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Layer Transfer Head with Independent Clamp Retraction

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Abstract

This disclosure describes a layer transfer head designed to handle full layers of unstable packages, such as cartons or bags. The head incorporates independently retractable side clamps with compliant clamp faces and a layer height sensing mechanism. This configuration prevents layer collapse during transfer and release by ensuring even pressure application and a controlled, sequenced release of the outermost packages. The system addresses the common problem of load instability when rigid or unevenly releasing clamp heads are used, particularly with non-uniform or stacked products.

1. Technical Field

[0001] The technical field relates to automated material handling, specifically the transfer of full layers of articles, such as packaged goods, from one location to another. This includes applications in palletizing, depalletizing, and general load forming processes within manufacturing, logistics, and warehousing environments.

2. Technical Context

[0002] In automated material handling systems, articles are often assembled into a full layer (54) before being transferred onto a pallet (50) or another conveyance. When these articles (52), particularly cartons or bags, exhibit inherent instability due to their shape, material, or packaging method, the integrity of the entire layer (54) can be compromised during transfer. Traditional layer transfer heads employ rigid clamping mechanisms that apply pressure to the outermost perimeter of the layer (54). If these rigid clamps release unevenly, or if the clamping pressure is not distributed appropriately, the layer (54) can shift, lean, or even collapse, especially at the edges, leading to product damage, line stoppages, and safety concerns. A common failure mode involves the outermost articles (52) tipping or sliding outwards prematurely during the initial phase of clamp retraction.

3. System Overview

[0003] The disclosed system comprises a layer transfer head (10) designed to securely grip and transfer a full layer (54) of articles (52). The head (10) is typically suspended from a gantry (62) or robotic arm, allowing for vertical and horizontal movement. Key features include independently retractable side clamp assemblies (20) and compliant clamp faces (26) to adapt to variations in layer (54) dimensions and article (52) surface irregularities. A layer height sensor (34) determines the precise vertical position of the layer (54) prior to engagement. A control system (40) manages the coordinated actuation of the clamps (20) and the transfer sequence, ensuring a smooth pick-up, transfer, and release, particularly optimizing the

release order to maintain layer (54) stability. FIG. 1 provides a block diagram of the primary functional components.

4. Components

[0004] The layer transfer head (10) is constructed around a main frame (12), typically a robust welded or bolted structure, providing rigidity for supporting the article layer (54). The main frame (12) incorporates attachment points for vertical actuators (14) and horizontal actuators (16) that position the entire head (10).

[0005] Multiple side clamp assemblies (20) are mounted to the main frame (12). Each side clamp assembly (20) consists of an outer side clamp (22) and an inner side clamp (24). These clamps (22, 24) are configured to move independently along guide rails (66) via linear bearings (68) to engage the sides of the article layer (54). Each clamp (22, 24) is driven by a dedicated retraction actuator (60), which may be an electric motor (42) coupled with a gearbox (44) and a drive belt or chain (46), or a pneumatic or hydraulic cylinder.

[0006] Attached to the inner surface of each clamp (22, 24) is a clamp face (26). This clamp face (26) is not rigidly fixed but is connected via a compliance mechanism (28). The compliance mechanism (28) may consist of a series of springs (30) or pneumatic cylinders, allowing the clamp face (26) to deflect slightly (e.g., 5 to 15 mm) when it makes contact with the article layer (54). This deflection provides a degree of conformability to irregularities in the layer (54) profile. Dampers (32), such as hydraulic or friction dampers, may be integrated into the compliance mechanism (28) to control the rate of clamp face (26) movement during engagement and release.

[0007] A layer height sensor (34) is integrated into the head (10), typically mounted on the main frame (12) or an extension thereof. This sensor (34) can be a proximity sensor (36) (e.g., ultrasonic, laser, or inductive), an optical sensor (38) (e.g., through-beam or diffuse reflective), or a combination thereof. Its function is to detect the upper surface of the article layer (54) before the head (10) descends.

[0008] A control system (40), comprising a programmable logic controller (PLC) or industrial computer, orchestrates the entire operation. It receives input from the layer height sensor (34) and position sensors associated with the retraction actuators (60). It outputs control signals to the vertical actuator (14), horizontal actuator (16), and each retraction actuator (60) to manage clamping force, position, and sequence. Load cells (58) may be optionally integrated into the clamp structure to provide feedback on applied clamping force.

