams. An important example of these kinematic mechanisms is represented by the well-known variable-pitch screw cam system for actuating the gripper, for example as also described in EP 164,627.

[0005] Recently weaving looms equipped with direct-drive systems have appeared, in other words systems where a flywheel for regulating the speed during the operating cycle is no longer used. An example of this loom is described in EP-A-1,158,081.

[0006] Said weaving looms equipped with direct-drive systems allow the weaving program to be set according to the physical characteristics of the yarn and the surrounding conditions in which the said looms are operating.

[0007] It has been found, moreover, that there are some circumstances for which it is desirable to find solutions more advantageous than those offered by the known art.

[0008] One of these weaving-related requirements, which arises upon weaving various yarns with an air jet loom, is that of keeping the behaviour of the weft as constant as possible (repeatability) during insertion, despite the variability in the physical characteristics and load conditions which occur between the start and end of the weft yarn reel. At present it is possible to take into account this variability to a very limited degree, for example by means of "air control" systems used in the air jet looms, said systems controlling the stresses imparted to the weft yarn by regulating the flowrate of the air output by the nozzle.

[0009] Further, there are many other factors which vary with the characteristics of the yarn. For example, some yarns are very sensitive to the friction against the grippers, therefore it is required to set a long shed opening time in order to allow insertion of the weft without difficulty, something which inevitably slows down the average speed of the loom; in other cases a greater amount of friction may be tolerated, thus allowing to increase the weaving speed.

[0010] A further requirement occurs in natural, synthetic or artificial flock yarns which have a relatively low strength and therefore in any case result in the need for a sufficiently low insertion speed of the weft yarn and consequently low speed of the entire loom.

[0011] All these individual requirements are met in the looms of the prior art using specific groups of cams or kinematic mechanisms associated with the weaving components which must be varied depending on the specific articles, regulating the kinematic mechanisms or cam components so that the motion laws are redefined in such a way as to have efficient operation in the new conditions. This, as can be understood, is somewhat complex.

[0012] For example, in the case of an air jet loom, it is desirable to be able to adapt operation of the loom to the weft insertion timing (duration of insertion and time of arrival) which can be in turn be determined on the basis of the yarn. The problems which arise from an incorrect weft arrival time and other problems associated with a "slack weft" and "inset weft" are currently solved by reducing the speed of the loom or by changing - mechanically (i.e. with replacement of the sley cams) - the time available for insertion.

[0013] The Applicant has instead decided to abandon the usual approach, investigating totally new areas and leaving aside the established findings and theories which existed hitherto in this field, in order to be able to obtain a loom which overcomes at least partially the drawbacks of the prior art.

Summary of the invention

[0014] The object of the present invention, therefore, is that of obtaining the maximum benefit from the direct-drive system by providing a direct-drive loom which is controlled in an efficient manner so as to obtain the best result in weaving terms. This result is achieved by departing in an original manner from the traditional approach of attempting to achieve continuity and uniformity of operation and instead searching in an original and inventive manner the best possible way of exploiting the new capabilities and flexibility offered by a direct-drive loom.

[0015] According to the invention a new technology for controlling the motor is implemented, said technology exploiting the possibility of varying, within a cycle or over several cycles, the speed of the said motor - and therefore at least the main shaft of the loom - so to vary correspondingly the motion law of the main weaving components (sley, grippers, heald frames) associated therewith.

[0016] A preferred embodiment provides that the variation in speed is advantageously managed so as to increase the duration of the insertion period of the weft yarn (a phase which is undoubtedly critical for the quality of the final fabric) as needed and correspondingly shorten a portion of the working cycle which is less critical (for example beating-up) in order to recover "lost" time.

[0017] According to a first aspect, therefore, a direct-drive loom is provided where the speed of rotation of the single motor is varied within one or more cycles.

[0018] According to a further aspect, the speed of the motor is varied within the cycle on the basis of the requirements of a main weaving component, the motion law of the other components being determined on the basis of the former. In this way, for example, it is possible to define the speed law curve of the motor so as to obtain the desired motion law of the grippers using a mechanism which is simplified and cheap (for example, in the case of the screw mechanism a system with a constant pitch, instead of a variable pitch may be used). The average operating speed of the loom is nevertheless constant.

[0019] According to another aspect of the invention, the motor speed is varied so as to satisfy "on average" the overall operating requirement of the loom, optimising the general behaviour thereof; for example, as already mentioned, by obtaining a reduction in speed during the part of the cycle where insertion is performed, so that a greater amount of time is available with the sley in the backward position and correspondingly a greater amount of time is available with the shed open. This situation is particularly convenient for those articles woven using an air jet loom (for example synthetic yarns) for which the phase of crossing-over of the yarns coincides with or is slightly different from beating-up time of the loom.

