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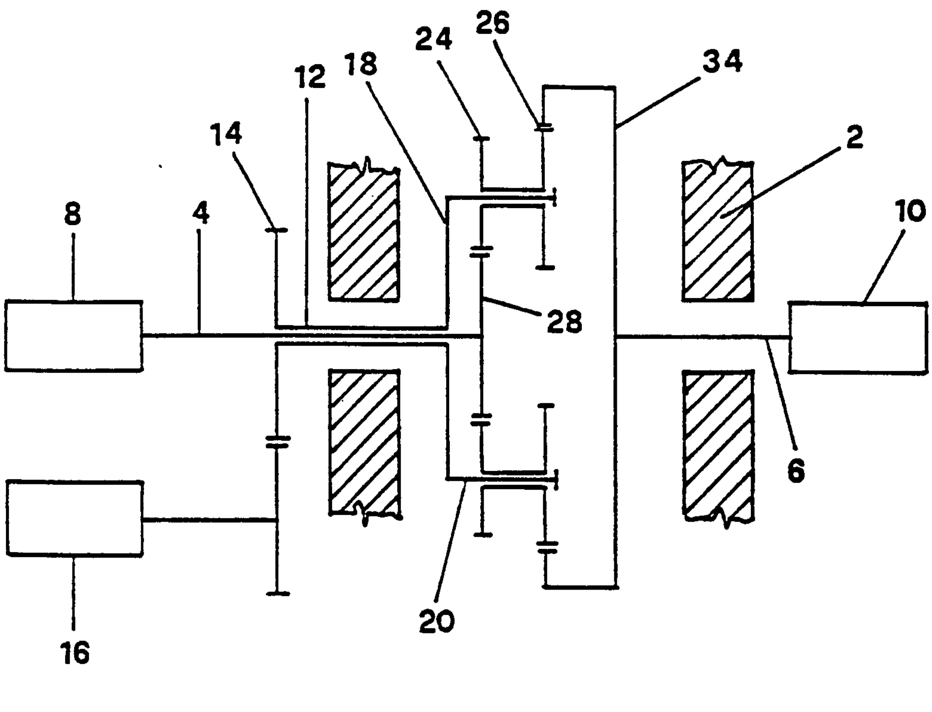

(57) Abstract

A coupling device for power units, to be interposed between two power units (8, 10) and a user machine (16) powered thereby, characterised by comprising: two input shafts (4, 6) coupled to said power units (8, 10), an output shaft (12) coupled to said user machine (16), and a linkage with two degrees of freedom operated by the two input shafts (4, 6) and connected to the output shaft (12).

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DEVICE FOR COUPLING POWER UNITS

The invention relates to a device for coupling power units.

Couplings of various types are known for coupling a driver machine (or power unit) to a user machine, which may be a motor vehicle, an operation-performing machine etc.. They take the form of rigid couplings, universal joints, homokinetic mobile couplings, torsionally rigid flexible couplings, torsionally elastic flexible couplings, viscous couplings etc., depending on their principle of operation.

They are however able to couple only one driver machine to a user machine, whatever their principle of operation.

It is also possible to couple more than one user machine to one driver machine, but it has not been possible up to the present time to effectively couple together more than one driver machine, in such a manner as to transmit mechanical energy to one user machine.

The main object of the invention is to be able to connect at least two driver machines simultaneously or independently to one user machine in such a manner as to be able to use one or both driver machines, depending on the particular situation in which the user machine is to operate and/or the specifict requirements arising.

A further object of the invention is to be able to couple two driver machines of identical or completely different type to one user machine.

A further object of the invention is to provide a device of simple construction and reliable operation.

These and further objects which result from the following description are attained according to the invention through a device for coupling power units as described in claim 1.

A preferred embodiment of the present invention is described in detail hereinafter with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates the principle on which the device of the invention is based;

Figure 2 is a longitudinal schematic section through one possible embodiment of the device of the invention;

Figure 3 is a schematic block diagram showing a configuration comprising a user machine powered by five driver machines via four devices of the invention;

Figures 4a, 4b and 4c show the variation in the absolute angular velocity of respectively the two input shafts 4 and 6, the planet gears 26 and the output shaft 12 with time, when the power units consist of particular electric motors, Figures 5a, 5b and 5c show the variation in the same quantities with time, when the power units consist of electric motors of different torque-angular velocity characteristics;

Figures 6a, 6b and 6c show the variation in the same quantities with time, when the power units consist of electric motors of even more different torque-angular velocity characteristics;

Figures 7a, 7b and 7c show the variation in the same quantities with time when a disturbance is applied to one of the power units;

Figures 8a, 8b and 8c show the variation in the same quantities with time when the two power units have different torque-angular velocity characteristics; and

Figures 9a, 9b, 9c; 10a,10b, 10c; and 11a, 11b, 11c show the variation in the same quantities with time when the two power units have even more different torque-angular velocity characteristics.

As can be seen from the figures, the device of the invention comprises a box casing, indicated overall by 2, into which there enter two shafts 4 and 6 which are coupled in conventional manner to two driver machines or power units

8 and 10 respectively. The driver machines 8 and 10 can be identical in terms of their principle of operation, or can be completely different in the sense that they can be electrical machines, heat engines, etc.. In addition, the performance of the two machines can be identical or completely different.

In the described embodiment the box casing 2 is of cylindrical form and the two input shafts 4 and 6 are mutually aligned; however this arrangement is not binding for the principle on which the present invention is based.

From the box casing 2 there also emerges an output shaft 12, which is hollow, is coaxial with the input shaft 4 and is provided externally with a ring gear 14 for its coupling to an operation-performing machine 16. Again in this case, the arrangement of the output shaft could be different as could the method of coupling to the operation-performing machine, without leaving the scope of the present invention.

The output shaft 12 extends within the box casing 2 into a planet gear carrier disc 18 supporting two or more pins 20 for the idle rotation of a like number of planet gears 22 provided with two gear wheels 24 and 26. The pins 20 and hence the planet gears 22 have their axis parallel to the axis of the shafts 4, 6 and 12. Within the box casing 2 there is coupled to the input shaft 4 a gear wheel 28 meshing with the gear wheel 24 of the two planet gears 22, between said shaft 4 and said gear wheel 28 there being interposed a free-wheel device 30, which provides rigid coupling between the two when the input shaft 4 rotates in the direction imposed by driver machine 8 to rotate said ring gear 28.

An internally toothed ring gear 34 is coupled to the input shaft 6 via a free-wheel device 32, and meshes with the gear wheel 26 of the two planet gears.

The operation of the device according to the invention is as follows:

the two driver machines 8 and 10 independently rotate the respective input shafts 4 and 6 in the same direction, ie in the direction indicated in Figure 2 by the arrows 36 and 38 respectively, to cause the respective ring gears 28 and 34 to rotate. These, which mesh with the gear wheels 24 and 26 of the planet gears 22 but with different gear ratios, cause the planet gear carrier disc 18 to rotate in the same direction at a velocity related to the characteristics of the movement impressed on said shafts 4 and 6 and on the transmission ratios of the linkage. The rotation of the planet gear carrier disc 18 is transmitted to the operation-performing machine 16 via the output shaft 12.

To enable the device of the invention to be coupled to and decoupled from the driver machines 8, 10 and operation-performing machine 16, traditionally clutches (not shown), preferably of friction type, are interposed between these latter and the respective shafts 4,6 and 12.

Basically, the device of the invention can be viewed as a differential of traditional type but operating in reverse. In this respect, whereas a differential comprises one input shaft rotating at a certain angular velocity and two output shafts rotated at angular velocities such that the velocity of the input shaft represents a linear combination of the velocities of the output shafts, in the case of the device of the invention there are two input shafts rotated mutually independently, and one output shaft rotated at an angular velocity representing a linear combination of the angular velocities of said input shafts.

From the analytical viewpoint, the following equations of motion can be written for the device of the invention, which in the illustrated form consists essentially of an epicyclic linkage with two degress of freedom:

$$\begin{aligned} A\ddot{\theta}_6+B\ddot{\theta}_4&=M_6+1/2M_{12} \\ B\ddot{\theta}_6+C\ddot{\theta}_4&=M_4+1/2M_{12} \end{aligned} \qquad (1)$$

in which θ_i represents the rotational velocity of the i^{th} shaft, $\dot{\theta}_i = d\theta_i/dt$, $\ddot{\theta}_i = d\dot{\theta}_i/dt$, M_4 and M_6 are the torques applied to the shafts 4 and 6 respectively, and M_{12} is the resistant torque applied to the shaft 12.

From an analysis of the system:

$$\dot{\theta}_{12}\left(1+\frac{N_{26}N_{28}}{N_{34}N_{24}}\right)=\dot{\theta}_6+\dot{\theta}_4\ \frac{N_{26}N_{28}}{N_{34}N_{24}}$$

where N_{24}, N_{26}, N_{28} and N_{34} are the number of teeth of the gear wheel carrying the i^{th} reference.

The equations of motion (1) were obtained assuming that

$$\frac{N_{26}N_{28}}{N_{34}N_{24}} = 1$$

Assuming rotation in the anticlockwise direction, observing the device from the right in Figure 2, to be positive, then

$$\dot{\theta}_{26} = \dot{\theta}_6\ \frac{\alpha+1}{2}\ - \dot{\theta}_4\ \frac{\alpha-1}{2}$$

where $\alpha = N_{34} / N_{26}$.

If I_{34}, I_{14} e I_{26-24} are the moments of inertia of the gear wheels 34,14,26,28 respectively, of which the latter two are rigid with each other, and if m_s is the total mass of the gear wheels 26 and 24 and r_{14} is the distance between the axis of rotation of the gear wheels 26 and 24 and the axis of rotation of the gear wheel 14, equations (1) become:

$$A = \frac{I_{14}}{4} + I_{34} + I_{26-24}\left(\frac{\alpha+1}{2}\right)^2 + \frac{m_s r_{14}^2}{4} \qquad (2)$$

$$B = \frac{I_{14}}{4} - I_{26-24}\left(\frac{\alpha^2-1}{2}\right) + \frac{m_s r_{14}^2}{4} \qquad (3)$$

$$C = \frac{I_{14}}{4} + I_{28} + I_{26-24}\left(\frac{\alpha-1}{2}\right)^2 + \frac{m_s r_{14}^2}{4} \qquad (4)$$

If two direct current electric motors with independent excitation are used as the input driver machines 8 and 10, the torque-feed voltage-angular velocity characteristic is expressed (ignoring winding inductance) by the equation:

$$M_i\left(u,\dot{\theta}_i\right) = \frac{C_{m_i}}{r_i} u - C_{V_i}\dot{\theta}_i \qquad (5)$$

where u is the control voltage, C_m is the torque constant [Nm/A], r is the winding resistance, and C_V is the constant defining the ratio of torque to angular velocity [Nm/rad/s].

