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Adaptive Vibratory Feeder Amplitude for Fill Level Regulation

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Abstract

A system for managing part flow in a vibratory feeder bowl dynamically adjusts vibratory amplitude based on the detected fill level of parts within the bowl. This arrangement prevents part starvation when the bowl is nearly empty and mitigates jamming when the bowl is refilled. A fill level sensor continuously monitors the part volume, and a controller adjusts the vibratory drive’s amplitude according to a predetermined schedule. Jamming events are detected by monitoring part flow at the outlet, triggering a specific amplitude sequence to clear blockages. A controlled refill strategy avoids abrupt amplitude changes, ensuring continuous, stable part delivery.

1. Technical Field

[0001] The present disclosure relates to automated assembly systems, specifically to devices and methods for feeding discrete parts from a bulk supply to a downstream process or station. More particularly, it concerns vibratory feeding mechanisms employed in industrial automation.

2. Technical Context

[0002] Vibratory feeders are widely utilized in manufacturing and assembly operations to deliver parts in a desired orientation and at a controlled rate. A typical vibratory feeder includes a bowl with helical tracks, driven by an electromagnetic or piezoelectric vibratory unit. The vibration causes parts to move along the tracks, aligning and orienting them before they exit the bowl. A common challenge in operating such feeders is maintaining a consistent part delivery rate as the volume of parts within the feeder bowl changes. When the bowl is full, the mass of parts can dampen the vibratory action, requiring a higher amplitude to achieve the desired feed rate. Conversely, as the bowl empties, the reduced mass allows parts to move more readily, and the same high amplitude can lead to excessive part speed, recirculation, or even damage. If the feeder is tuned for a full bowl, it may starve the downstream process as the bowl empties. If tuned for an empty bowl, it may jam or overfeed when the bowl is refilled. Abrupt changes in bowl fill level, such as during a refill operation, can exacerbate these issues, leading to temporary interruptions in part flow or persistent jamming.

3. System Overview

[0003] The disclosed system provides an adaptive control method for a vibratory feeder that adjusts the vibratory amplitude in response to the fill level of parts within the feeder bowl. This dynamic adjustment aims to maintain a more consistent part feed rate regardless of the bowl's fill status, mitigate jamming, and prevent starvation. The system comprises a vibratory feeder bowl (12), a vibratory drive unit (14), a part hopper (10) for bulk supply, a fill level sensor (16), a part outlet sensor (18), and a system controller (20). The fill level sensor (16) continuously or periodically measures the quantity of parts in the bowl (12). This data is transmitted to the system controller (20), which then adjusts the power supplied to the vibratory drive unit (14) to alter its amplitude. The controller (20) employs an amplitude schedule or algorithm that correlates desired amplitude with detected fill level. The system also incorporates jam detection logic, typically based on feedback from the part outlet sensor (18), which triggers specific amplitude adjustments to clear blockages. Furthermore, a controlled refill strategy is implemented to gradually introduce new parts from the part hopper (10) and manage amplitude changes, thereby avoiding sudden impacts on part flow stability. FIG. 1 illustrates the overall system architecture.

4. Components

[0004] The adaptive vibratory feeder system includes several key components:

[0005]

- **Vibratory Feeder Bowl (12)**: This is a conical or cylindrical container with internal helical tracks or tooling designed to sort, orient, and convey parts. It is typically mounted on springs or resilient mounts, allowing it to vibrate freely. The bowl (12) has an outlet from which oriented parts are discharged.
- **Vibratory Drive Unit (14)**: This unit generates the vibratory motion. It commonly consists of an electromagnet and an armature assembly, or a piezoelectric stack. When energized, it causes the bowl (12) to vibrate at a specific frequency and amplitude, propelling parts along the tracks. The drive unit (14) is connected to the system controller (20) which modulates its power input.
- **Part Hopper (10)**: This is a bulk storage container for parts, typically positioned above the vibratory feeder bowl (12). It releases parts into the bowl (12) either continuously or on command from the system controller (20), often via a gate or a secondary vibratory feeder.
- **Fill Level Sensor (16)**: This sensor measures the quantity or volume of parts present in the vibratory feeder bowl (12). Examples include optical sensors (e.g., proximity sensors, laser distance sensors), ultrasonic sensors, capacitive sensors, or load cells measuring the bowl's weight. The sensor (16) provides a signal to the system controller (20) indicative of the current fill level.
- **Part Outlet Sensor (18)**: Located at the exit of the vibratory feeder bowl (12), this sensor detects the passage of individual parts. It can be an optical sensor (e.g., through-beam or reflective), a magnetic sensor, or a mechanical switch. Its primary function is to monitor part flow and detect potential jams or starvation at the outlet.
- **System Controller (20)**: This is a programmable logic controller (PLC), microcontroller, or industrial PC that orchestrates the operation of the entire system. It receives inputs from the fill level sensor (16) and part outlet sensor (18), executes the amplitude control algorithm, manages refill operations, and outputs control signals to the vibratory drive unit (14) and the part hopper (10).

