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(54) **VIBRATING CONVEYOR AND THE METHOD FOR CONTROLLING THE OPERATION OF THE VIBRATING CONVEYOR**

(57) The subject matter of the invention relates to a vibrating conveyor and a method for controlling the operation of the vibrating conveyor with variable performance, with the possibility of stopping transport. The conveyor is characterised in that it comprises a dynamic mass of the eliminator (2), the centre of gravity (9) of which lies on the line of action of the resultant force of the electro-vibrators (3), and also comprises a resilient suspension of the mass of the eliminator (2) which is provided by an additional coil spring (5) with the axis coinciding with the direction of the line of action of the electro-vibrators (3) resultant force and at least a pair of spring bars (6) with a longitudinal axis perpendicular to the direction of the line of action of the resultant force of the electro-vibrators (3). The method for controlling the operation of the vibrating conveyor consists in that, the excitation frequency (ω) of the electric motors of the electro-vibrators (3) is set and smoothly adjusted by means of inverters (7) so that the operating point (W) is situated on the rising slope of the second resonance of the conveyor characteristic A(ω) describing the dependence of the vibration amplitude (A) of the trough (1) on the excitation frequency (ω), whereas in order to stop the transport, with the vibration drive on, the excitation frequency (ω) is reduced to a value equal to or close to the partial eigenfrequency ω_{e1} of the mass of the eliminator (2) so that the operating point (W) is situated in the anti-resonance valley (V) preceding the second resonance.

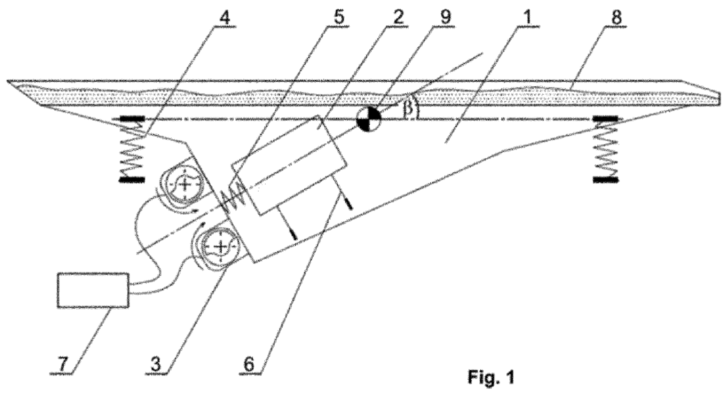

Fig. 1

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Description

[0001] The subject matter of the invention relates to a vibrating conveyor and a method for controlling the operation of the vibrating conveyor with variable performance, with the possibility of stopping transport, applicable to the transport of materials, especially in the mining and processing industry, in technological lines requiring frequent stopping and changing of operating parameters.

[0002] The American patent specification US3064357A discloses a conveyor having a control system which, by means of an arrangement of sensors, analyses the thickness of the feed layer and the transport speed. On this basis, the amount of material that has been transported is calculated and it is possible to switch off the conveyor at the right moment. After switching off the vibrating conveyor, the transport continues for some time due to machine vibrations during coastdown. A similar effect also occurs in the solutions known from American patent specifications US3053379A or US4771894A, in which a trough supported on a spring system is excited to vibrations by means of counter-rotating self-synchronizing vibrators. The resultant force originating from the vibrator system passes through the centre of mass of the trough system causing its rectilinear vibrations and is transferred to the feed, causing its transport.