[0009] A base plate (64) may be integrated beneath the article layer (54) for support during initial layer formation and prior to pickup.

[0010] FIG. 2 illustrates a detailed view of a side clamp assembly (20) with its compliant clamp face (26).

5. Operation

[0011] The operation of the layer transfer head (10) involves several phases: approach, engagement, transfer, and release.

[0012] **Start-up and Initial State:** The layer transfer head (10) is typically in a retracted position, with all side clamp assemblies (20) fully open and elevated above the pickup or deposit zone. The control system (40) is initialized, and all actuators (14, 16, 60) are homed or set to a known starting position.

[0013] **Approach Phase:** The horizontal actuator (16) and vertical actuator (14) move the layer transfer head (10) to a position directly above the article layer (54) to be transferred. During this descent, the layer height sensor (34) continuously monitors the distance to the top surface of the article layer (54). Once the sensor (34) detects the layer (54) within a defined range (e.g., 50 to 100 mm), the vertical actuator (14) slows its descent.

[0014] **Engagement Phase:** Based on the layer height sensor (34) data, the control system (40) determines the precise clamping height. The head (10) continues to descend until the lower edge of the clamp faces (26) are positioned at a specified height relative to the layer (54), typically near its vertical midpoint or slightly below the top edge. Subsequently, the retraction actuators (60) for each side clamp assembly (20) are activated simultaneously to close the clamps (22, 24) onto the article layer (54). As the clamp faces (26) make contact, the compliance mechanism (28) allows for slight deflection, ensuring even pressure distribution across the irregular surface of the article layer (54). The clamping force is applied until a predetermined pressure or position is reached, as monitored by the retraction actuator (60) current draw or optional load cells (58).

[0015] **Transfer Phase:** Once the article layer (54) is securely clamped, the vertical actuator (14) lifts the layer transfer head (10) clear of any underlying support structure, such as a base plate (64) or conveyor (56). The horizontal actuator (16) then moves the head (10) to the designated deposit location, typically above an empty pallet (50) or another layer (54) on a pallet (50).

[0016] **Release Phase:** The vertical actuator (14) lowers the article layer (54) onto the pallet (50) or existing layer (54) until a predefined contact force is detected or a specific vertical position is reached. To prevent collapse of unstable cartons (52), the clamps (22, 24) are released in a carefully controlled sequence. The retraction actuators (60) for the outer side clamps (22) begin to retract first, slowly releasing pressure while maintaining contact or very close proximity. After a brief delay (e.g., 0.1 to 0.5 seconds) or a specified retraction distance (e.g., 5 to 10 mm), the inner side clamps (24) begin to retract. This sequenced retraction ensures that the outermost articles (52) remain supported by the outer clamps (22) for a slightly longer duration, allowing the internal stability of the layer (54) to be established on the underlying surface. Once all clamps (22, 24) are fully retracted and clear of the article layer (54), the vertical actuator (14) lifts the head (10), and the horizontal actuator (16) moves it back to its home or next pickup position.

[0017] **Fault or Interruption:** In the event of a fault (e.g., sensor (34) error, actuator (60) overcurrent, emergency stop), the control system (40) immediately halts all motion. If the layer (54) is clamped, it typically remains clamped in position. If a safe retraction is possible, the system may attempt a controlled clamp release followed by a full retraction to a safe position. If the layer (54) is being lowered, the vertical actuator (14) will lock its position. The system provides error feedback to an operator for intervention.

6. Example Embodiments

[0018] **Embodiment 1: Four-Sided Clamping with Independent Pairs** In this embodiment, the layer transfer head (10) includes four side clamp assemblies (20), one for each side of the rectangular article layer (54). Each side clamp assembly (20) consists of an outer side clamp (22) and an inner side clamp (24). All four outer side clamps (22) are actuated simultaneously to engage the layer (54), providing initial peripheral support. Subsequently, all four inner side clamps (24) are actuated to apply additional, more localized pressure. During release, the

outer side clamps (22) retract by 5 mm, then the inner side clamps (24) fully retract, followed by the complete retraction of the outer side clamps (22). This two-stage release maintains support for the outermost articles for a longer duration.