Taking into account the equation of motion (1) and the motor equation (5), the following matrix relationship is obtained, defining the equations of motion in the case under consideration:

$$\dot{p} = Ap + bu \qquad (6)$$

Obviously the output torque M_{12} has not been considered, as this does not influence the controllability and observability of the system.

The matrices and vectors present in (6) are defined as follows:

$$A = - M^{-1} C$$

$$b = M^{-1} b$$

$$M^{-1} = \begin{bmatrix} A & B \\ B & C \end{bmatrix}^{-1}$$

$$C = \begin{bmatrix} C_{V_6} & O \\ O & C_{V_4} \end{bmatrix}$$

$$b = \begin{bmatrix} C_{M_6}/r_6 \\ C_{M_4}/r_4 \end{bmatrix}$$

$$p = \begin{Bmatrix} \dot{\theta}_6 \\ \dot{\theta}_4 \end{Bmatrix}$$

From (6) it can be seen that the system has only one input, the voltage u being the same for both motors. For the system defined by (6) to be controllable by a single input, the following condition must apply:

$$\text{rank } (C_o) = 2$$

the system being of dimension 2 and C_o being the controllability matrix defined as follows:

$$C_o = \left[b \;\vdots\; Ab \right]$$

It can be demonstrated that the rank of this matrix is 2.

The observability characteristic relates to the ability to reconstruct the variation with time of the state of the system (ie the elements of the vector p) on the basis of measurements, taken of a part of it or of a combination of its elements.

The measurement of the velocity of the angular velocities of the input shafts 4 and 6, the measurement equation therefore being:

$$y = H.p$$

where

$$H = \left[\begin{array}{c:c} \frac{1}{2} & \frac{1}{2} \end{array}\right]$$

The system is observable if the observability matrix θ, defined by the equation

$$\theta = \left[\begin{array}{c} H \\ \hdashline HA \end{array}\right]$$

has a rank of 2.

Again in this case it can be demonstrated that this condition is satisfied.

Consequently it can be seen that if the two input shafts 4 and 6 of the device of the invention are driven by direct current electric motors, when under steady working conditions the inherent individualities of the respective power units are respected.

These power units are in this case fed at constant voltage, the torque-angular velocity relationship being expressed by:

$$M_i\ (\dot{\theta}_i) = M_{o_i} - C_{v_i}\,\dot{\theta}_i \qquad (7)$$

where M_o is the static torque.

Expressing the motion equations (1) together with (4) in the form of a Laplace transformation and assuming constant applied torques, then:

$$\begin{matrix} \dot{\theta}_6(s) \\ \dot{\theta}_4(s) \end{matrix} = \begin{bmatrix} A_s + C_{v_6} & B_s \\ B_s & C_s + C_{v_4} \end{bmatrix}^{-1} \cdot \frac{1}{s} \cdot \begin{Bmatrix} M_{o_6} + 1/2M_{12} \\ M_{o_5} + 1/2M_{12} \end{Bmatrix}$$

where s is the Laplace variable.

Applying the final value theorem for the Laplace transformation, under steady working the following is obtained:

$$\theta_{i_\infty} = \frac{M_{o_i} + 1/2M_{12}}{C_{v_i}}$$

this signifying that under stationary conditions the two motors act as if the torque $M_{12}/2$ were applied separately to each of them.

However even in the general case in which the two motors have any torque-angular velocity relationship, they can be kept decoupled. In this respect the coupling terms are the extra-diagonal ones of the inertia matrix, in particular the element indicated by B in (3). From this equation it can be seen that the variable which can be easily manipulated is the ratio $\alpha = N_{34}/N_{26}$; if this value is chosen such that

$$\alpha = \left((I_{12} + r_{14}^2 m_s)/I_6 \right)^{0,5}$$

the two motors are also decoupled during transients.

The choice is obviously restricted by the value of the moment of inertia I_{12}, which represents the driven inertia and can also reach a large value. In such cases the coupling can only be reduced but not eliminated, because the ration N_{34}/N_{26} would become too big. In any event, if torques dependent on the movement of the output shaft 12 were to act on this shaft, decoupling would never be totally possible because a further coupling term would be introduced.

As stated, Figure 3 shows schematically a configuration comprising one operation-performing machine 16 driven by five driver machines $10_1, 10_2, 10_3, 10_4, 10_5$ via four devices D_1, D_2, D_3, D_4 of the invention. In this case the two input shafts 4_1 of the first device D_1 are obviously connected to two driver machines $10_1, 10_2$; the input shafts 4_i and 6_i (i=2,3,4) of the subsequent devices D_i are connected the one 4_i to a driver machine 10_{i+1}, the other 6_i to the output shaft 12_{i-1} of the upstream device D_{i-1}, and the output shaft 12_4 of the last device D_4 is connected to the operation-performing machine 16.

If the subscript j, k indicates the j^{th} shaft (j=4,6,12) of the k^{th} device (k=1,2,3,4), the resistant torque is $M_{12,4}$, the drive torques being applied to the shaft 4_k with obvious exception of M_{61} which is applied to the shaft 6_1. There are five degress of freedom of the system in the illustrated configuration, namely

$$\theta_{6,1},\ \theta_{4,1},\ \theta_{4,2},\ \theta_{4,3},\ \theta_{4,4}$$

A kinematic analysis of the system shows that

$$\theta_{6,i} = \sum_{k=1}^{i-1} \frac{\dot{\theta}_{4,i-k}}{2^k} + \frac{\dot{\theta}_{6,1}}{2^{i-1}}$$

By a Lagrange approach the following system of equations of motion are obtained:

$$M\dot{p} = \begin{Bmatrix} M_{10_1} \\ M_{10_2} \\ M_{10_3} \\ M_{10_4} \\ M_{10_5} \end{Bmatrix} + \begin{Bmatrix} 1/16 \\ 1/16 \\ 1/8 \\ 1/4 \\ 1/22 \end{Bmatrix} \cdot M_{12,4} \qquad (9)$$

M being the system inertia matrix and p the vector

$$p^T = \dot{\theta}_{4,1}\ \dot{\theta}_{6,1}\ \dot{\theta}_{4,2}\ \dot{\theta}_{4,3}\ \dot{\theta}_{4,4}$$

where $(.)^T$ is the transposing operator. The terms of the mass matrix will be omitted for brevity.

From equation (9) it can be seen that with a suitable arrangement of the devices of the invention, the driver machines can be used in their most efficient zone of operation, in such a manner as to distribute the available power in an optimum manner. It can also be seen that this is not the only arrangement possible, in that their layout can assume various configurations, dependent on the manner in which the power is to be distributed.

The illustraed embodiment provides generally for coupling the device of the invention to the two power units 8 and 10 and to the user machine 16. These couplings can be of direct type, or can comprise a friction clutch for smooth, gradual engagement.

The two input shafts 4,6, which as seen are independent of each other, can also be rigidly coupled together to prevent operation of the device in order to satisfy temporary requirements. This can for example be the case during starting of the system. In this particular case, instead of providing each power unit 8,10 with an independent starting device (such as an electric motor if the power units 8,10 are internal combustion engines), it is possible to provide only one power unit 8 or 10 with a starting device and start the other power unit by entrainment by the device of the invention, in which the two input shafts 4,6 have been previously rigidly connected together.

For greater clarity, some examples of application of the device of the invention are given hereinafter, both using direct current motors and using motors of any torque-angular velocity characteristic.

With reference to the device shown in Figure 2, in order to take account of a certain applied inertial load it is assumed that $I_{12}=I_6$ and it is further assumed that the rotational inertia of the two motors 8 and 10 is negligible.

Figures 4a,4b and 4c respectively show the absolute angular velocities of the two input shafts (4 and 6), of the planet gears 26 and of the output shaft 12, where the two power units 8 and 10 consist of two identical, easily obtainable direct current motors having the following characteristic:

$$M_i(\dot{\theta}_i)=2.5 - 7.4610^{-3}\dot{\theta}_i$$

The applied torque is 2 Nm. It can be seen from the curves of these figures that steady working is achieved at individual values corresponding to one half the applied torque. As the two motors are perfectly identical, the angular velocity of the shaft 12 is obviously that of the two motors 8 and 10 rigidly connected together, with the 2 Nm torque applied.

Figures 5a, 5b and 5c show the same quantities as in the previous case, but relative to the following torque-angular velocity characteristics:

$$M_6(\dot{\theta}_6)=2.5-7.4610^{-3}\dot{\theta}_6$$

$$M_4(\dot{\theta}_4)=2.0-7.4610^{-3}\dot{\theta}_4$$

These curves show the behaviour of the device of the invention when the torque-angular velocity relationships begin not to be perfectly equal. It can be seen that the condition expressed by (8) is satisfied and that the two motors 8 and 10 maintain their inherent individualities at steady working.

The behaviour consequent on further differing the applied torques can be observed in Figures 6a, 6b and 6c. In this case the characteristics are:

$$M_6(\dot{\theta}_6)=2.5-7.4610^{-3}\dot{\theta}_6$$

$$M_4(\dot{\theta}_4)=1.1-7.4610^{-3}\dot{\theta}_4$$

It can be seen that the motor 8 (the "weaker") initially rotates in the opposite direction, to then reach its steady working speed.

This behaviour therefore suggests that the free-wheel device 30 should be used at least for the shaft 4 to which the motor 8 is applied, in order to prevent the shaft rotating in the opposite direction and undergo that phenomenon which can arise when one of the two motors is engaged while the other is already under steady working. It should be noted that this phenomenon, which can be acceptable if the motor 8 is electric, is absolutely to be avoided if the motor is of a different type and is unable to rotate in the opposite direction.