[0020] According to yet another aspect, the motion law of the motor is gradually varied from one cycle to another, for example in order to take into account the variations in the unwinding characteristics of the weft yarn between the fill and empty reel; in particular, the period of time during which the shed is kept open for insertion of the weft is gradually reduced upon reduction of the yarn still stored in the reel.

[0021] According to another aspect, a dual-drive loom is provided, i.e. with one drive for the main components and another drive for the weaving machine - in which an independent variation in the speed of the two main motors of the loom is established so as to regulate and vary independently the motion law of the loom and the weaving machine and reduce further the need for replacement of the mechanical control components (for example, cams and kinematic mechanisms) in order to achieve a greater operating flexibility and efficiency.

[0022] According to another aspect, the invention provides a method for controlling weaving of a loom in which the instant of arrival of the weft yarn is detected by means of suitable sensors (for example, photocells, etc.), establishing the statistical progression of the weft arrival over time and modifying the speed, within a cycle, of at least the main motor (if necessary also of the weaving machine) in order to alter the duration of the time available for insertion on the basis of said establishment. Combined operation with the air control device, which is designed to launch the weft yarn in air jet looms, are also preferably envisaged.

[0023] Yet another aspect of the invention relates to a method which envisages determining the motion law of the main motor on the basis of strength parameters of the weft yarns so as to establish - for each single weft (in the case of an article which envisages the insertion of several wefts with different strength characteristics) - the proper and sufficient time for insertion of the said weft, with the correct air flowrate so that the yarn does not break, correspondingly increasing or reducing in an optimum manner the time available for insertion. Advantageously, by means of statistical processing of the number of weft breakages, it is possible to modify the calculation of the speed profile of the loom as a function of the different wefts, without stopping operation, keeping always below the maximum limit the stresses which act on the individual weft (adjustable for example by means of the air flow parameters of the air jet device) within the specific operating conditions.

Brief description of the drawings

[0024] Further characteristic features and advantages of the loom and the associated control method according to the invention will nevertheless emerge more clearly from the detailed description which follows of some preferred embodiments thereof, provided by way of example and also illustrated in the accompanying drawings in which:

Fig. 1 is a diagram showing three exemplary curves illustrating the rotation speed of the sley cam against time;

Fig. 2 is a diagram showing three curves for acceleration of the sley, corresponding to the curves of

Fig. 1;

Fig. 3 is a diagram showing three curves for the displacement of the sley, corresponding to the curves of Fig. 1; and

Fig. 4 is a diagram showing three curves for the linear speed of the sley, corresponding to the curves of Fig. 1.

Detailed description of some preferred embodiments

[0025] Reference looms which can be used to implement the teaching of the present invention are for example those described in the application EP 01830717.7 or in EP-A-1,158,081, which documents are understood as being included here by way of reference. Consequently, the general structure of such a loom will not be described in detail.

[0026] According to the invention, the direct-drive motor for driving the main components of the loom is controlled and regulated so as to vary the speed according to different criteria, with the aim of taking into account the effect on the actuated components in mechanical and weaving terms, without however neglecting the aspect of energy efficiency.

[0027] According to a first embodiment, the speed of the direct-drive motor of the loom is varied according to a given motion law which is identical for each cycle.

[0028] In a first case, the speed law is defined so as to control in the desired manner a specific weaving component, for example the motion of the gripper couple of a gripper loom.

[0029] Consequently, the grippers may for example be controlled by means of a screw device having a constant instead of variable pitch, while the optimised motion law during insertion is achieved by means of adjustment of the motor speed. Moreover, a corresponding specific cam profile for actuation of the sley and the weaving machine is designed, so as to obtain the desired optimum motion laws.

[0030] In a second case, the motor speed law or profile is defined so as to optimise the behaviour of the loom, mainly in weaving terms.

[0031] Advantageously, in the case of an air jet loom, it may be envisaged, according to the invention, slowing down the speed of the main motor during insertion of the weft yarn. Slowing down during the insertion phase results in the advantage of greater time available both as regards the sley and as regards the weaving machine, in particular for those articles where crossing-over of the warp yarns does differ greatly, in terms of phase, from beating-up of the reed.

[0032] In any case, an example of a law profile may envisage a linear behaviour of the speed of rotation, with a maximum at beating-up (0° of the loom) and minimum at 180° of the loom. In this way the required motor torque is constant with a deceleration from 0° to 180° and constant with an acceleration from 180° to 360°.

[0033] This basic law may then be modified to include several variations in speed of different amount and also different shape (sinusoidal, polynomial).