5. Operation

[0006] The operation of the adaptive vibratory feeder system proceeds through several phases: initialization, steady-state feeding, jam detection and recovery, and managed refilling.

[0007] **Initialization (Start-up)**: Upon system activation, the system controller (20) queries the fill level sensor (16) to determine the initial part volume in the vibratory feeder bowl (12). Based on this reading, the controller (20) sets an initial vibratory amplitude for the drive unit (14) according to a predefined start-up schedule. If the bowl (12) is empty, a refill sequence may be initiated immediately.

[0008] **Steady-State Feeding**: During normal operation, the fill level sensor (16) continuously monitors the part level within the bowl (12). The system controller (20) regularly compares the detected fill level to a set of thresholds. As the fill level decreases, indicating fewer parts in the bowl (12), the controller (20) gradually increases the vibratory amplitude of the drive unit (14) to compensate for the reduced part mass and maintain a consistent feed rate. Conversely, if the fill level increases (e.g., due to downstream blockage or a slow refill), the amplitude is gradually decreased. This adjustment is performed incrementally to avoid sudden changes in part behavior. The relationship between fill level and amplitude is defined by an amplitude schedule stored within the controller (20), as conceptually shown in FIG. 2.

[0009] **Jam Detection and Recovery**: The part outlet sensor (18) monitors the flow of parts exiting the bowl (12). If the sensor (18) indicates an absence of parts for a duration exceeding a set threshold, or if it detects an abnormal accumulation (e.g., multiple parts simultaneously triggering a single-part sensor), a potential jam is registered. Upon detecting a jam, the system controller (20) initiates a jam-clearing sequence. This typically involves momentarily increasing the vibratory amplitude beyond normal operating levels, followed by a brief reduction or even a reversal of vibration (if the drive unit (14) supports it) to dislodge the blockage. This sequence may be repeated several times. If the jam persists, the system may halt the feeder and signal for operator intervention.

[0010] **Managed Refilling**: When the fill level sensor (16) indicates that the part level has dropped below a predefined refill start level (34), the system controller (20) initiates a refill sequence. Before parts are introduced from the part hopper (10), the controller (20) may temporarily adjust the vibratory amplitude to a lower, stable level suitable for a partially full bowl, anticipating the influx of new mass. The part hopper (10) then releases a controlled quantity of parts into the bowl (12). This release can be in batches or a continuous, slow trickle. During the refill, the vibratory amplitude is continuously adjusted based on the rising fill level, preventing a sudden damping effect that could lead to jamming as the bowl (12) fills. The refill process stops when the fill level reaches a refill stop level (36), ensuring the bowl (12) is adequately replenished without overfilling. The amplitude then stabilizes according to the new, higher fill level.

6. Example Embodiments

[0011] **Embodiment 1** In this embodiment, the fill level sensor (16) comprises a series of optical proximity sensors mounted at different heights inside the vibratory feeder bowl (12). Each sensor detects the presence or absence of parts at its respective height. The system controller (20) interprets these signals to determine the approximate fill level (e.g., low, medium, high). The amplitude schedule is defined in discrete steps: a specific amplitude is assigned to each fill level band. For instance, if the fill level is detected as "low," the amplitude is set to 80% of maximum; if "medium," it is set to 60%; and if "high," it is set to 45%. The part outlet sensor (18) is a through-beam infrared sensor. Jam detection triggers a 1-second pulse at 95% amplitude, followed by a 0.5-second pause, repeated three times. Refilling is initiated when the lowest sensor is uncovered and stops when the highest sensor is covered.

During refill, the amplitude is held constant at 50% until all refill parts have settled, then resumes adaptive control.

[0012] **Embodiment 2** This embodiment utilizes a load cell integrated beneath the vibratory feeder bowl (12) to serve as the fill level sensor (16). The load cell provides a continuous analog signal proportional to the total weight of the bowl (12) and its contents. The system controller (20) converts this weight measurement into a precise fill level percentage. The amplitude schedule is a continuous function (e.g., a linear or piecewise linear relationship) that maps fill level percentage directly to vibratory drive voltage or current, allowing for fine-grained amplitude adjustments. For example, amplitude might be calculated as `A = A_max - (Fill_Percentage * (A_max - A_min)) / 100`. The part outlet sensor (18) is a magnetic sensor detecting ferrous parts. Jam detection uses a feedback loop: if the part outlet sensor (18) does not register a part within a calculated interval (based on target feed rate), the amplitude is increased by 5% increments for 2 seconds until a part is detected or a maximum amplitude limit is reached. The refill strategy employs a secondary vibratory feeder to trickle parts from the part hopper (10) into the main bowl (12) over a period of 10 to 20 seconds, while the main bowl's amplitude is dynamically adjusted based on the real-time weight increase.