[0003] The Polish patent specification PL425086B1 discloses a highly efficient dosing vibrating conveyor with the possibility of a smooth adjustment of performance during operation. The conveyor comprises a main suspension, a vibrating trough driven by self-synchronizing inertial vibrators with a smooth adjustment of rotational speed, the resultant force of which passes through the centre of gravity of the conveyor body. Moreover, the conveyor comprises at least one additional resonant vibration damping system connected to the vibrating trough, one end of the damping system being connected to the vibrating conveyor, and the other end thereof being fixed in an immovable manner. Stopping the speed carried out by slowing down the vibrations of the trough to low speeds at which the transport stops. When being stopped, the system passes through a resonant zone, but is equipped with special dampers which reduce undesired excitation in this zone. To some extent, it regulates the course of the trough braking and the transport speed of the feed. A characteristic is then obtained which allows the device to be used as a dispenser. Also, in Japanese patent specification JP6206962B2 stopping the transport of the feed on the conveyor is carried out by reducing the excitation frequency and, consequently, the amplitude of vibrations of the trough. The operating and stopping points of the conveyor in the above solution are determined at over resonance frequencies. This allows the system to gradually reduce the transport speed until it stops.

[0004] There are also known vibration conveyors in which dynamic elimination of excitation forces acting on the trough is used to suppress vibrations causing transport. For example, the Polish patent application P.425950, discloses a vibrating conveyor comprising a trough open at least at one end, resiliently supported in a substantially horizontal position, and a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators suspended under the conveyor trough at an angle such that their resultant force passes through the centre of gravity of the trough lying on a vertical plane guided through the longitudinal axis of the trough, and the axes of rotation of the electro-vibrators are perpendicular to that plane. By means of an additional resilient suspension, which may be provided by e.g. coil springs with axes parallel to the direction of action of the resultant force of the electro-vibrators, a mass of the eliminator is attached to the trough in such a way that its centre of gravity coincides with the centre of gravity of the trough. The mass of the eliminator has degrees of freedom limited to one translational degree in the coincident direction with the direction of the resultant force of electro-vibrators, which are connected via known drive transmission means to electric motors equipped with rotational speed regulators.

[0005] The present invention provides for a steady-state operation of a conveyor in the resonance zone of the second resonance and solves a technical problem, that consists in the combination of features such as: the possibility of smoothly controlling the performance from 0-100% during operation, the possibility of immediately stopping the flow of feed from the conveyor without to switch off the drive and without the necessity for the system to pass through successive resonance zones, as well as the problem of too large amplitudes of the eliminator in the case of steady-state operation before the anti-resonance zone.

[0006] The essence of the vibrating conveyor, comprising a trough open at least at one end, resiliently supported in a substantially horizontal position, and a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators with the possibility of smooth adjustment of rotation and suspended under the conveyor trough at an angle such that their resultant force passes through the centre of gravity of the trough lying on a vertical plane passing through the longitudinal axis of the trough, and the axes of rotation of the electro-vibrators are perpendicular to this plane, and further comprising a mass of the eliminator attached to the trough by means of a resilient suspension in such a way that the mass of the eliminator has degrees of freedom limited to one translational degree in the coincident direction with the direction of the resultant force of electro-vibrators, which are connected via known drive transmission means to electric motors equipped with rotational speed regulators, which are inverters, consists in that the centre of gravity of the mass of the eliminator lies on the line of action of the resultant force of the electro-vibrators, and the resilient suspension of the mass of the eliminator is provided by an additional coil spring with the axis coinciding with the direction of the line of action of the resultant force of the electro-vibrators and at least one pair of spring bars with a longitudinal axis perpendicular to the direction of the line of action of the resultant force of electro-vibrators.

[0007] Preferably, the resilient support of the trough is provided by four identical coil springs arranged in the corners of the trough at equal distances from its centre of gravity.

[0008] Also preferably, the direction of action of the resultant force of the electro-vibrators is inclined relative to the surface of the trough at an angle of 30 degrees.

[0009] Also preferably, the mass of the eliminator is supported on four spring bars, arranged in pairs on both its sides.