[0034] As can be understood, in the first case mentioned relating to a gripper loom, the solution of the invention results in considerable advantages in terms of mechanical simplification, flexibility of use (hence greater rapidity in change-over of the article), reduction in costs; the constant-pitch screw already per se offers a clear benefit compared to a variable-pitch screw, with an improvement in the sliding block/screw connection with lower hertzian pressures and therefore an increase in the reliability (i.e. less play resulting from wear and greater duration); in the second case mentioned, advantages in terms of productivity and yield are obtained.

[0035] According to a further embodiment, the speed law is varied from one cycle to another.

[0036] For example, in an air jet loom, a device for controlling the arrival of the weft is provided, said device comprising two photocell sensors by means of which it is possible to detect deviations of the real values of the weft arrival time from the estimated values. By processing these values over time it is possible to define a behaviour curve for the arriving weft yarn (depending on environmental factors, physical characteristics of the reel, etc.) on the basis of which suitable variations to the speed of the motor may be introduced.

[0037] In particular, in the case where an increasing delay in arrival of the weft yarn with respect to the reference phase of the operating cycle is detected, it will be possible to modify the speed profile of the motor so as to provide a slowing down phase in correspondence of the weft insertion.

[0038] If, moreover, an air control device is provided on the air jet nozzle, it is possible to co-ordinate the variation in speed of the motor with flowrate and insertion duration parameters within the permitted maximum values for the specific yarn.

[0039] The modifications of the speed of the motor over time may moreover be defined on the basis of suitable statistical functions which use as a parameter, in addition to the shed opening times and to the signals supplied by the weft arrival sensor, also an index relating to the number of weft breakages over time. Once in possession of the inventive teaching offered here, any person skilled in the art is able to suitably adapt these statistical functions for regulating the motion law.

[0040] Due to this further feature, it is possible to take into account, for example, the frequency of breakage of the warp yarns and, especially in a gripper loom, the ratio between the breakages in the side zones and the total breakages. This ratio is a measure of an existing damaging interference between the grippers and the mouth of the warp shed: by means of suitable adjustment of the speed profile it is instead possible to solve this problem by varying the motion profiles of the weaving machine, performing more or less rapid raising of the warp yarns, again by modifying the speed motion of the weaving machine motor.

[0041] According to yet another embodiment, the loom is equipped with a dual drive system, namely it has a first motor for the main weaving components (for example sley for the air jet loom; sley and gripper for the gripper loom) and a second motor for the weaving machine, both being mounted with a direct drive system. Preferably the first motor is designed to "track and follow" (positionwise or speedwise) the second motor, whereby the latter must normally have a greater power.

[0042] As a result of this arrangement, it is possible to achieve an even greater flexibility since further mechanical connections are eliminated and therefore results in the speed control of the first unit being independent of that of the second unit. The two motors are connected together in a non-mechanical manner - by means of an electronic control unit - and therefore it is very easy to adjust the individual operating profiles.

[0043] It is thus possible to obtain, in addition to the advantages already seen above in the case of an individual motor, a wide range of variations in speed of the motor of the weaving machine (and optionally, but not necessarily of the loom also) so as to provide the most suitable motion laws depending on the different articles; it is possible to obtain, for example, a more or less marked separation of the warp yarns depending on the type of yarn or the article to be woven.

[0044] Advantageously, according to the method of the invention, said variations in speed of the two independent motors of the loom and the weaving machine are correlated with the statistical data as to the type and number of weft/warp breakages detected by the control system.

[0045] It must also be pointed out that, according to the state of the art, the motions of the warp yarns - defined by means of the weaving machine - are more or less rapid as a function, among other things, of the various articles. Said motions are obtained at present by means of special mechanisms of the weaving machine (cams for dobbies and external gears, jacquard modulators, etc.).

[0046] According to the invention, a variable speed profile is employed, with a - for example - linear, sinusoidal or polynomial profile, so that it is possible to obtain different motions of the warp yarns by modifying the parameters of the motor instead of replacing the above-mentioned mechanisms (cams, etc.).

[0047] It must be pointed out that the variation in the motor motion law is suitably set as a compromise between the various requirements, which include minimising the torques to be applied to the motor, not exceeding certain load limits in the dynamic behaviour of the system, and optimising the motion laws of the various weaving components (grippers, reed, weaving machine).

[0048] Some possible examples of the speed variation, with the associated implications, are provided below.

[0049] In an air jet loom, with a separate dual drive system, having an average speed of 970 rpm, a speed variation of +/- 30 rpm was obtained with a brushless motor having a nominal torque of 30 Nm. Considering that the time allotted to weft insertion is half the cycle (180 loom degrees), it was possible to achieve a deceleration, in the same half cycle, equal to 1.5% in the case of a linear variation; in the case of a sinusoidal variation, this deceleration was as much as 2.2%; it should be noted that a percentage of 2.2% corresponds to about 4 loom degrees at the average speed of 970 rpm.