[0013] **Embodiment 3** In this configuration, an ultrasonic sensor is mounted above the vibratory feeder bowl (12) to measure the distance to the part surface, thereby determining the fill level. This provides a non-contact measurement that is robust to part geometry. The system controller (20) implements a predictive control algorithm that not only adjusts amplitude based on current fill level but also considers the historical rate of change of the fill level and the downstream demand signal (if available). For jam detection, an acoustic sensor (e.g., a microphone) is mounted near the bowl outlet. A change in the characteristic acoustic signature, such as an increased rattling noise or a sudden dampening of sound, indicates a jam. The jam clearing sequence involves short bursts of varied frequencies and amplitudes to dislodge parts. The refill strategy is integrated with the upstream part supply system; the part hopper (10) features a variable-speed conveyor that gradually increases its output as the bowl (12) empties and then slows down as the bowl (12) approaches the refill stop level (36), ensuring a smooth transition in mass without a sudden dump of parts. The vibratory amplitude of the main feeder bowl (12) is then adjusted smoothly using a PID (Proportional-Integral-Derivative) controller to maintain a constant part flow rate at the outlet.

7. Alternative Configurations

[0014] The fill level sensor (16) could alternatively employ a vision system that analyzes the part distribution and volume within the bowl (12). The vibratory drive unit (14) could be a piezoelectric actuator, with amplitude controlled by varying the applied voltage or frequency. The part outlet sensor (18) could be integrated with a vision system to not only detect part presence but also verify part orientation, triggering corrective actions or re-feeding if parts are incorrectly oriented. The part hopper (10) might integrate a level sensor to signal for bulk material replenishment, creating a cascaded control system. Jam detection could also involve monitoring the current draw of the vibratory drive unit (14); a sudden increase or decrease in current draw, inconsistent with expected changes due to fill level, could indicate a jam or an empty track.

8. Parameter Variations

Parameter	Range	Effect of Increasing Value	Effect of Decreasing Value
Vibratory Amplitude	0.5 to 3.0 mm (peak-peak)	Higher part velocity, increased risk of part damage/jumping	Lower part velocity, increased risk of starving/clogging
Vibratory Frequency	50 to 150 Hz	Faster part progression, more vigorous sorting	Slower part progression, gentler handling
Fill Level Thresholds	10% to 90% of bowl volume	More frequent amplitude adjustments, tighter control	Less frequent adjustments, potentially wider flow variations
Jam Detection Timeout	0.5 to 5.0 seconds	Quicker response to jams, potential false positives	Slower response, longer flow interruptions
Refill Rate	10 to 100 parts/second	Faster bowl replenishment, higher potential for transient jams	Slower replenishment, longer periods of reduced capacity
Part Size	1 to 50 mm (characteristic)	Larger mass requires higher amplitude per part, more inertia	Smaller mass more susceptible to air currents, easier to move
Bowl Diameter	150 to 1000 mm	Larger part capacity, longer tracks, more parts in transit	Smaller capacity, shorter tracks, quicker response to changes

9. Additional Implementations

[0016] This adaptive vibratory feeding principle can be extended to various industrial applications beyond simple part sorting. For instance, it can be applied to vibratory conveyors that transport bulk materials, where the material flow rate needs to be maintained constant despite variations in bed depth or material density. The system can be integrated into automated assembly lines where multiple vibratory feeders supply different components; a master controller can then coordinate the amplitude adjustments and refill cycles across all feeders to ensure synchronized part delivery to a common assembly point. Furthermore, the principles of adaptive amplitude control based on fill level can be applied to vibratory sieves or screens, where the efficiency of separation is dependent on the material layer thickness. In such cases, the amplitude could be adjusted to maintain an optimal material layer to maximize screening effectiveness without blinding the mesh. The system can also be adapted for hazardous environments, such as those handling sensitive electronic components or explosive powders, where precise control over part motion and minimal mechanical stress are critical.