[0010] The essence of a method for controlling the operation of the vibrating conveyor, comprising a trough open at least at one end, resiliently supported in a substantially horizontal position, and a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators with the possibility of smooth adjustment of rotation and suspended under the conveyor trough at an angle such that their resultant force passes through the centre of gravity of the trough lying on a vertical plane passing through the longitudinal axis of the trough, and the axes of rotation of the electro-vibrators are perpendicular to this plane, and further comprising a mass of the eliminator attached to the trough by means of a resilient suspension in such a way that the mass of the eliminator has degrees of freedom limited to one translational degree in the coincident direction with the direction of the resultant force of electro-vibrators, which are connected via known drive transmission means to electric motors equipped with rotational speed regulators, which are inverters, and where the centre of gravity of the mass of the eliminator lies on the line of action of the resultant force of the electro-vibrators, and the resilient suspension of the mass of the eliminator is provided by an additional coil spring with the axis coinciding with the direction of the line of action of the resultant force of the electro-vibrators, and at least one pair of spring bars with a longitudinal axis perpendicular to the direction of the line of action of the resultant force of electro-vibrators, is characterised in that in order to set the mode of operation of the conveyor at the state of transport with a predetermined performance, by means of inverters, the excitation frequency of the electric motors of the electro-vibrators is set at the operating point located on the rising slope of the second resonance, and in order to change the performance of the conveyor, during its operation, the excitation frequency is adjusted by means of inverters so that the operating point reaches the required vibration amplitude of the trough and is still on the rising slope of second resonance, whereas in order to stop the transport, with the vibration drive on, the excitation frequency is reduced by means of inverters to a value equal to or close to the eigenfrequency of the mass of the eliminator on its suspension so that the operating point is situated in the anti-resonance valley, preceding the second resonance.

[0011] An exemplary embodiment of the invention is illustrated by means of a schematic drawing, where Fig. 1. shows a simplified drawing of the conveyor, whereas Fig. 2 shows amplitude characteristics of the operation of its trough with marked an anti-resonance valley and an operating point on the rising slope of the second resonance.

[0012] The vibrating conveyor (Fig. 1) comprises a trough 1 open on both sides, resiliently supported so that its working surface is in a horizontal position. The support of the trough 1 is provided by four identical coil springs 4 arranged in the corners of the trough 1 in such a way that the support places are located at equal distances from the centre of gravity 9 of the trough 1. To the trough 1, in the lower part of the body, which is an integral part thereof, is suspended a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators 3 equipped with rotational speed regulators which are inverters 7. The direction of action of the resultant excitation force of the electro-vibrators 3 passes through the centre of gravity 9 of the trough 1 lying on a vertical plane passing through the longitudinal axis of the trough 1 and is inclined relative to the surface of the trough 1 at an angle (β) = 30°. The axes of rotation of the electro-vibrators 3 are perpendicular to this plane. Inside the body integrated with the trough 1, there is the mass of the eliminator 2 such that its centre of gravity 9 lies in the direction of action of the resultant force of the electro-vibrators 3. The mass of the eliminator 2 has degrees of freedom limited to one translational degree in the coincident direction with the direction of resultant force of the electro-vibrators 3 due to the fact that it is suspended inside the body of trough 1 by means of a resilient suspension which is provided by an additional coil spring 5 with the axis coinciding with the direction of the line of action of resultant force of the electro-vibrators 3, and two pairs of spring bars 6 with a longitudinal axis perpendicular to the direction of the line of action of resultant force of the electro-vibrators 3, arranged in pairs, symmetrically on both sides of the mass of the eliminator 2.