[0050] At the same average speed of 970 rpm, a variation in speed of +/- 150 rpm (which requires a nominal torque of the motor equal to about 100 Nm) produces a deceleration equal to 7.7% in the case of a linear variation and a deceleration of 12% in the case of a sinusoidal variation (corresponding to about 18 degrees or 4 milliseconds at the average speed).

[0051] The percentage decelerations (during the weft insertion phase) correspond to an equal percentage increase in the loom throughput value.

[0052] The motion law of the sley vary as a result of the sinusoidal variations above mentioned according to the curves shown in the accompanying figures.

[0053] As can be understood, with the method according to the invention it is possible to achieve a series of advantageous results in connection with the problems encountered in the prior art.

[0054] A variation in the motion of the loom is produced in such a way as to allow optimum operation of the various weaving components, therefore making it possible to achieve a textile product having an improved quality and lower cost.

[0055] In particular, it is possible to reduce the speed of the loom during the weft insertion phase, so as to maintain an average speed over the loom cycle higher than the speed in the insertion phase, with the advantage of an increase in productivity.

[0056] As a result of the novel technique described here, it is also possible to perform a change-over of article without having to mechanically modify the loom, but by simply varying some parameters from a control panel (console), with an obvious advantage in terms of flexibility of use.

[0057] Moreover an operational flexibility of the weaving machine is achieved such that, ultimately, the motion profile of the warp yarns may be modified depending on the various articles, whilst maintaining overall a high productivity.

[0058] Furthermore, according to the method of the invention it is possible to relate the variation of the speed profile (for example of the weaving machine of a dual-drive gripper loom) to statistics relating to breakage of the warp yarns (in particular to the ratio of breakage in the side zones to the total yarn breakages), said statistics being determined by means of a controller device.

[0059] It is understood, however, that the invention is not limited to the embodiments illustrated above, which represent only non-limiting examples of the scope of the invention, but that numerous variations are possible, all within the reach of a person skilled in the art, without thereby departing from the scope of the invention.

Claims

1. Weaving loom comprising at least one weaving machine, a sley, weft inserting members, and a main motor driving at least the sley and the weft yarn inserting members, **characterized in that** said motor operates at a variable speed on the basis of predetermined textile requirements.

2. Loom according to Claim 1, in which said speed of the motor is variable within each loom operating cycle.

3. Loom according to Claim 1 or 2, in which said speed of the motor is variable over several successive operating loom cycles.

4. Loom according to Claim 1 or 2, in which the speed of the motor is variable within each operating loom cycle depending on the individual different wefts to be inserted.

5. Weaving loom according to Claim 2, 3 or 4, in which a second motor mechanically independent of the main motor is also envisaged for driving the weaving machine, said second motor also operating at a variable speed on the basis of predefined textile requirements.

6. Loom according to any one of the preceding claims, in which said variable speed follows a law profile such that, with respect to a nominal speed of rotation of the motor, a deceleration during insertion of weft yarn is provided.

7. Loom according to any one of Claims 2 to 6, in which said variable speed follows a linear function against time.

8. Loom according to any one of Claims 2 to 6, in which said variable speed follows a polynomial function against time.

9. Loom according to any one of Claims 2 to 6, in which said variable speed follows a sinusoidal function against time.

10. Loom according to any one of the preceding claims, in which said loom is of a gripper type and the speed profile of the main motor is set on the basis of the speed profile required by the grippers, the motion of other weaving members being determined by means of cam systems or equivalent kinematic mechanisms as a function of said set speed profile of the main motor.

11. Loom according to any one of the preceding claims, further provided with a device for detecting the arrival time of the weft yarn, said device being able to detect the timing shift of the weft arrival time, the speed profile of the main motor being adjusted on the basis of said detected timing shift.

12. Loom according to any one of the preceding claims, in which said variable speed profile of the motor is also set on the basis of the signal supplied by a yarn breakage detector.

13. Loom according to Claim 12, in which the signal of said yarn breakage detector is a weighted function of the statistical number of breakages of yarns in relation to their distance from the side zones of the fabric.

14. Method for controlling weaving operation of a loom provided with at least one weaving machine, a sley, weft inserting members and a main motor for driving at least the sley and the weft yarn inserting members, **characterized in that** said main motor is operated by varying the speed thereof on the basis of predetermined textile requirements.

15. Method according to Claim 14, in which said main motor speed is varied within each operating weaving cycle.

16. Method according to Claim 14 or 15, in which said variation in the motor speed is modulated over a time frame including several successive operating weaving cycles.

17. Method according to Claim 14 or 15, in which the motor speed is varied within each operating cycle depending on the individual various wefts inserted.

