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# Carrier Pitch-Synchronized Induction for Cross Belt Sorters


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## Abstract

An arrangement for a cross belt sorter synchronizes article induction with carrier movement. This system utilizes a high-resolution encoder to precisely track carrier positions on a continuous loop. Induction timing is dynamically calculated based on the detected pitch of carriers, ensuring articles are released only when a carrier is correctly aligned within an induction window. This mitigates issues of articles falling between carriers or spanning multiple carriers, thereby improving sortation accuracy and throughput. The system also includes mechanisms for detecting and reporting carriers that remain loaded after their designated discharge point, preventing recirculation of misdirected items.


## 1. Technical Field

[0001] The present disclosure relates to material handling systems, and more particularly to sortation systems employing cross belt carriers, with a focus on synchronized article induction.

## 2. Technical Context

[0002] Automated sortation systems are widely used in logistics, e-commerce, and postal operations to direct articles to specific destinations. Cross belt sorters are a common type of such system, comprising a continuous loop of interconnected carriers (12), each equipped with a conveyor belt. Articles (14) are introduced onto these carriers (12) at induction points and subsequently discharged at designated divert locations. A critical aspect of efficient sortation is the precise placement of articles (14) onto the carriers (12). If an article (14) is inducted too early or too late, it may fall into the gap between two adjacent carriers (12) or span across parts of two carriers (12). Both scenarios can lead to article damage, system jams, or mis-sorts, reducing throughput and increasing operational costs. The challenge is to ensure that each article (14) is deposited entirely within the boundaries of a single carrier (12), irrespective of minor variations in carrier pitch or system speed.

## 3. System Overview

[0003] The disclosed system provides a method and apparatus for synchronizing the release of articles (14) from an induction conveyor (16) onto a cross belt sorter carrier (12). A high-resolution track encoder (20) monitors the absolute or relative position of the sorter's drive mechanism, from which the precise location of each carrier (12) can be determined. A carrier position processor (22) processes these encoder signals to calculate the real-time position and velocity of each carrier (12) along the sorter loop. An induction controller (24) uses this carrier position information to define a dynamic induction window for each carrier (12) as it approaches an induction point. An article (14) awaiting induction on an induction conveyor (16) is held until the induction controller (24) determines that a suitable carrier (12) is correctly positioned within its window. Upon proper alignment, the induction controller (24) activates the induction conveyor drive (26) to release the article (14) onto the carrier (12). The system also incorporates logic to manage missed inductions and to detect carriers (12) that remain loaded beyond their discharge points.

## 4. Components

[0004] The system comprises several interconnected components, as depicted in FIG. 1 and FIG. 2. A **drive rail** (10) or similar track structure guides a continuous loop of **carriers** (12). Each carrier (12) typically consists of a frame and an integrated cross belt mechanism (not shown) for transporting and discharging an article (14). An **article** (14) is the item to be sorted, such as a parcel or a tote. An **induction conveyor** (16) is positioned perpendicular or at an angle to the sorter track. This conveyor (16) temporarily holds articles (14) before releasing them onto the carriers (12). It typically includes an **induction conveyor drive** (26), such as an electric motor and gearing, to propel articles (14) forward. A **track encoder** (20) is coupled to the sorter's drive mechanism, such as a drive shaft or the main chain. This encoder (20) generates electrical pulses or absolute position data corresponding to the movement of the sorter. It can be an incremental encoder providing pulses per unit distance or an absolute encoder providing direct position readings. A **carrier position processor** (22) receives signals from the track encoder (20). This processor (22) is typically a programmable logic controller (PLC) or an industrial PC. It calculates the current position of each individual carrier (12) on the sorter loop by tracking the number of encoder pulses since a known reference point, or by directly reading absolute positions. It also tracks carrier speed and acceleration. An **induction controller** (24) receives carrier position and speed data from the carrier position processor (22). This controller (24) computes the optimal moment to release an article (14) from the induction conveyor (16). It also manages the state of the induction process, including queuing articles (14) and handling exceptions. An **article sensor** (28), such as a photoelectric sensor or proximity switch, is located on the induction conveyor (16) to detect the presence of an article (14) ready for induction. Additional sensors (not shown) may be placed downstream of the induction point to confirm successful induction or detect articles (14) falling between carriers (12). Each carrier (12) may include an **on-board sensor** (30), such as a load cell or a photoelectric sensor, to detect if an article (14) is present on its belt. This sensor (30) communicates its status to a central control system, often wirelessly or via inductive data transfer.

## 5. Operation

[0005] The operation begins with the sorter system running at a nominal speed.## Technical Field The present disclosure relates to material handling systems, and more particularly to sortation systems employing cross belt carriers, with a focus on synchronized article induction.

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(30), such as a load cell or a photoelectric sensor, to detect if an article (14) is present on its belt. This sensor (30) communicates its status to a central control system, often wirelessly or via inductive data transfer.

## 9. Operation

[0009] The operation begins with the sorter system running at a nominal speed.

[0010] **Start-up Sequence:**

[0011]

- Upon system activation, the carrier position processor (22) initializes its internal carrier map. If an absolute track encoder (20) is used, individual carrier (12) identities and positions are known immediately. For incremental encoders (20), the system may perform a homing sequence or rely on a known start-up state where the position of a specific reference carrier (12) is established.
- The track encoder (20) begins transmitting position signals to the carrier position processor (22).
- The induction controller (24) enters a ready state, awaiting an article (14) at the induction point.