Figures 7a, 7b and 7c show the angular velocities of the two input shafts 4 and 6, the planet gears 26 and the output shaft 12 when the two power units 8 and 10 are two identical direct current motor of characteristic:

$$M_i(\dot{\theta}_i)=2.5 - 7.4610^{-3}\dot{\theta}_i$$

and at a certain time, t=30s, a disturbance in the form of a resistant torque of 2 Nm is applied to the shaft 4 of the motor 8 unitl the time t=40s. It can be seen that the falling angular velocity of the disturbed motor results in a corresponding increase in that of the undisturbed motor, the system hence having the tendency for self-compensation. This phenomenon is accentuated if a counter-reaction is present at the exit (the angular velocity of the shaft 12):

$$M_6(\dot{\theta}_6,\dot{\theta}_4)=2.5-7.4610^{-3}\dot{\theta}_6-(\dot{\theta}_{12}-500)0.02$$

$$M_4(\dot{\theta}_6,\dot{\theta}_4)=2.5-7.4610^{-3}\dot{\theta}_4-(\dot{\theta}_{12}-500)0.02$$

The curves of these figures show a more accentuated tendency for self-compensation. It can also be seen that with this counter-reaction the two motors 8 and 10 are controlled by the same controlling quantity, this confirming that the system is controllable with a single input (whether the two motors 8 and 10 are identical or different).

Figures 8a, 8b and 8c show the variation in the angular velocity of the two input shafts 4 and 6, the planet gears 26 and the output shaft 12 with time if the two motors 8 and 10 have different characteristics, and in particular have non-linear torque-rpm characteristics, the illustrated example being that of a vehicle (user machine 16) having a mass of 800 kg and a certain aerodynamic resistance to advancement. The mass of the vehicle 16, reduced to the axis of rotation of the shaft 10, has the following moment of inertia:

$$I^*=m\left(\frac{r}{n}\right)^2$$

when r is the tyre radius (assumed hereinafter to be 0.25 m) and n is the transmission ratio between the axis 12 and the tyres, including that of the bevel gear pair of the ordinary differential and gearbox. The first is generally 4, and the second is 1 if fourth gear is engaged. I^*=3.125 kgm^2, to be added to I_{12} relative to the device of the invention itself. With regard to the vehicle resistance, a head area of 2.0 m^2 is assumed together with a vehicle resistance coefficient Cr of 0.4 and an air density ρ of 1.2 Kg/m^3, hence the torque corresponding to the vehicle resistance, reduced to the axis 14 (Figure 1), is given by:

$$-\frac{1}{2}\rho c_r A \left(\frac{\dot{\theta}_6+\dot{\theta}_4}{2}\right)^2 \frac{r}{n}^3$$

which, substituting numerical values, equals:

$$-2.929\ 10^{-5}\left(\dot{\theta}_6+\dot{\theta}_4\right)^2$$

Figures 9a,9b and 9c; 10a,10b and 10c; 11a,11b and 11c show the variation in the same quantities if motors 8 and 10 with the following torque-angular velocity characteristics are applied to the two input shafts 4 and 5:

$$T_2=90-0.001\dot{\theta}_6^2$$
$$T_5=90-0.001\dot{\theta}_4^2$$
$$T_2=90-0.001\dot{\theta}_6^2$$
$$T_5=70-0.001\dot{\theta}_4^2$$
$$T_2=90-0.001\dot{\theta}_6^2$$
$$T_5=90-0.001\dot{\theta}_4^{2.5}$$

These curves show the extreme versatility of the invention in coupling power units with different characteristics.

From the aforegoing it is clear that the device of the invention is suitable for coupling to a single operation-performing machine, and more generally to a user shaft to which one or more user machines can be coupled, driver machines which can be of completely different type (electrical, thermal, biological etc.) and, for one and the same type, machines with torque-angular velocity characteristics which are completely different.

The device of the invention can be used for many applications in the machine tools, robotics, terrestrial, maritime and aerial traction and similar fields.

In particular, the device of the invention can be applied to all systems for which high reliability and safety are required, such as underwater and spatial robotics systems and cable systems, for which the presence of the reserve motor is fundamental. In this respect, the device of the invention allows two or more motors to be present, for use when necessary, for istance if one of them suffers a sudden power loss, the remainder being able to make up this deficiency without the need for complicated safety devices. This self-compensation characteristic appears particularly useful if the entrained inertia is high, or if the system uses driver machines with a decreasing torque-angular velocity characteristic, or if the system has a counter-reaction on the exit angular velocity, or if such circumstances are variously combined.

A further characteristics of the device of the invention, where the driver machines are direct current electric motors, is the fact that the system can be controlled by a single inuput instead of by several separate inputs relative to the individual driver machines. In addition, again for driver machines in the form of direct current electric motors, the system is observable by merely measuring the exit angular velocity, which means that an estimating system can be set up which by processing this measurement estimates the individual angular velocities (and rotations). These characteristics, for any type of final user, whether this be a simple controlled shaft of a machine tool or a complex coupling of a manipulator, are of fundamental importance from the diagnostic, measurement and control viewpoint.

In certain particularly favourable cases (for example low entrained inertia), two driver machines can be perfectly decoupled, even during transients, so eliminating interaction between them and enabling the control strategy to be further simplified, in that the individual driver machines can be controlled seaparately by traditional methods.

The device of the invention can also be effectively and advatageously utilized in the traction field, and in particular terrestrial traction, as it enables power draw-off and hence pollutant emission to be matched to actual requirements. In particular, motor vehicles can be equipped with two internal combustion engines coupled to the single transmission shaft by a device of the invention. When travelling on the open road both engines operate to provide the vehicle with the power required for the particular type of travel. In constrast, when travelling in town, where power requirements are more limited and the problem of atmospheric pollution is more evident, one engine can be halted to substantially reduce pollutant emission.

C L A I M S

1. A coupling device for power units, to be interposed between two power units (8,10) and a user machine (16) powered thereby, characterised by comprising:
- two input shafts (4,6) coupled to said power units (8,10),
- an output shaft (12) coupled to said user machine (16), and
- a linkage with two degrees of freedom operated by the two input shafts (4,6) and connected to the output shaft (12).

2. A device as claimed in claim 1, characterised in that the linkage with two degrees of freedom is of epicyclic type.

3. A device as claimed in claim 2, characterised in that the epicyclic linkage comprises a planet gear carrier (18) coupled to the output shaft (12) and supporting at least two planet gears (22), each provided with two gear wheels (24,26) coupled to two gears (28,34) rigid with the two input shafts (4,6).

4. A device as claimed in claim 3, characterised in that the two input shafts (4,6) are coaxial.

5. A device as claimed in claim 3, characterised in that the output shaft (12) is coaxial with at least one input shaft (4,6).

6. A device as claimed in claim 1, characterised in that a free-wheel device (30,32) is applied to at least one input

shaft (4,6).

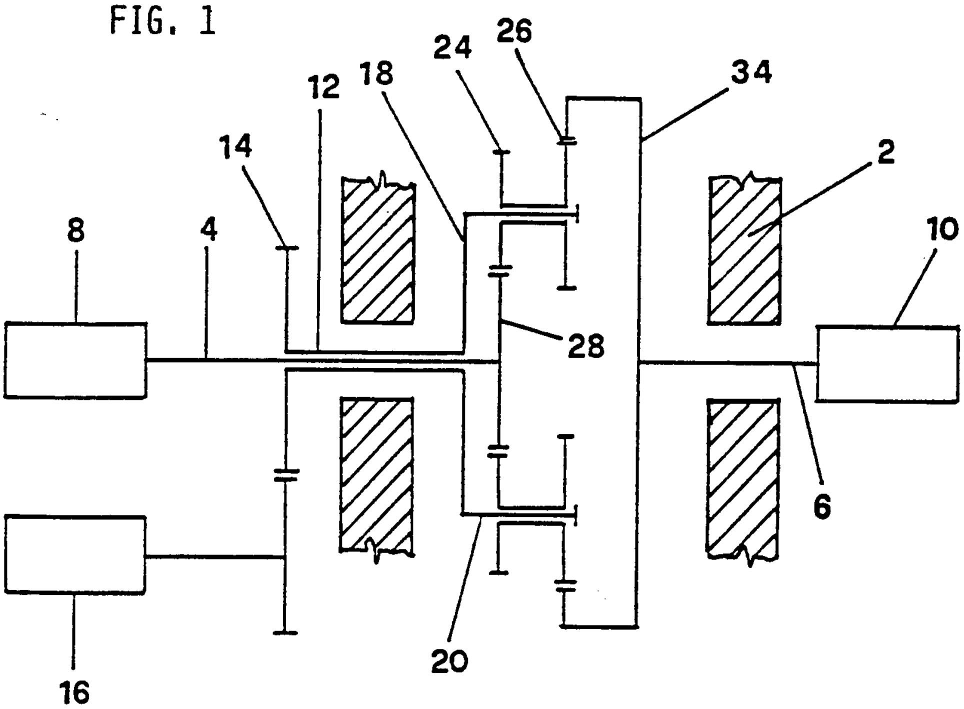
7. A device as claimed in claim 1, characterised by comprising means for rigidly connecting the two input shafts (4,6) together.

8. A device as claimed in claim 1, characterised in that a clutch device is interposed between at least one input shaft (4,6) and the respective power unit (8,10).

9. A device as claimed in claim 8, characterised in that a friction clutch is interposed between at least one input shaft (4,6) and the respective power unit (8,10).

10. A multiple coupling device for N power units (10_i, i=1,2....N) and one user machine (16), using N-1 coupling devices (R_r, r=1,2,....N-1) in accordance with one or more of claims 1 to 9 characterised in that two power units (10_1,10_2) are connected to the input shafts (4_1,6_1) of the first coupling device (D_1), one power unit (10_{r+1}) and the output shaft (12_{r-1}) of the upstream coupling device (D_{r-1}) are connected respectively to the input shafts (4_r,6_r) of the oter coupling devices (D_r), and the user machine (16) is connected to the output shaft (12_{N-1}) of the last coupling device (D_{N-1}).