18. Method according to Claim 15, 16 or 17, in which the speed of a second motor mechanically independent of the main motor and allotted to the weaving machine operation is also varied.

19. Method according to any one of Claims 14 to 18, in which said motor speed is varied following a profile speed such that, compared to a nominal speed of rotation of the motor, a slowing-down during insertion of the weft yarn is produced.

20. Method according to any one of Claims 14 to 19, in which said slowing-down, and subsequent speeding-up, is achieved through a linear function.

21. Method according to any one of Claims 14 to 19, in which said slowing-down, and subsequent speed-

ing-up, is achieved through a polynomial function.

22. Method according to any one of Claims 14 to 19, in which said slowing-down, and subsequent speeding-up, is achieved with a sinusoidal function.

23. Method according to any one of Claims 14 to 22, in which said speed of the main motor is varied following a profile based on the requirements of the weft insertion device, the motion law of other weaving members being determined depending on said main motor speed profile.

24. Method according to any one of Claims 14 to 23, in which the following steps are also performed:

- detecting the performance characteristics against time of the weft yarn;
- establishing the arrival time of the weft yarn on the basis of said detection;
- modifying the speed profile of the main motor on the basis of said determination.

25. Method according to any one of Claims 14 to 24, in which the following steps are also performed:

- detecting the number of breakages of yarns over time;
- modifying the speed profile of the main motor on the basis of said detection.

26. Method according to Claim 25, in which the step of modifying the speed profile of the weaving machine motor on the basis of said detection is also provided.

27. Method according to Claim 25 or 26, in which said detecting step further comprises determining a breakage parameter in the form of a weighted function of the statistical number of weft breakages in relation to their distance from the side zones of the fabric.

28. Method for controlling a weaving loom equipped with two motors for driving respectively a weaving machine and weaving members, said weaving members being at least the sley and optionally a weft inserting device, **characterized in that** said motors are operated by varying the speed thereof within the weaving cycle on the basis of predetermined textile requirements.

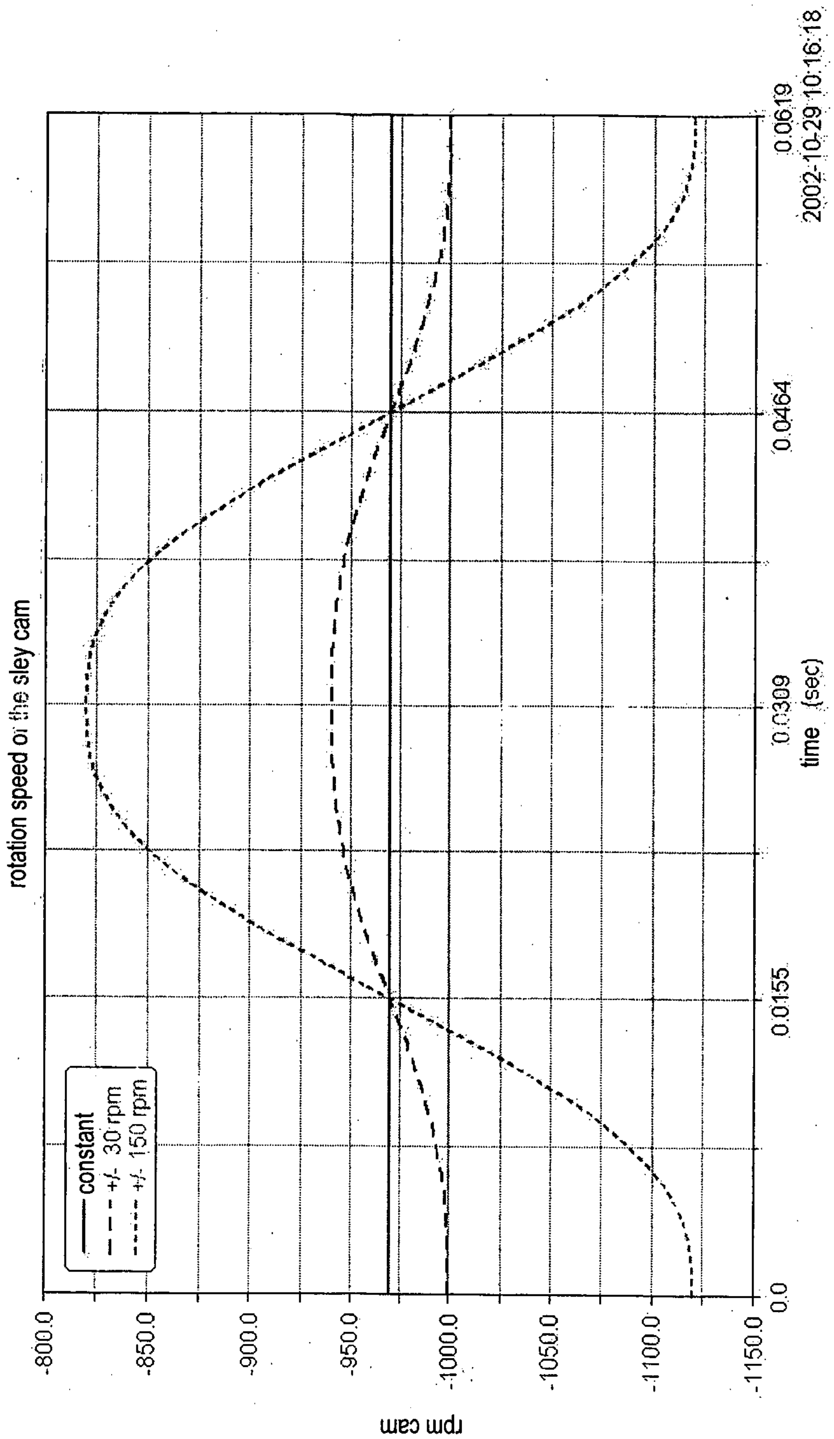
rotation speed of the sley cam
constant
+/- 30 rpm
+/- 150 rpm
rpm cam
-800.0
-850.0
-900.0
-950.0
-1000.0
-1050.0
-1100.0
-1150.0
0.0
0.0155
0.0309
0.0464
0.0619
time (sec)
2002-10-29 10:16:18