[0013] The method for controlling the operation of the vibrating conveyor consists in that, after switching on the drive, the excitation frequency (ω) is increased by means of inverters 7 so that the conveyor passes through the first resonance (Fig. 2) at ω=35 rad/s (5.6 Hz) and through the anti-resonance valley (V) in the range ω=110÷120 (17.5 Hz ÷ 19.1 Hz) in the vicinity of the dynamic elimination frequency, which takes place at $\omega=\omega_{el}$ =115 rad/s (18,3 Hz), reaching the operating point (W) with a fixed performance, situated on the rising slope of the second resonance. In the embodiment, the achieved operating point (W) on the amplitude characteristic of the conveyor A(ω), describing the dependence of the amplitude (A) of the trough 1 on the excitation frequency (ω), has the coordinates ω=157 rad/s (25 Hz) and A=0.0026 m. This ensures the appropriate amplitude, suitable for the assumed lift coefficient and the assumed transport speed. With these parameters, the feed 8 starts to be fed onto the conveyor and the transport is carried out with a predetermined performance. In order to change the performance of the conveyor, during its operation, the excitation frequency (ω) is adjusted by means of inverters 7 increasing or decreasing it so that the operating point (W) reaches another, required vibration amplitude (A) of the trough 1 and is still on the rising slope of the second resonance. In this way, the performance of the conveyor can be smoothly adjusted. On the other hand, in order to stop the transport, with the vibration drive switched on, the excitation frequency (ω) is decreased by means of inverters 7 so that the operating point (W) is in the anti-resonance valley (V) preceding the second resonance, which corresponds to the excitation frequency (ω) being equal or close to the eigenfrequency ω_{el} of the mass of the eliminator 2 on its suspension, in the direction of the resultant excitation force. The mass of the eliminator 2 at this excitation frequency acts as a dynamic eliminator of the mass of the trough 1, in a similar way to the Frahm eliminator. Additionally, to ensure the desired movement, the mass of the eliminator 2, is guided by a set of spring bars 6 having a high longitudinal stiffness. This ensures oscillation of the mass of the eliminator 2 along the excitation straight line.

[0014] If the mass of the eliminator 2 is m_{el} and the total stiffness of its suspension in the direction of action of the excitation force is k_{el}, the eigenfrequency ω_{el}, the so-called partial in this direction is defined by the following formula:

$$\omega_{el} = \sqrt{\frac{k_{el}}{m_{el}}}$$

[0015] At the excitation frequency (ω) equal to or close to the eigenfrequency (ω_{el}, the vibrations of the mass of the eliminator 2 are established in such a way that the force in the resilient elements balances - in the absence of damping in the system - the exciting force $P_0 \sin \omega t$, extinguishing the vibrations of the mass of the trough 1. This phenomenon occurs regardless of the frequency of natural vibrations of the basic system before attaching the eliminator 2.

[0016] In this case, the Frahm eliminator system operates in an anti-resonance valley surrounded on two sides with resonance regions; the width of the valley depends on the ratio of the mass of the eliminator 2 to the mass of the trough 1. Stopping the vibrations of the trough 1, and thus the transport of the feed, can be achieved in a short time, and the vibrations of the trough 1 may be suppressed almost completely. It should be noted that the transport of the feed 8 is stopped even with small vibrations of the trough 1 before their complete extinction, as soon as the lift coefficient is less than one.

[0017] This conveyor is very well suited for a precise dosing of the feed, especially in the mode of frequent stopping of transport. The advantage of this solution is also the fact that the feed 8 on the trough 1 is evenly distributed along its length when the transport is stopped. The transport is resumed when the excitation frequency (ω) of unbalanced masses of electro-vibrators 3 increases to a frequency close to the system resonance associated with the second resonance zone. Then the vibrations of the mass of the eliminator 2 will not significantly affect the vibrations of the mass of the trough 1 and the transport will take place at a speed typical of a given class of machines.

[0018] By manipulating the motor operating frequency within the range of 20-25Hz, the full performance range (0-100%) can be achieved. The device therefore enables quick and smooth changes of performance, including stopping, and enables an efficient resumption of the transport, as there is no need to stop and start the motors.

Claims

1. A vibrating conveyor, comprising a trough open at least at one end, resiliently supported in a substantially horizontal position, and a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators with the possibility of a smooth adjustment of rotation and suspended under the conveyor trough at an angle such that their resultant force passes through the centre of gravity of the trough lying on a vertical plane passing through the longitudinal axis of the trough, and the axes of rotation of the electro-vibrators are perpendicular to this plane, and further comprising a mass of the eliminator attached to the trough by means of a resilient suspension in such a way that the mass of the eliminator has degrees of freedom limited to one translational degree, in the direction coincident with the direction of the resultant force of the electro-vibrators equipped with rotational speed regulators, which are inverters, **characterised in that** the centre of gravity of the mass of the eliminator 2 lies on the line of action of the resultant force of the electro-vibrators (3), and the resilient suspension of the mass of the eliminator (2) is provided by an additional coil spring (5) with the axis coinciding with the direction of the line of action of the resultant force of the electro-vibrators (3) and at least one pair of spring bars (6) with a longitudinal axis perpendicular to the direction of the line of action of the resultant force of the electro-vibrators (3).