FIG. 1


26
24
34
12
18
14
2
8
4
10
28
6
20
16

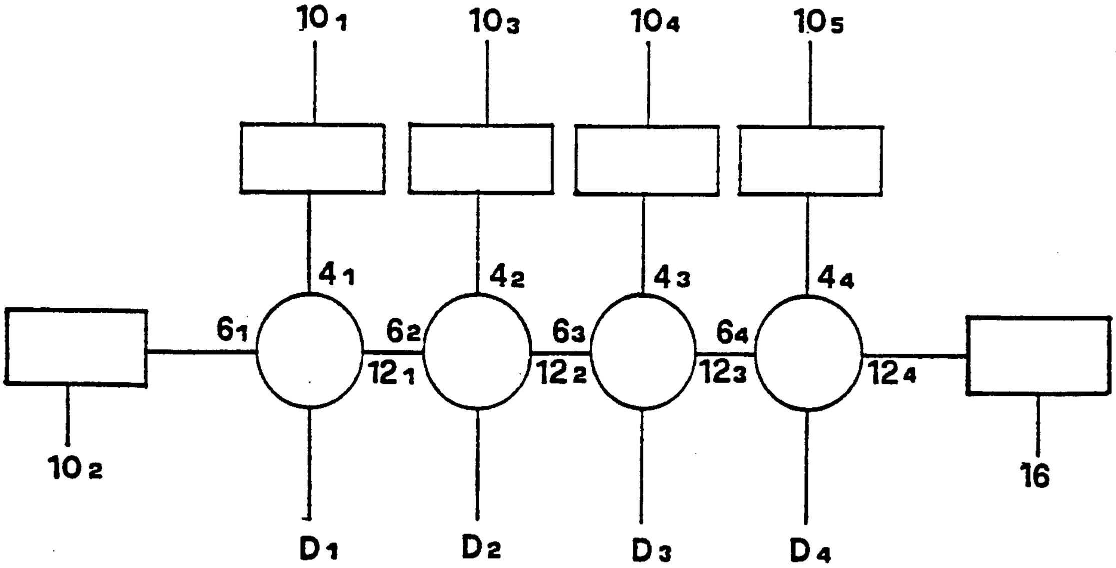

10_1
10_3
10_4
10_5
4_1
4_2
4_3
4_4
6_1
6_2
6_3
6_4
12_1
12_2
12_3
12_4
10_2
16
D_1
D_2
D_3
D_4

FIG. 3

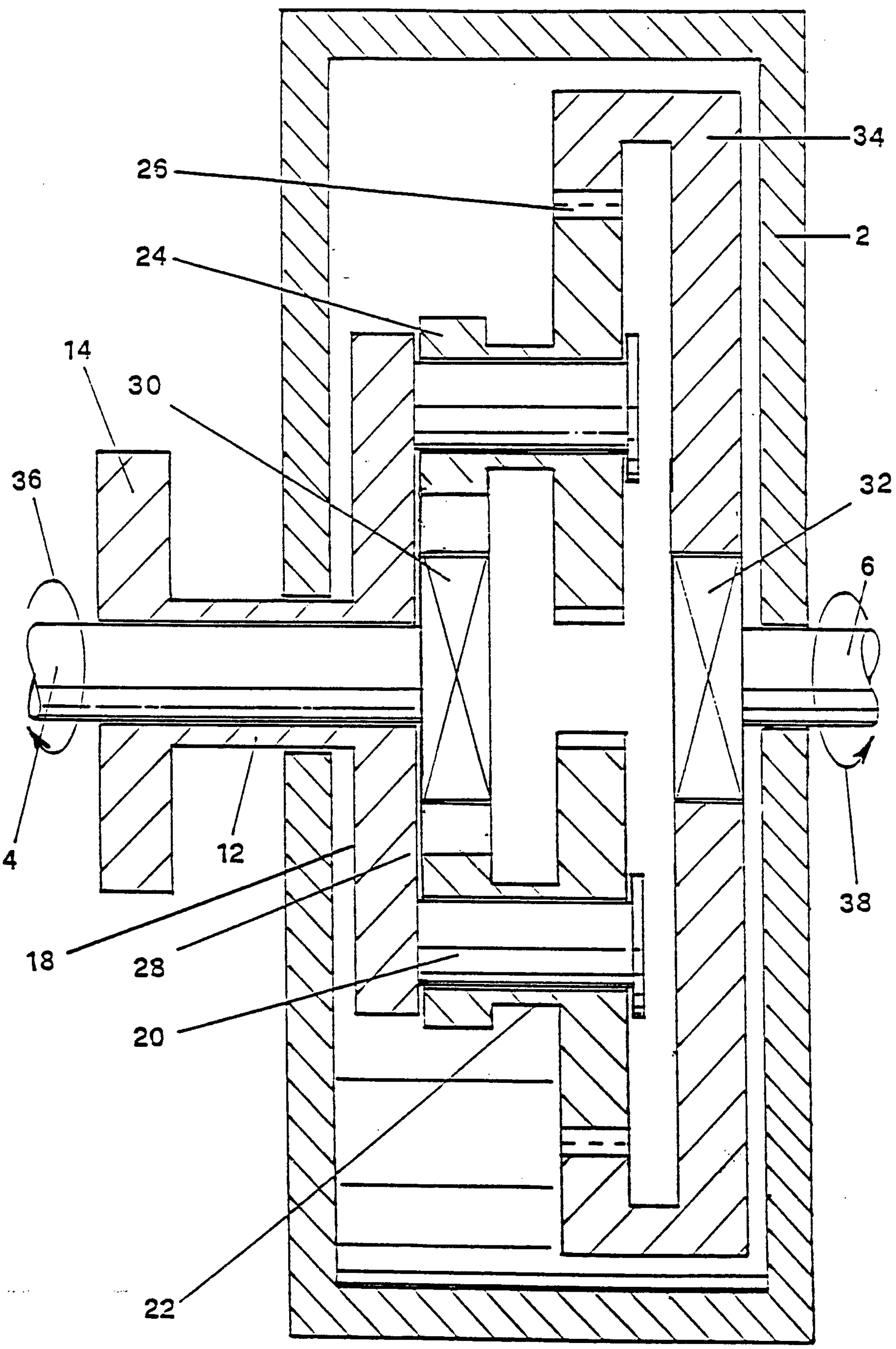


FIG. 2

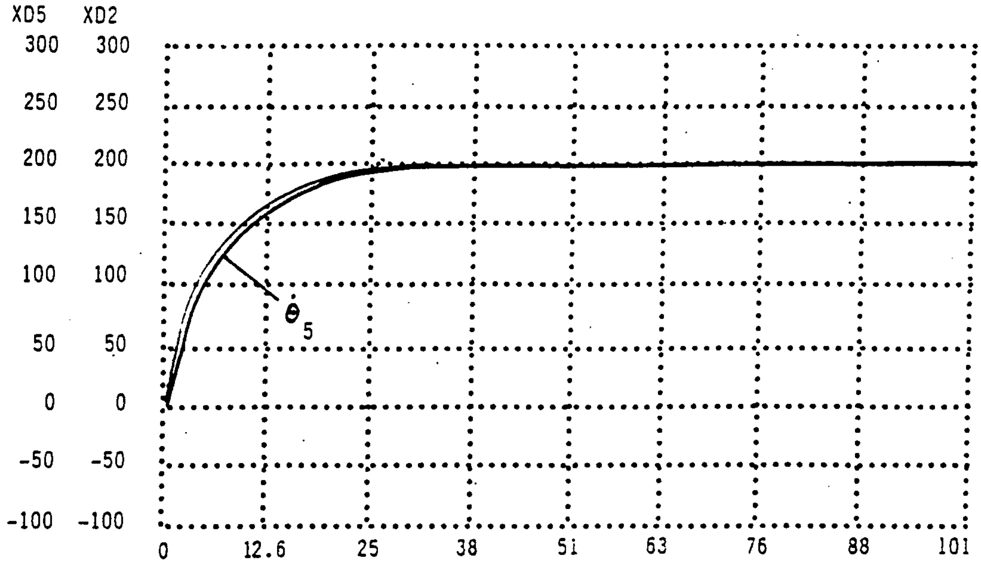


FIG. 4A

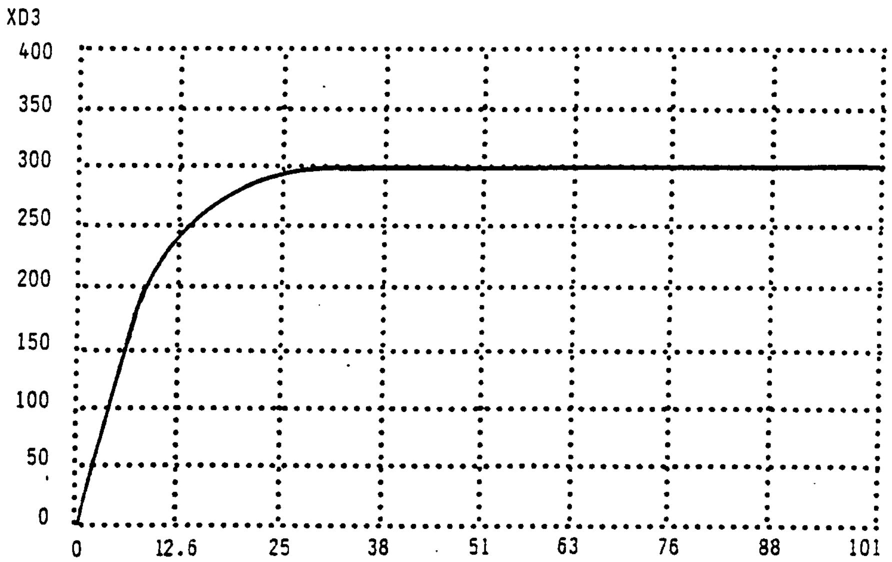


FIG. 4B

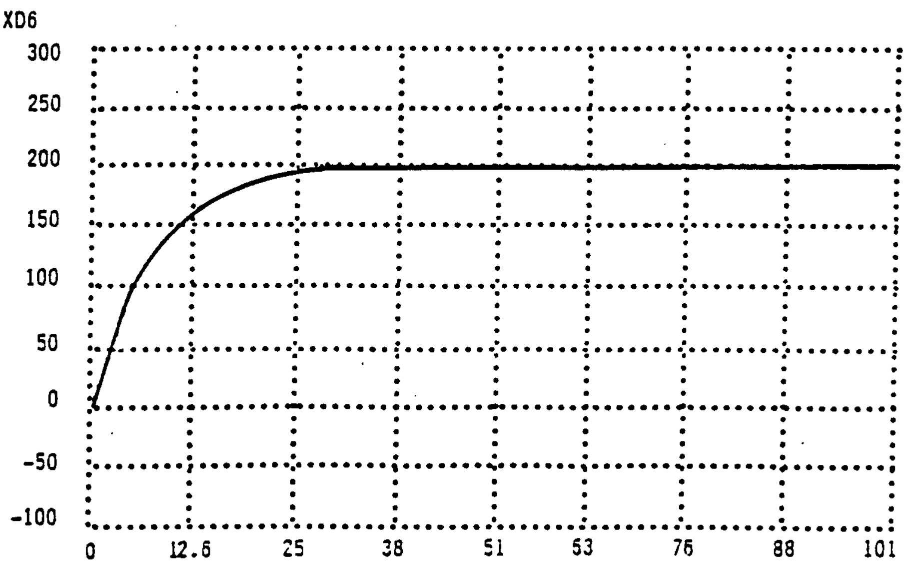


FIG. 4C

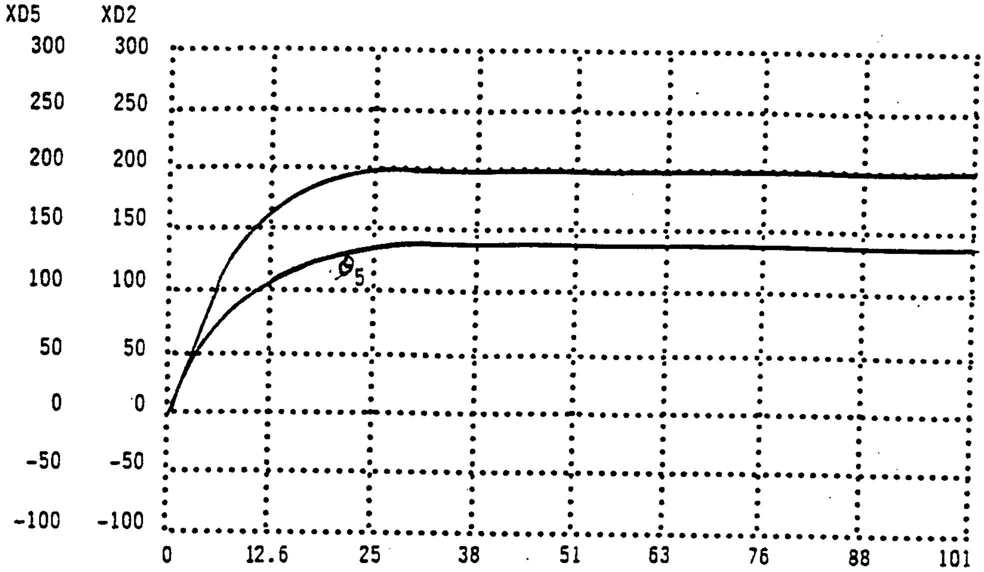


FIG. 5A

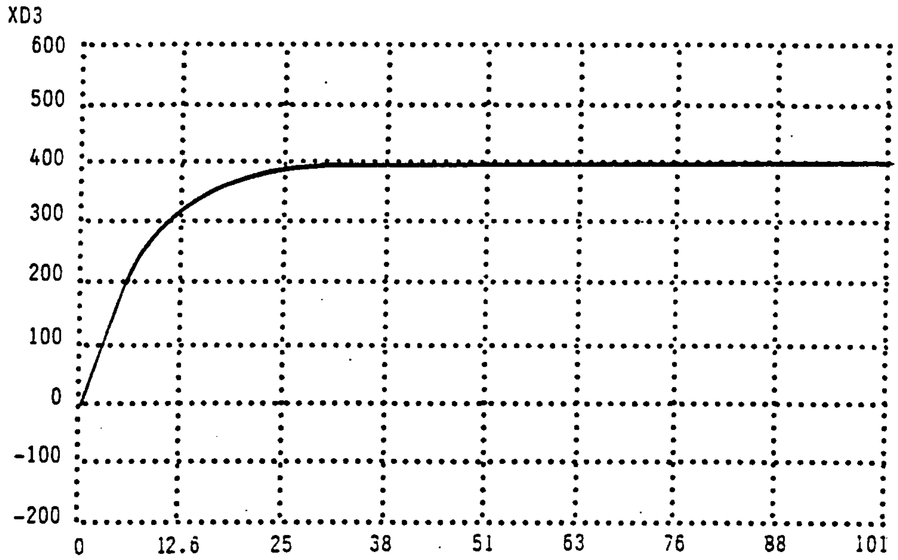


FIG. 5B

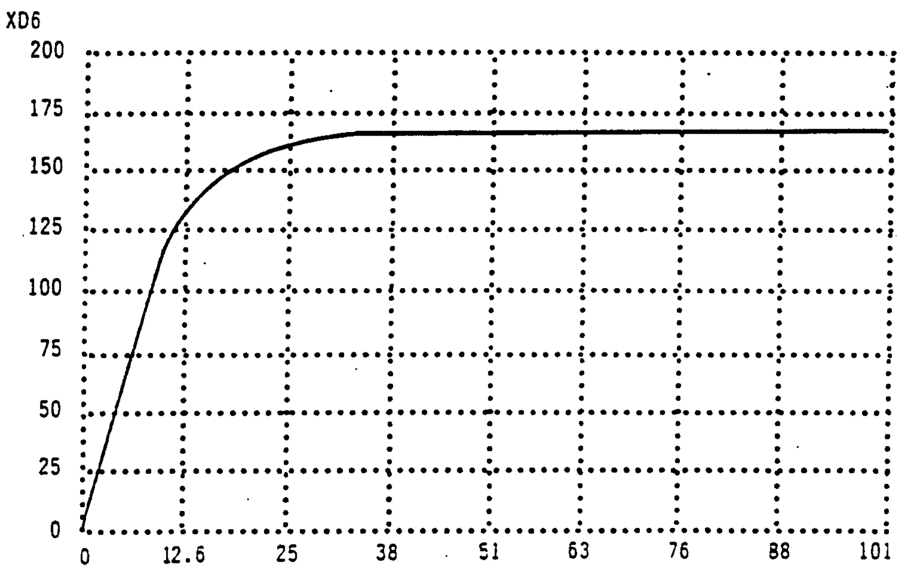