FIG. 1

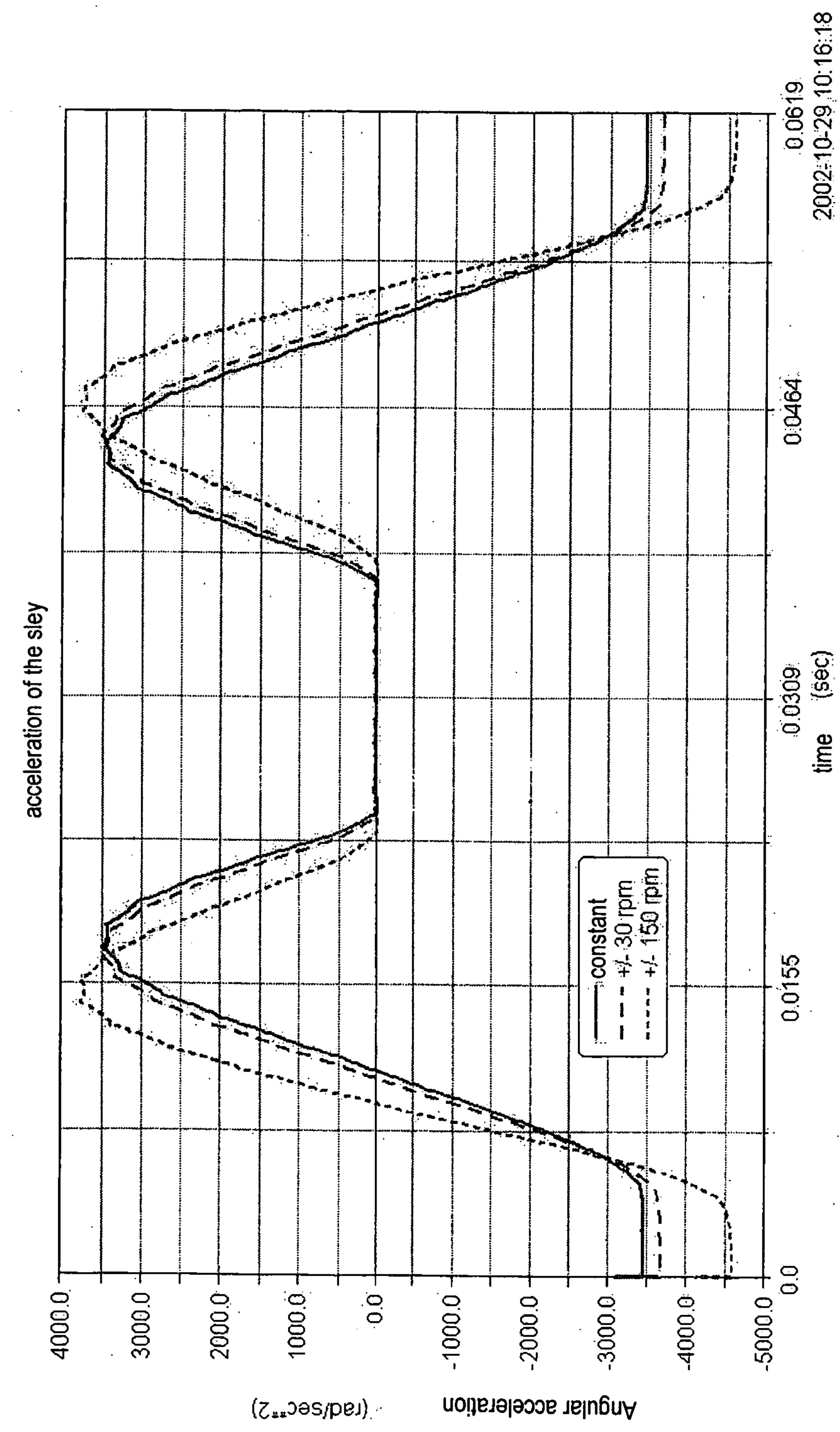
acceleration of the sley
Angular acceleration (rad/sec**2)
4000.0
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-3000.0
-4000.0
-5000.0
0.0
0.0155
0.0309
0.0464
0.0619
time (sec)
2002-10-29 10:16:18
constant
+/- 30 rpm
+/- 150 rpm