2. The vibrating conveyor according to claim 1, **characterized in that** the resilient support of the trough (1) is provided by four identical coil springs (4) arranged in the corners of the trough at equal distances from the centre of gravity (9) of the trough (1).

3. The vibrating conveyor according to claim 1, **char-**

acterized in that the direction of the line of action of the resultant force of the electro-vibrators (3) is inclined relative to the surface of the trough (1) at an angle (β) = 30°.

4. The vibrating conveyor according to claim 1, **characterized in that** the spring bars (6) are arranged in pairs on both sides of the mass of the eliminator (2).

5. A method for controlling the operation of the vibrating conveyor, comprising a trough open at least at one end, resiliently supported in a substantially horizontal position, and a vibration drive in the form of a pair of self-synchronizing counter-rotating electro-vibrators with the possibility of smooth adjustment of rotation and suspended under the conveyor trough at an angle such that their resultant force passes through the centre of gravity of the trough lying on a vertical plane passing through the longitudinal axis of the trough and the axes of rotation of the electro-vibrators are perpendicular to this plane, and further comprising the mass of the eliminator attached to the trough by means of a resilient suspension in such a way that the mass of the eliminator has degrees of freedom limited to one translational degree in the direction of the resultant force of the electro-vibrators, which are connected via known drive transmission means to electric motors equipped with rotational speed regulators, which are inverters, and wherein the centre of gravity of the mass of the eliminator (2) lies on the line of action of the resultant force of the electro-vibrators (3), and the resilient suspension of the mass of the eliminator (2) is provided by a coil spring (5) with the axis coinciding with the direction of the line of action of the resultant force of the electro-vibrators (3) and at least one pair of spring bars (6) with a longitudinal axis perpendicular to the direction of the line of action of the resultant force of the electro-vibrators (3),
characterized in that

- in order to set the mode of operation of the conveyor in the transport state with a predetermined performance, inverters (7) are used to set the excitation frequency (ω) of the electric motors of the electro-vibrators (3) at the operating point (W) situated on the rising slope of the second resonance of the conveyor characteristics A(ω) describing the dependence of the vibration amplitude (A) of the trough (1) on the excitation frequency (ω), and
- in order to change the performance of the conveyor, during its operation, the excitation frequency (ω) is adjusted by means of the inverters (7) so that the operating point (W) reaches the required vibration amplitude (A) of the trough (1) and is still on the rising slope of the second resonance of the characteristic A(ω), whereas
- in order to stop the transport, with the vibration drive switched on, the excitation frequency (ω) is reduced by means of inverters (7) to a value equal to or close to the eigenfrequency ω_{el} of the mass of the eliminator (2) on its suspension, called the partial frequency, so that the operating point (W) is situated in the anti-resonance valley (V) preceding the second resonance.