FIG. 5C

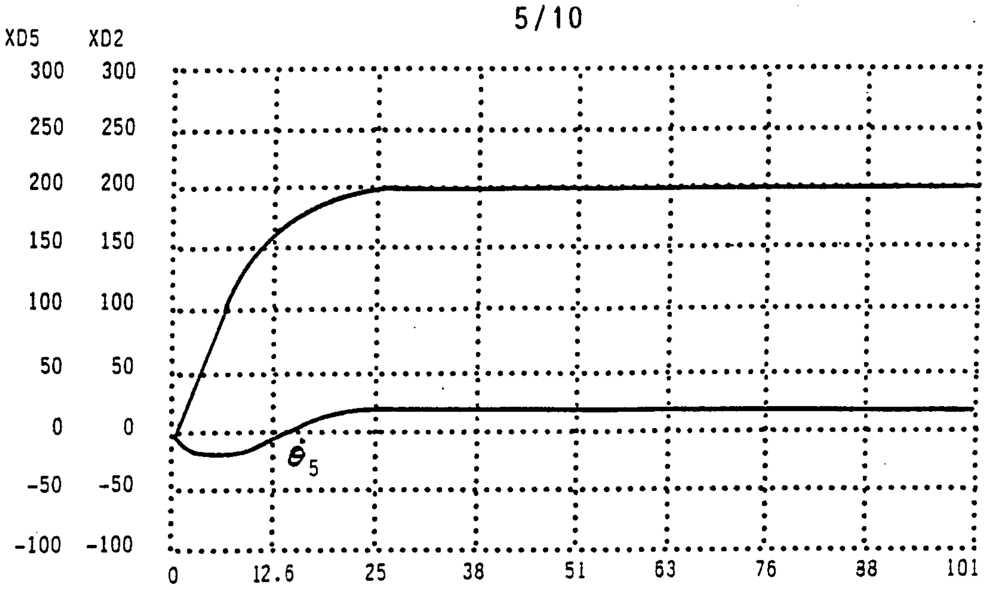


FIG. 6A

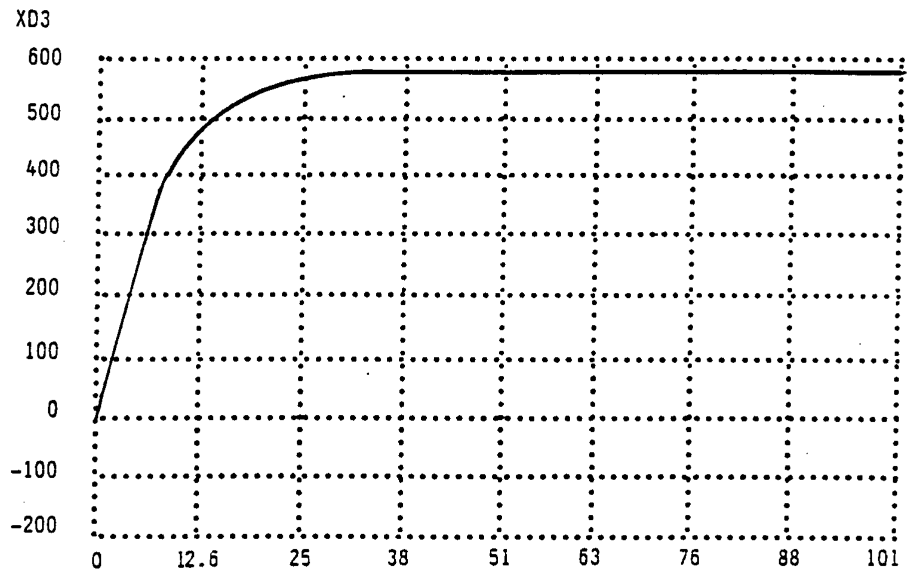


FIG. 6B

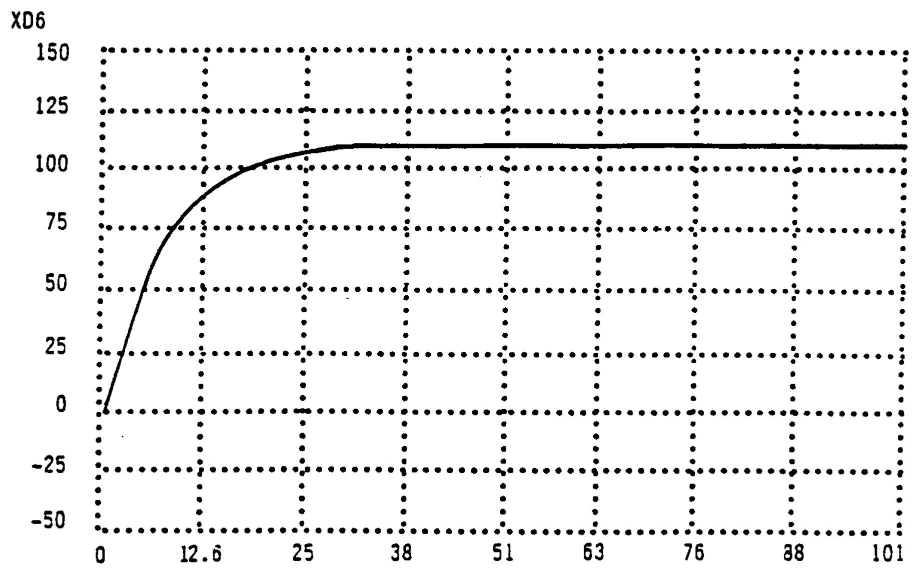


FIG. 6C

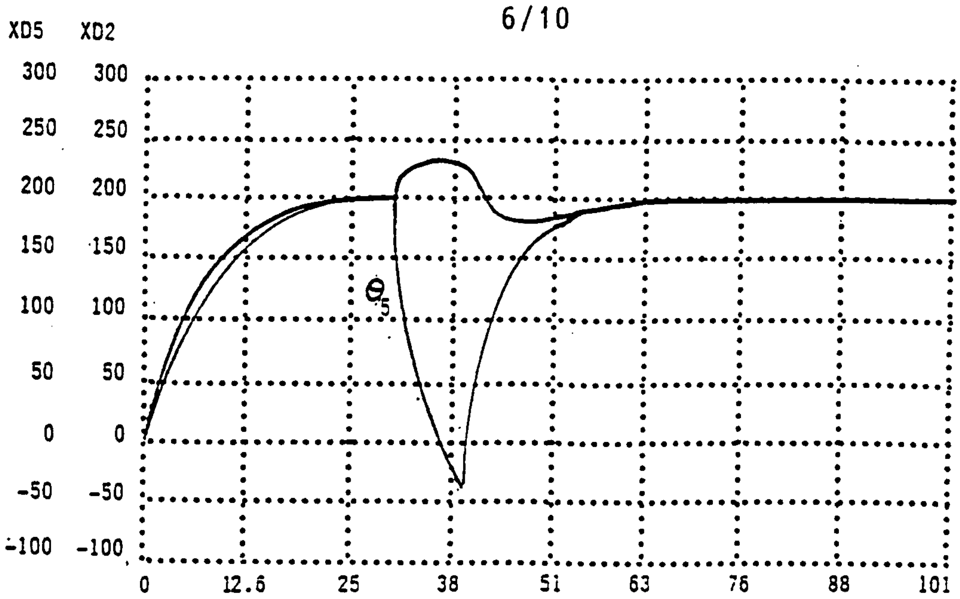


FIG. 7A

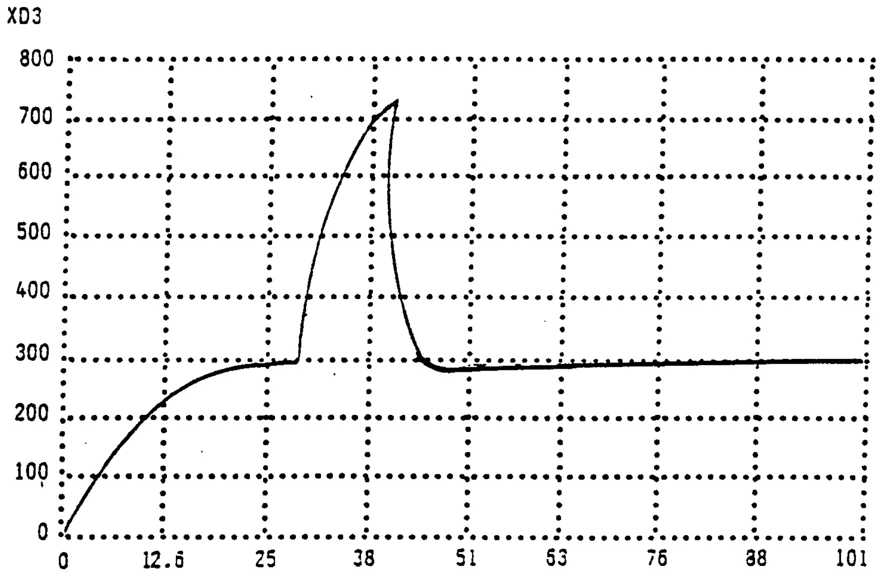


FIG. 7B

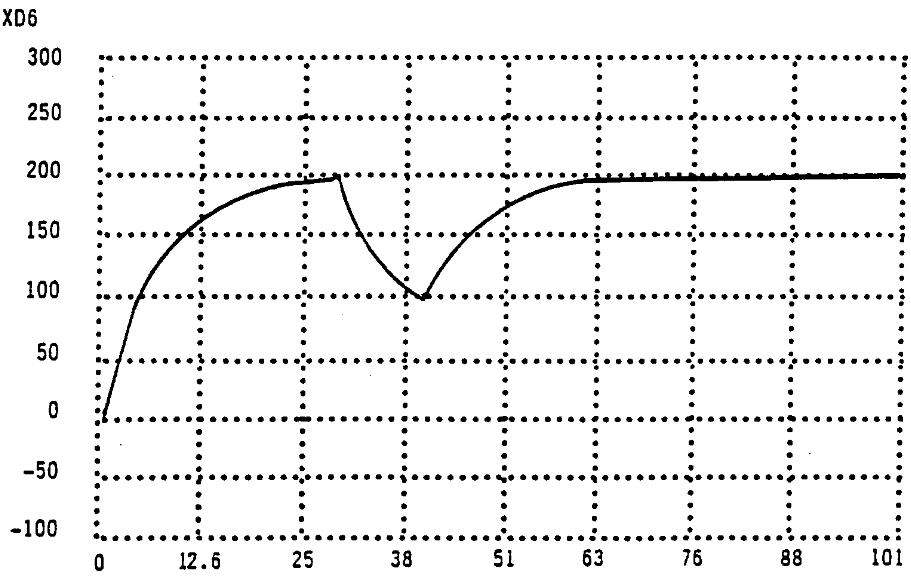


FIG. 7C

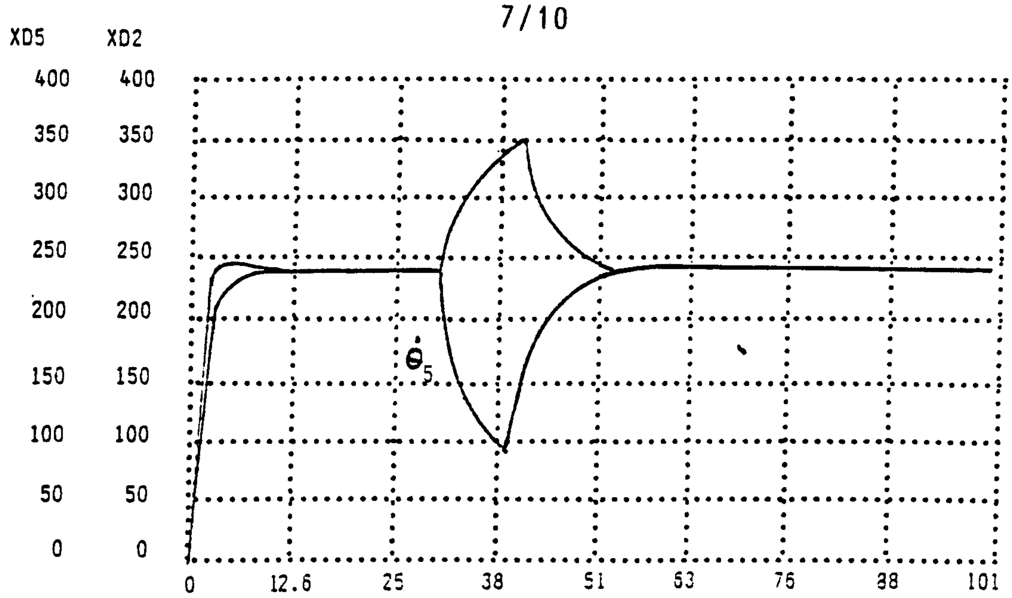


FIG. 8A

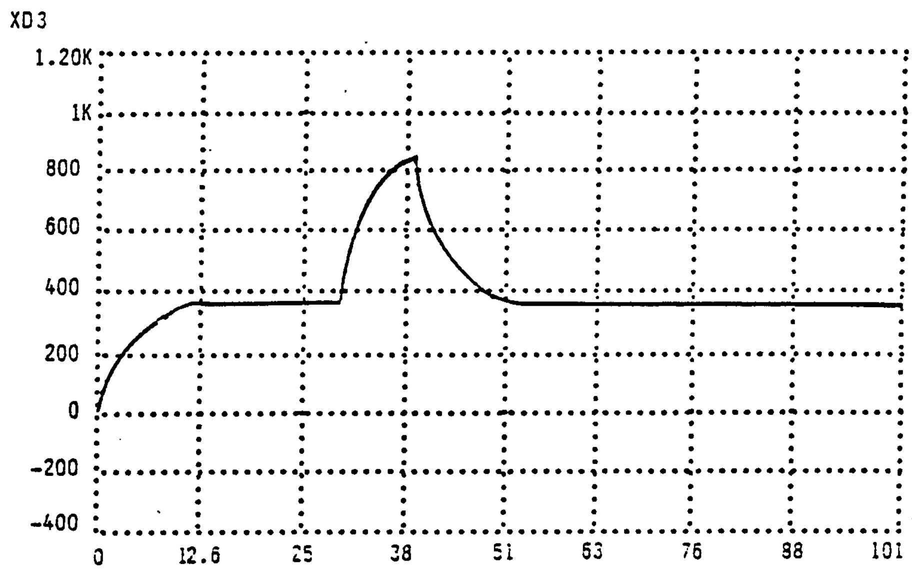


FIG. 8B

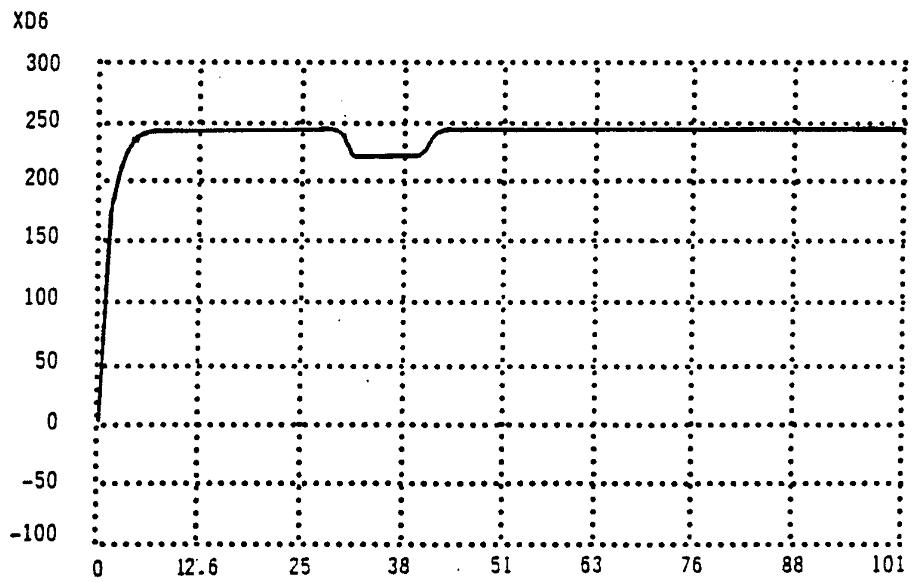


FIG. 8C

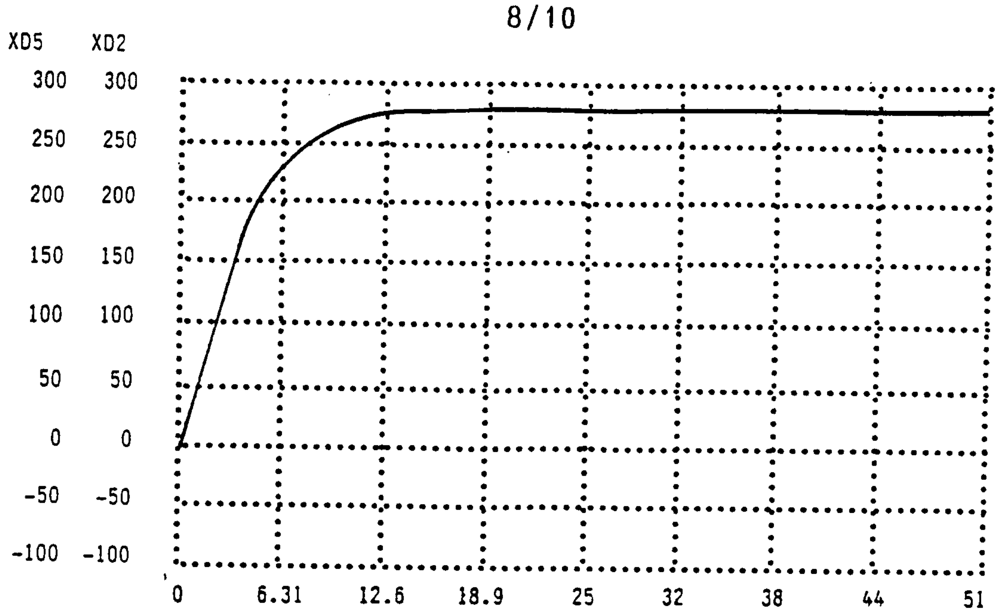


FIG. 9A