[0019] **Embodiment 2: Two-Sided Clamping with Adjustable Pitch** This embodiment is designed for layers (54) that have a consistent dimension in one axis but variable in the other, or for layers (54) where instability primarily occurs along two opposing sides. The head (10) features two opposing side clamp assemblies (20). Each assembly (20) has multiple segments of compliant clamp faces (26) mounted along its length, each segment actuated by a smaller, dedicated retraction actuator (60). This allows for a variable pitch clamping along the length of the layer (54). The layer height sensor (34) is an array of optical sensors (38) providing a height profile of the layer (54). The release sequence is initiated from the outer segments of the clamp faces (26) and progresses towards the center, ensuring the central, more stable part of the layer (54) is released last.

[0020] **Embodiment 3: Vacuum-Assisted Clamping for Irregular Articles** This configuration integrates a vacuum system into the compliant clamp faces (26) of the side clamp assemblies (20). The clamp faces (26) are perforated and connected to a vacuum pump via a manifold. After mechanical engagement of the outer (22) and inner (24) clamps with the compliant faces (26), a vacuum is applied to draw air from within the article layer (54), enhancing the grip, particularly for articles (52) with porous packaging or irregular shapes. The release sequence involves first releasing the vacuum, then the outer clamps (22), and finally the inner clamps (24), allowing for a gentle disengagement that minimizes disruption to the layer (54) integrity.

7. Alternative Configurations

[0021] The individual side clamp assemblies (20) can be configured with varying numbers of outer side clamps (22) and inner side clamps (24) along their length. For instance, a single long side clamp assembly (20) might incorporate three distinct inner side clamps (24) and two outer side clamps (22) that can operate as separate units, providing localized pressure where stability is most critical. The compliance mechanism (28) could be implemented using pneumatic bellows or hydraulic cylinders instead of mechanical springs (30), offering active control over the compliance force. This allows the control system (40) to adjust the "softness" of the clamp face (26) dynamically based on the detected layer (54) characteristics or article (52) fragility. The layer height sensor (34) could be a 3D vision system, providing a detailed topographical map of the article layer (54) surface. This data could then be used by the control system (40) to optimize the clamping pressure profile across the entire layer (54) to precisely match variations in article (52) height and distribution.

8. Parameter Variations

Parameter	Range	Effect of Moving to Lower End of Range	Effect of Moving to Higher End of Range
Clamp Face Compliance Range	5 to 15 mm	Less adaptation to layer irregularities; higher peak pressures.	Greater adaptation; more forgiving for uneven layers or articles.
Clamp Retraction Delay (Outer-Inner)	0.1 to 0.5 seconds	Faster release, potentially increasing instability risk.	Slower release, enhancing stability but increasing cycle time.
Clamping Force (per side)	100 to 500 N	Reduced grip, higher risk of layer slippage.	Increased grip, higher risk of article damage or deformation.

Parameter	Range	Effect of Moving to Lower End of Range	Effect of Moving to Higher End of Range
Layer Height Sensor Stand-off	20 to 100 mm	More precise height detection; higher risk of contact during descent.	Less precise height detection; lower risk of contact; longer search.
Number of Independent Clamp Segments	2 to 6 per side	Less localized control; broader pressure application.	More localized control; better adaptation to complex layer profiles.
Retraction Actuator Speed	50 to 200 mm/s	Slower clamp engagement/ release; increased cycle time.	Faster clamp engagement/release; reduced cycle time; potentially harsher release.

9. Additional Implementations

[0023] The layer transfer head (10) can be integrated with automated quality inspection systems. For example, before clamping, a vision system could scan the layer (54) to identify misaligned or damaged articles (52). The control system (40) could then adjust clamping parameters or initiate a rejection sequence for the entire layer (54). The system can be adapted for handling layers (54) of varying sizes by incorporating automatically adjustable main frame (12) dimensions. This involves additional actuators (16) that can expand or contract the overall width and length of the head (10) to accommodate different layer (54) footprints. For extremely fragile articles (52), a non-contact support mechanism, such as an air cushion system, could be integrated beneath the article layer (54) during the initial lift phase. This reduces the temporary bending stresses on the layer (54) while the clamps (22, 24) fully engage and the vertical actuator (14) begins its ascent. The air cushion would then be deactivated as the layer (54) becomes fully supported by the clamps (22, 24).