FIG. 2

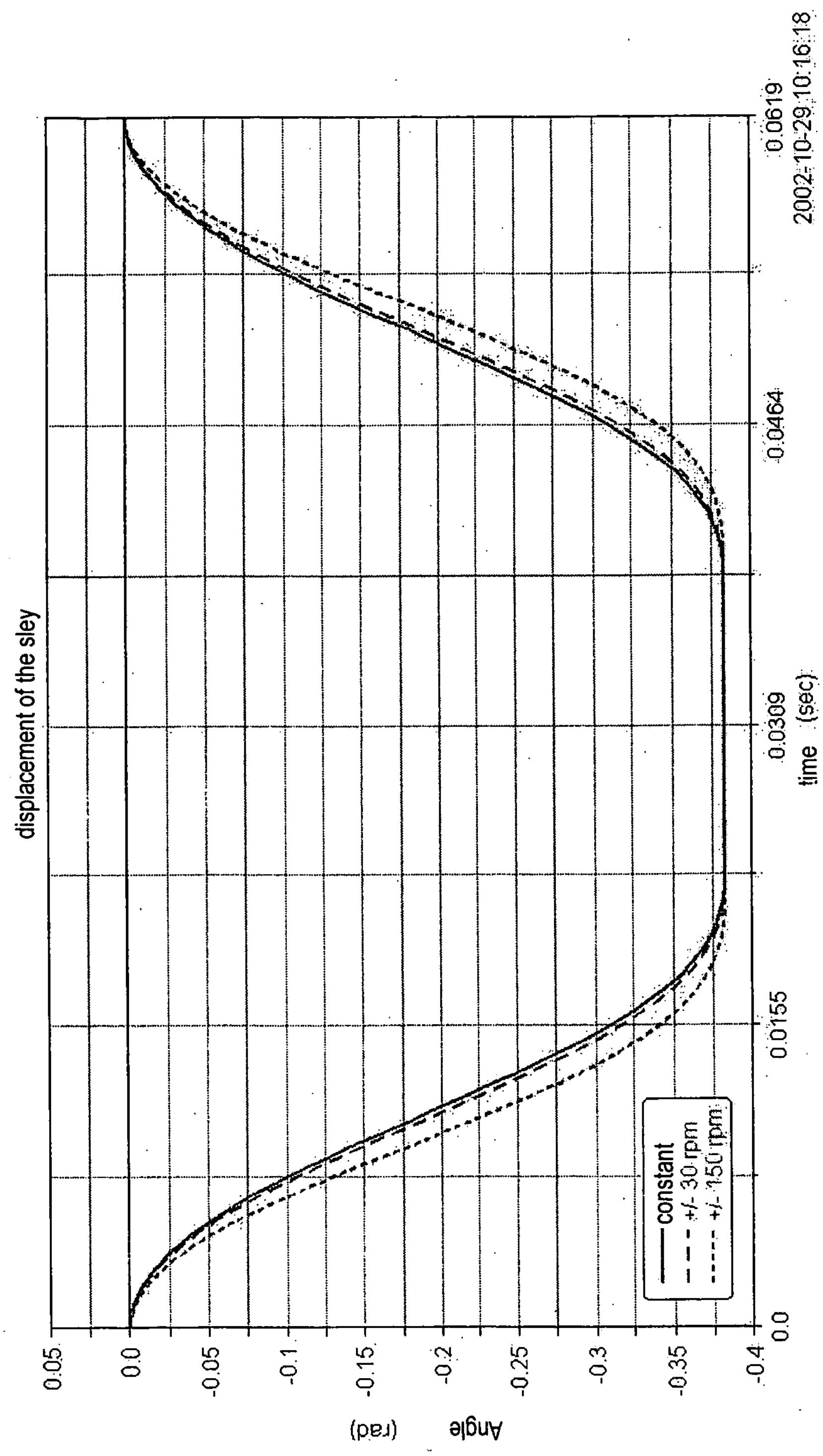
displacement of the sley
Angle (rad)
0.05
0.0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
0.0
0.0155
0.0309
0.0464
0.0619
time (sec)
constant
+/- 30 rpm
+/- 150 rpm
2002-10-29 10:16:18