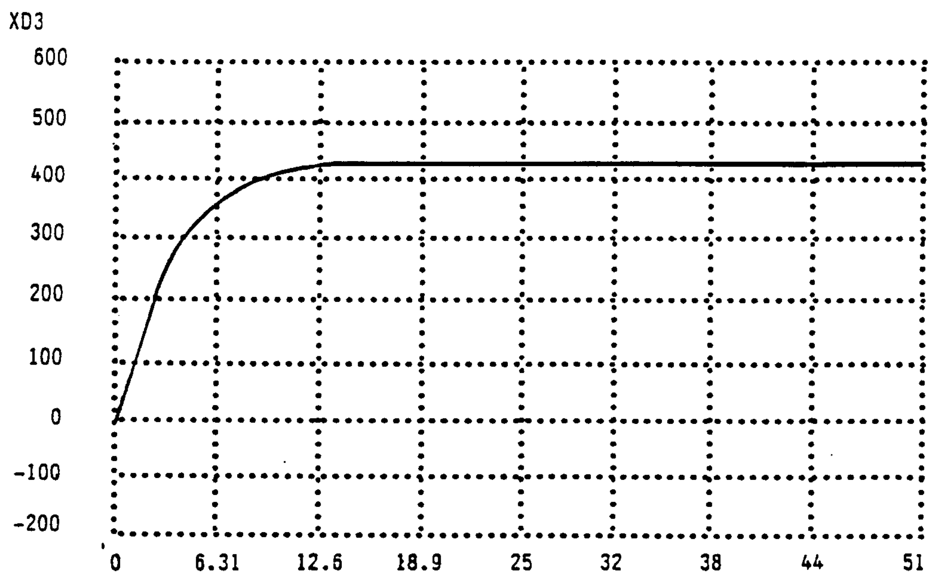


FIG. 9B

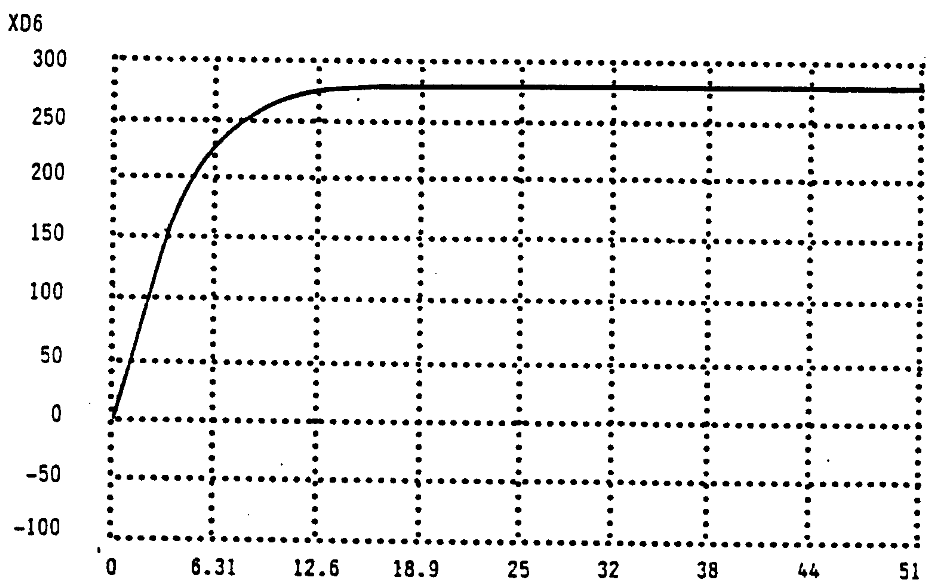


FIG. 9C

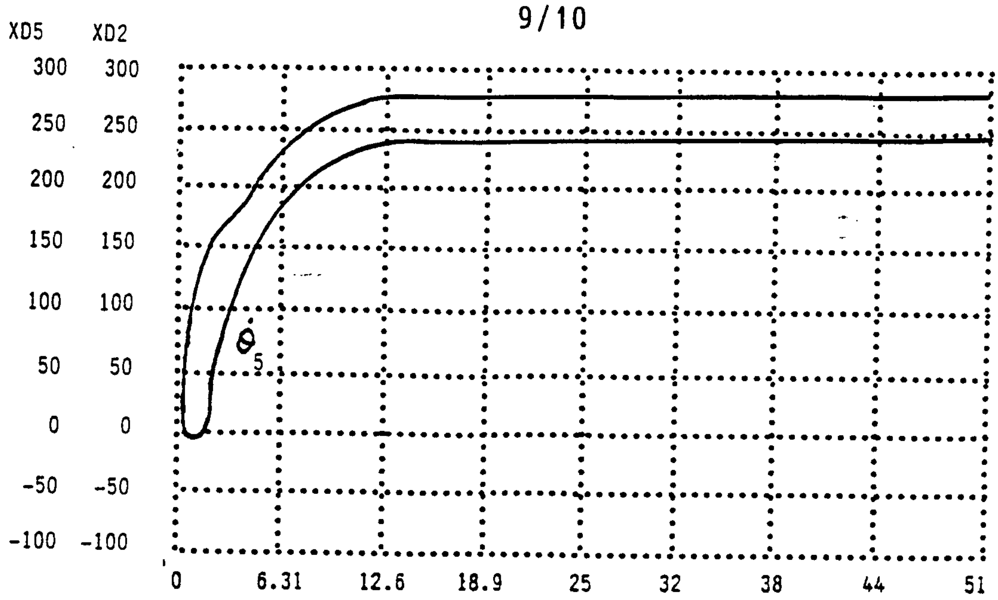


FIG. 10A

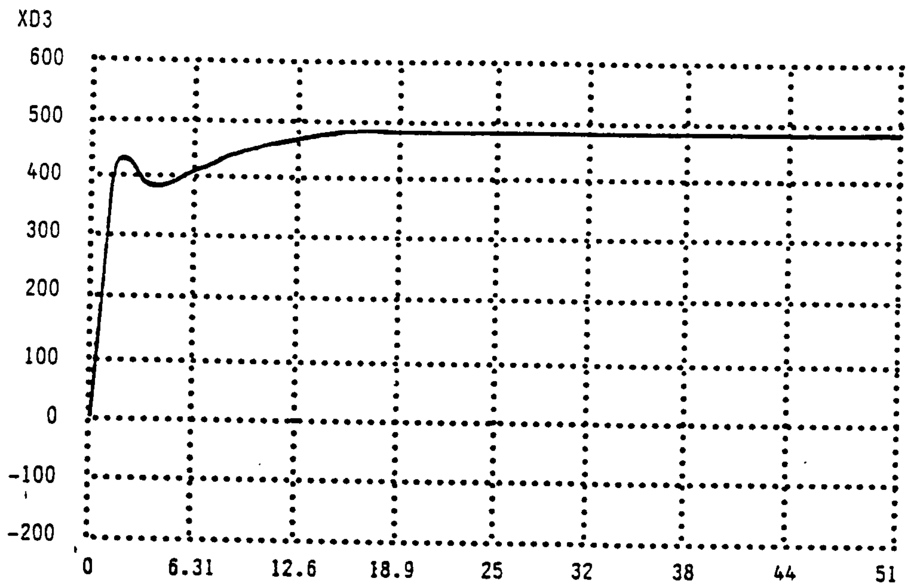


FIG. 10B

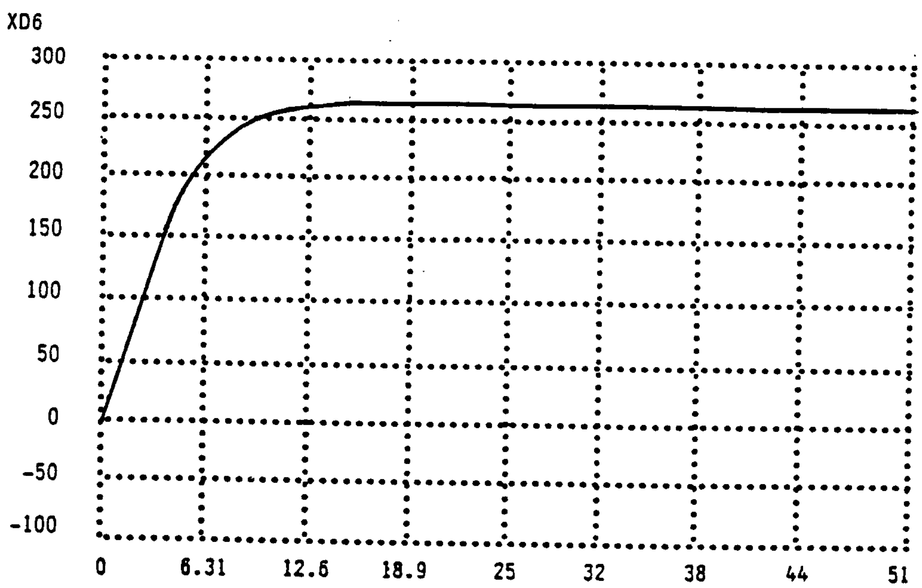


FIG. 10C

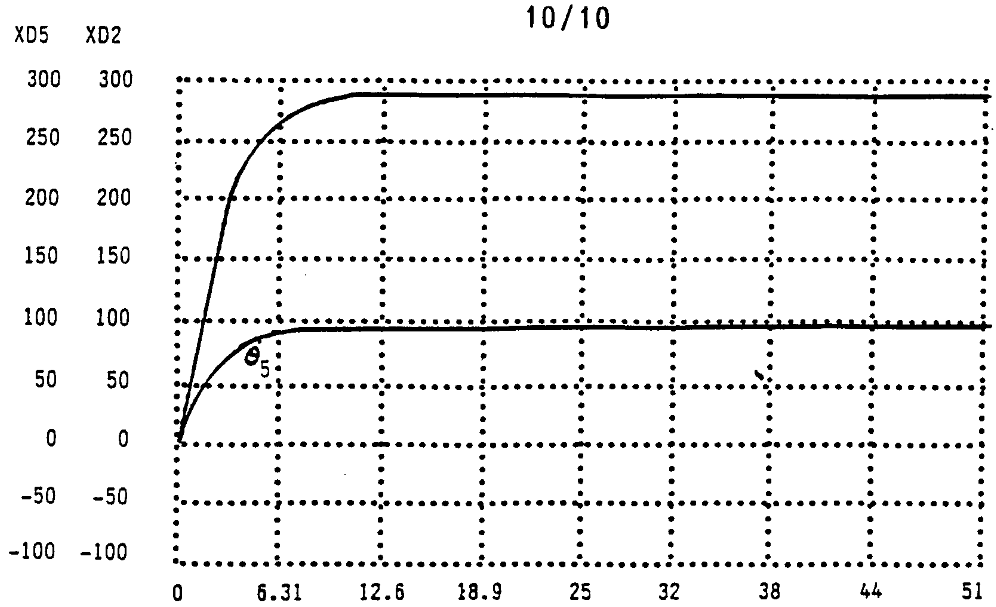


FIG. 11A

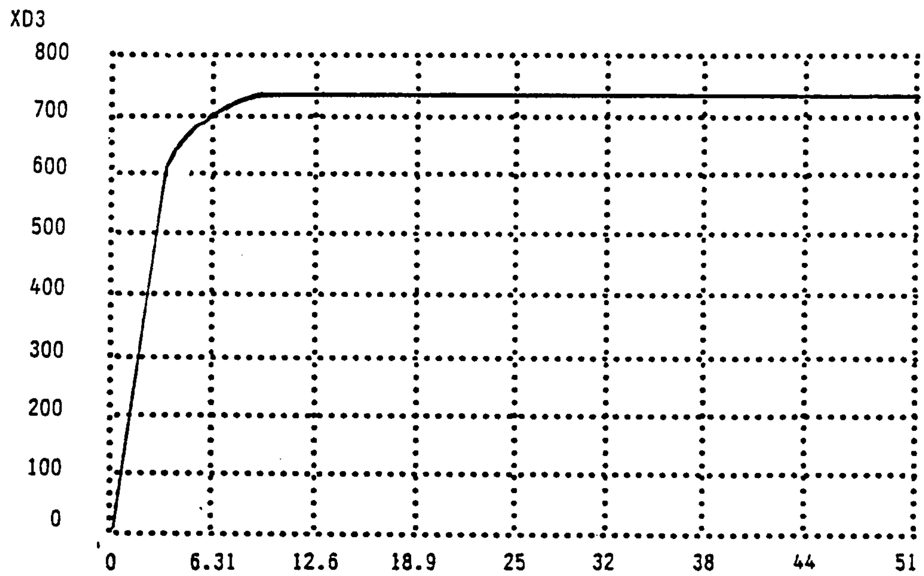


FIG. 11B

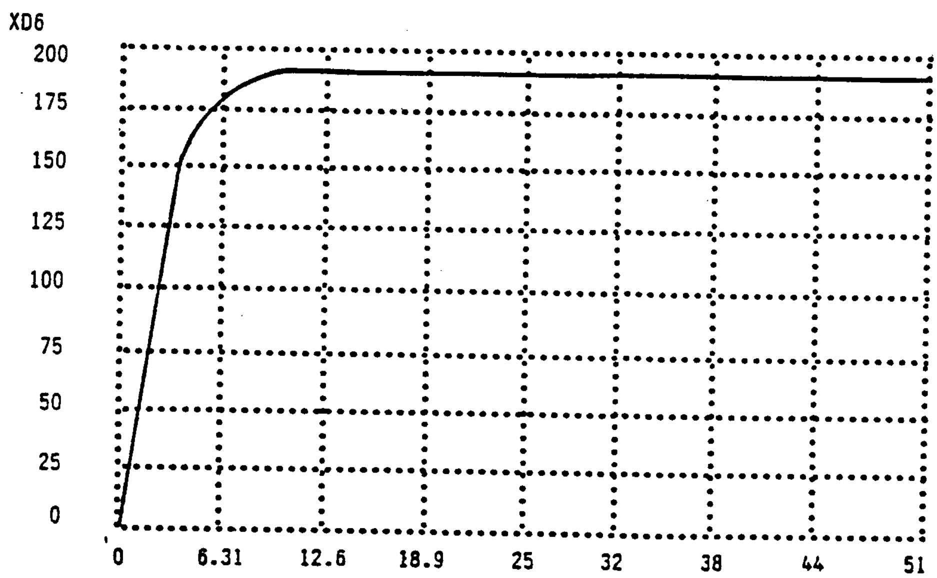


FIG. 11C

INTERNATIONAL SEARCH REPORT

Intern. al Application No
PCT/EP 93/02791

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 F16H3/72 F16H37/08

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)
IPC 5 F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE,C,875 896 (A. GAUNITZ) 7 May 1953 see the whole document ---	1-6
X	DE,A,36 40 146 (H. ECKHARDT) 1 June 1988 see claim 1; figure 1 ---	1,2,7
X	DE,C,37 28 507 (BEISSBARTH & MÜLLER GMBH) 1 September 1988 see claims 1,5; figure ---	1,2,8,9
X	GB,A,193 869 (J. BERTRAND) 19 June 1924 see the whole document ---	1,2,10
X	GB,A,2 063 804 (V.C. COCK) 10 June 1981 see page 2, line 88 - line 123; figures -----	1,6,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"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

1

Date of the actual completion of the international search	Date of mailing of the international search report
14 February 1994	21.02.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mende, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 93/02791

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-C-875896		NONE	
DE-A-3640146	01-06-88	NONE	
DE-C-3728507	01-09-88	DE-C- 3828896 EP-A- 0304919	23-05-90 01-03-89
GB-A-193869		NONE	
GB-A-2063804	10-06-81	NONE	