10. Figures

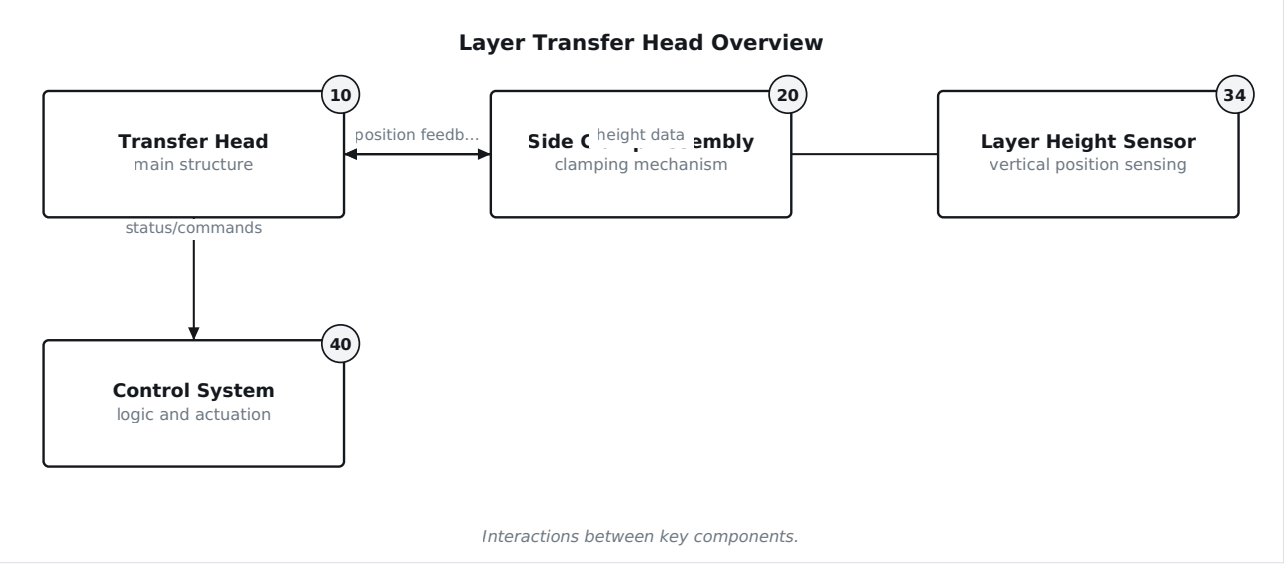

FIG. 1 This diagram illustrates the primary functional blocks of the layer transfer head. PNG

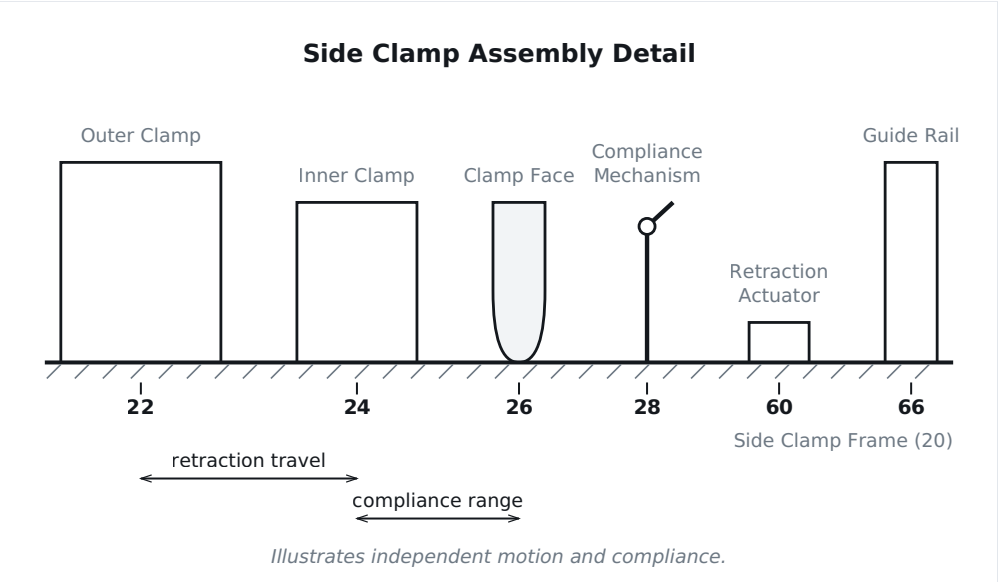

FIG. 2 This drawing shows a cross-section of the side clamp assembly with its compliant face. PNG

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