10. Figures

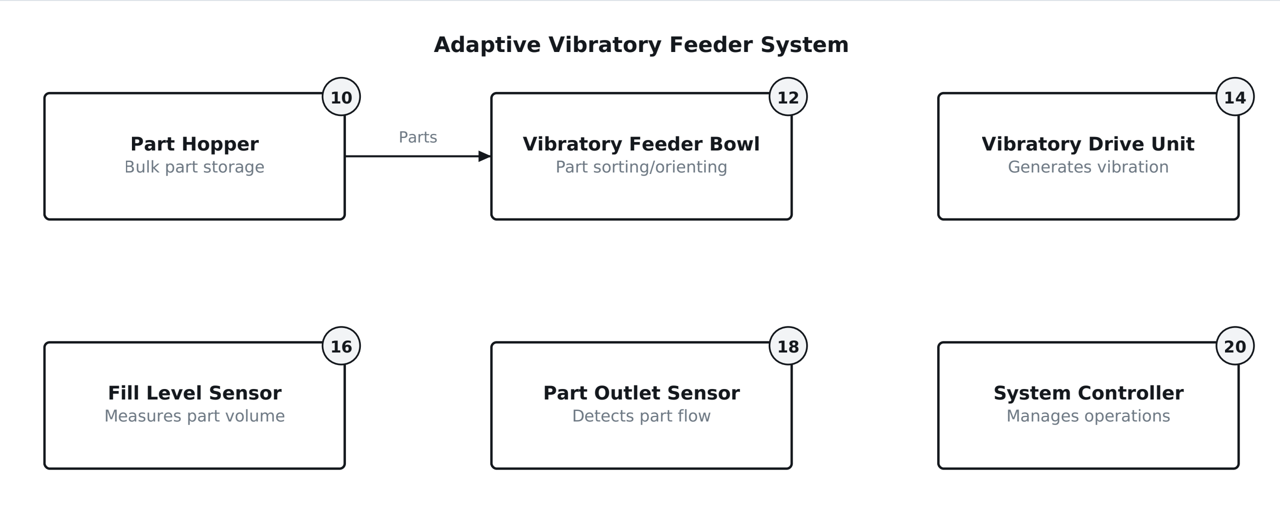

FIG. 1 A block diagram illustrating the main components and data flow within the adaptive vibratory feeder system. PNG

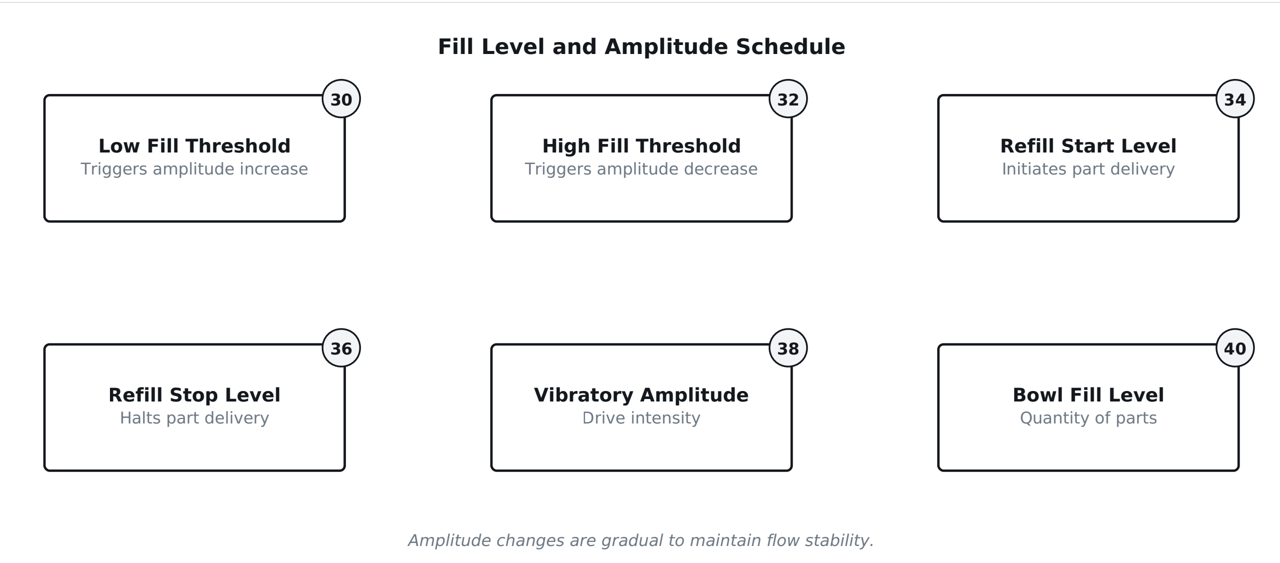

FIG. 2 A conceptual diagram showing the relationship between bowl fill level, vibratory amplitude, and refill trigger points. PNG

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