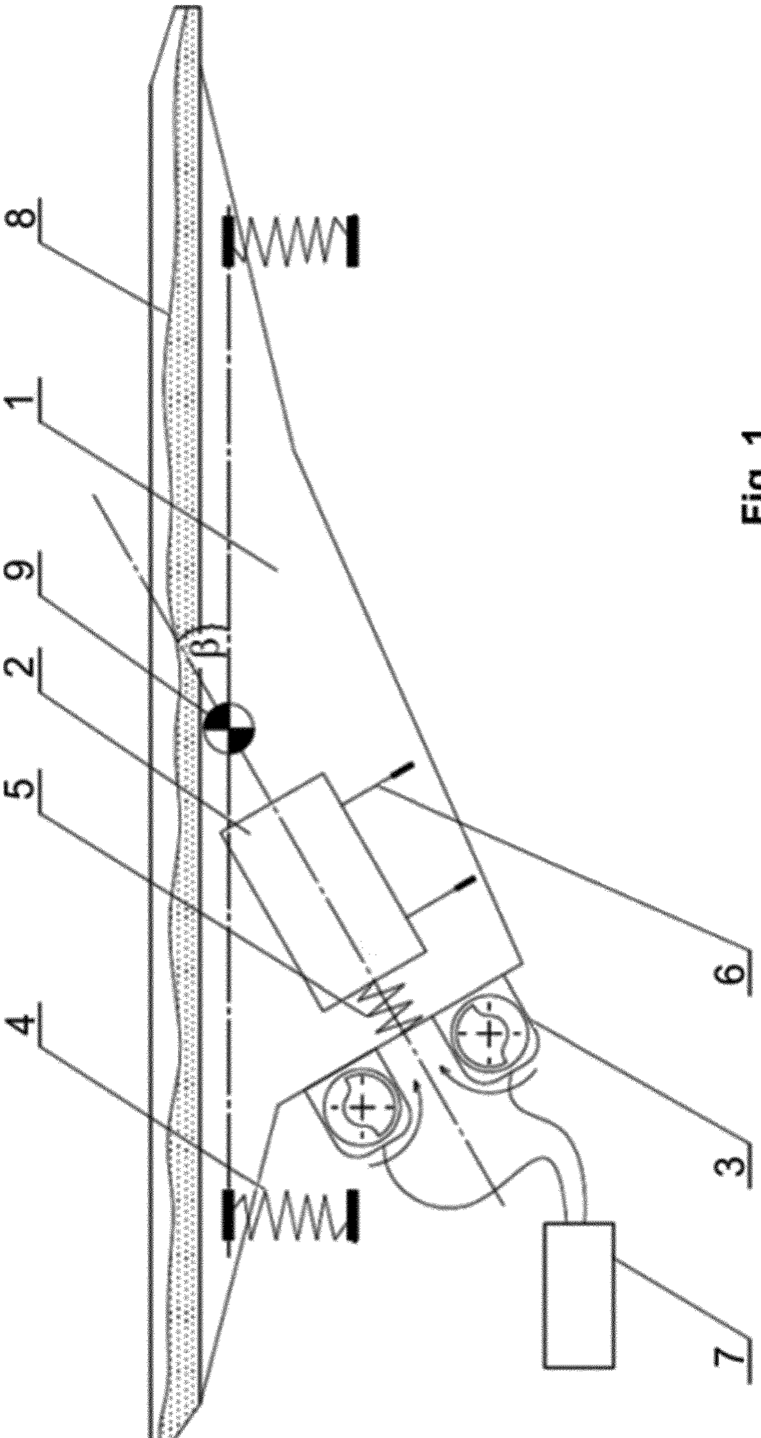

Fig. 1

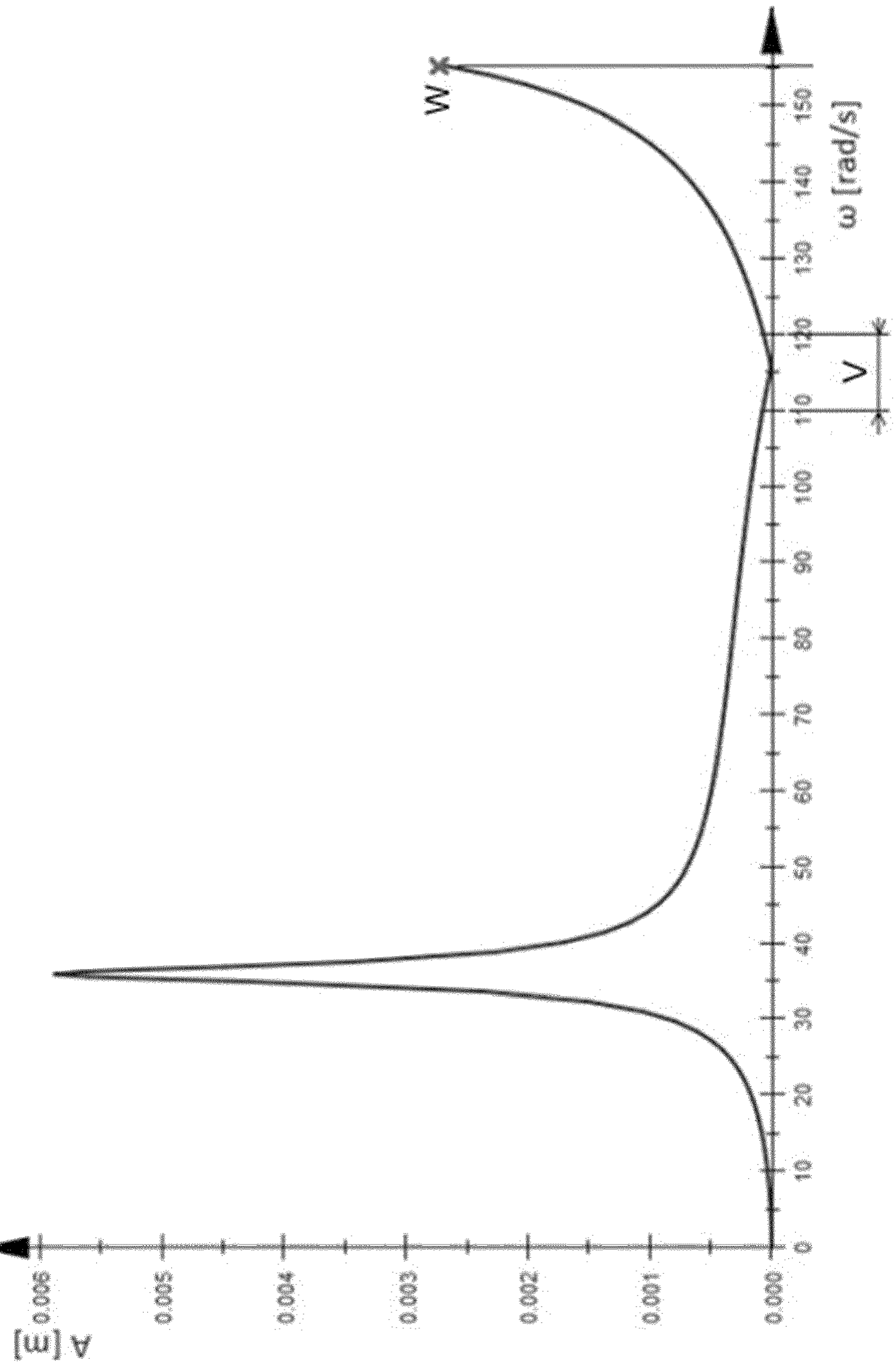
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Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 0719

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	CZUBAK PIOTR ET AL: "Analysis of a New Vibratory Conveyor Allowing for a Sudden Stopping of the Transport", TEHNICKI VJESNIK, [Online] vol. 27, no. 2, 1 April 2020 (2020-04-01), pages 520-526, XP055909747, HR ISSN: 1330-3651, DOI: 10.17559/TV-20181206111514 Retrieved from the Internet: URL:https://hrcak.srce.hr/en/file/343921> [retrieved on 2022-04-06] * the whole document * -----	1-5	INV. B65G27/20 B65G27/32
A	PL 425 950 A1 (AKADEMIA GORNICZO HUTNICZA IM STANISLAWA STASZICA W KRAKOWIE) 16 December 2019 (2019-12-16) * figures 1-5 * -----	1-5	
A,D	US 3 053 379 A (JOSEF RODER ET AL) 11 September 1962 (1962-09-11) * figures 1a, 1b, 2 * -----	1-5	TECHNICAL FIELDS SEARCHED (IPC)
A	US 4 017 060 A (BRANDER JAMES EDWARD ET AL) 12 April 1977 (1977-04-12) * figures 1-2 * -----	1-5	B65G

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	7 April 2022	Belz, Thomas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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PL 425950	A1	16-12-2019	NONE	
US 3053379	A	11-09-1962	NONE	
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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