FIG.3

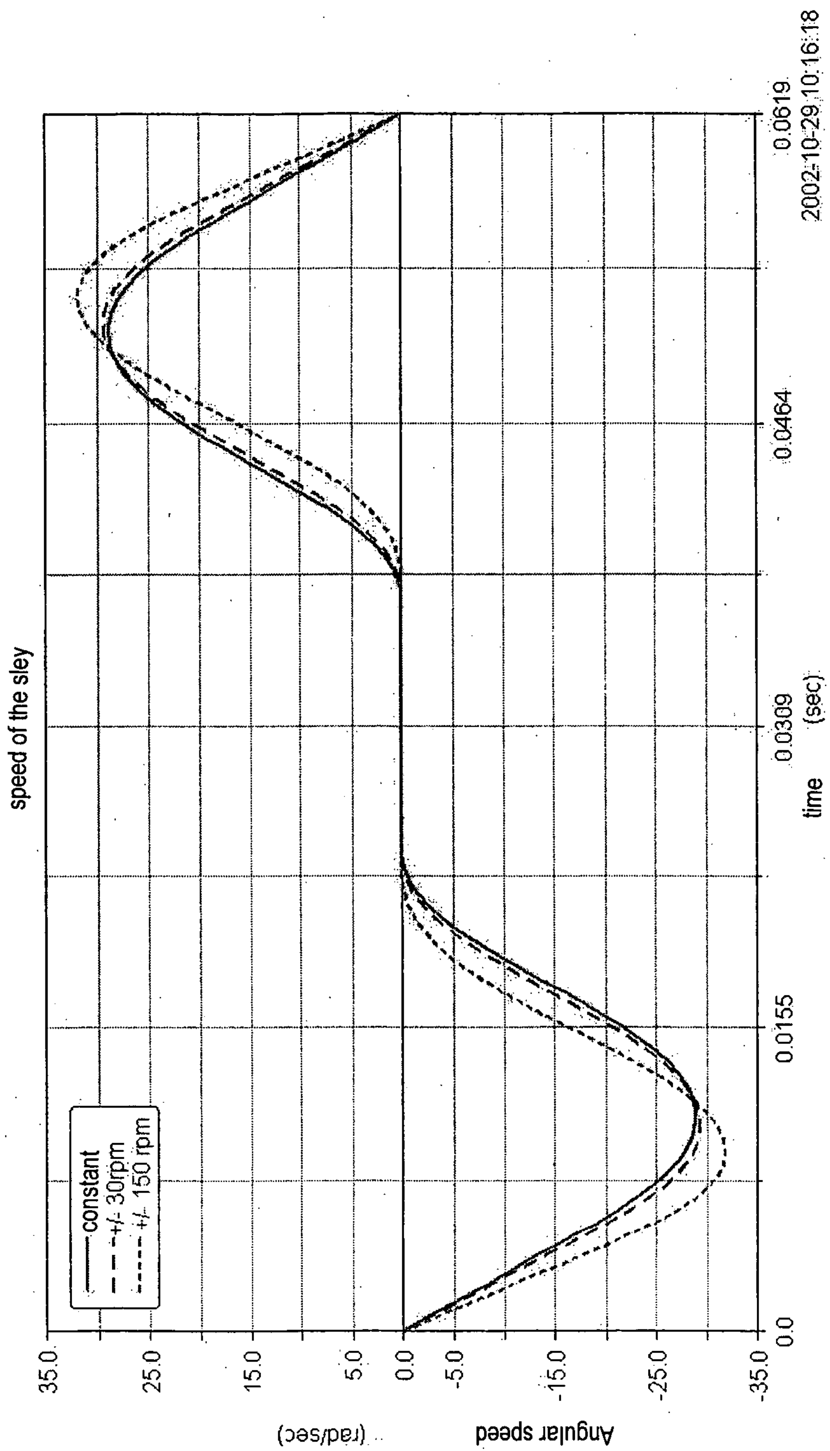
speed of the sley
constant
+/- 30rpm
+/- 150 rpm
Angular speed (rad/sec)
35.0
25.0
15.0
5.0
0.0
-5.0
-15.0
-25.0
-35.0
0.0
0.0155
0.0309
0.0464
0.0619
time (sec)
2002-10-29 10:16:18

FIG. 4