[0012] **Steady Running:**

[0013]

- An article (14) is introduced onto the induction conveyor (16) and is detected by the article sensor (28). The induction conveyor drive (26) temporarily stops or slows, holding the article (14) at a release point.
- The carrier position processor (22) continuously tracks the position of all carriers (12). It calculates the precise center and leading/trailing edges of each carrier (12) as it approaches the induction point, using the known carrier pitch (P) and carrier length.
- The induction controller (24) determines an optimal induction window for the next available carrier (12). This window is a specific range of positions where the article (14) can be released to land entirely on the carrier (12). The window calculation accounts for the sorter speed, the induction conveyor (16) speed, the article (14) length, and the required clear space on the carrier (12). For example, the release command might be issued when the leading edge of the carrier (12) is a calculated distance upstream of the induction conveyor (16) discharge point, to allow the article (14) to clear the induction conveyor (16) and settle on the carrier (12) as it passes underneath.
- When the leading edge of the designated carrier (12) enters the calculated induction window, the induction controller (24) sends a release command to the induction conveyor drive (26).
- The induction conveyor drive (26) accelerates the article (14) off the induction conveyor (16) at a controlled velocity, matching or exceeding the sorter speed in the direction of transfer, ensuring it lands smoothly onto the carrier (12).
- The carrier position processor (22) continually updates its carrier map, potentially including the load status of each carrier (12) based on induction events.

[0014] **Fault or Interruption:**

[0015]

- **Missed Induction:** If an article (14) is present at the induction point but no carrier (12) is available (e.g., due to system blockage or a previous carrier (12) being marked as unavailable), or if the induction window is missed due to timing anomalies, the article (14) remains on the induction conveyor (16). The induction controller (24) can then:
- Attempt induction onto the next available carrier (12) if sufficient time and space permit.
- Divert the article (14) to a reject spur or recirculate it back to the beginning of the induction line.
- Signal an alarm to an operator.
- **Carrier Overload/No-Load Detection:** After a carrier (12) passes its designated discharge location, the system expects it to be empty. An on-board sensor (30) on the carrier (12) detects if an article (14) is still present. This status is communicated to the central control system. If an article (14) is detected on a carrier (12) past its discharge point, it indicates a mis-sort or a failed discharge. The system can then:
- Flag the carrier (12) as "loaded past discharge."
- Attempt to discharge the article (14) at a downstream reject or recirculation chute.
- Trigger an alarm.
- Log the event for analysis.
- Prevent further inductions onto that specific carrier (12) until it is confirmed empty.
- **Encoder Fault:** If the track encoder (20) fails or provides erroneous data, the carrier position processor (22) will detect an anomaly (e.g., unexpected speed change, loss of signal). The system will typically:
- Stop all induction operations immediately.
- Initiate a controlled system shutdown or slow-down.
- Trigger an alarm.

## 10. Example Embodiments

[0016] **Embodiment 1** In this embodiment, the track encoder (20) is an incremental rotary encoder directly coupled to the main drive shaft of the sorter. The carrier position processor (22) uses a fixed pulse count per carrier pitch (P) to determine carrier positions. During initial setup or recalibration, a known carrier (12) with a unique identifier passes a fixed reference sensor, establishing a baseline for the pulse count. The induction controller (24) then calculates the target release point by adding a dynamic offset to the expected carrier center position, with the offset varying based on measured sorter speed and article (14) length. The induction window is defined as a specific number of encoder pulses before and after this target release point.

[0017] **Embodiment 2** This embodiment employs an absolute linear encoder (20) mounted along the drive rail (10) or main chain. Each carrier (12) has a unique identifier readable by the system (e.g., RFID tag or barcode). The carrier position processor (22) correlates the absolute position from the encoder (20) with the detected carrier ID to precisely know the location of each carrier (12). This eliminates the need for homing sequences and provides robust position data even after power interruptions. The induction controller (24) uses this precise absolute position to open the induction window when the carrier (12) is within a calculated spatial interval relative to the induction conveyor (16) discharge point, rather than relying solely on pulse counts or time delays.

[0018] **Embodiment 3** This embodiment integrates machine vision with the induction process. A camera system (not shown) is positioned above the induction point, continuously imaging the area where articles (14) transfer from the induction conveyor (16) to the carrier (12). The image processing unit identifies the precise leading and trailing edges of the approaching carrier (12) and the article (14) on the induction conveyor (16). The induction controller (24) then uses this real-time visual feedback, in conjunction with encoder data, to dynamically adjust the exact moment of article (14) release. This allows for compensation of minor mechanical misalignments or variations in article (14) placement on the induction conveyor (16), potentially narrowing the effective induction window for increased throughput.

## 11. Alternative Configurations

[0019] The track encoder (20) could be implemented as a series of magnetic sensors positioned along the sorter track, with magnets mounted on each carrier (12) or on the drive chain. The carrier position processor (22) would then calculate position based on the timing of sensor activations. The induction conveyor (16) might utilize a diverter arm or pusher mechanism instead of a belt conveyor for article (14) transfer, with the timing of the arm actuation synchronized by the induction controller (24). The communication from the on-board sensor (30) on the carrier (12) could be achieved through a continuous inductive loop along the track that powers the sensor (30) and transmits data, or via short-range radio frequency transmitters on each carrier (12) communicating with receivers positioned at strategic points. The article sensor (28) on the induction conveyor (16) could be replaced or augmented by a 3D scanner to measure article (14) dimensions, allowing the induction controller (24) to optimize placement based on article (14) length and width.

## 12. Parameter Variations

| Parameter | Realistic Range | Effect of Increasing Value | Effect of Decreasing Value |
|---|---|---|---|
| **Carrier Pitch (P)** | 400 to 1200 mm | More space per article, lower carriers per meter. | Denser packing, higher carriers per meter, smaller articles. |
| **Sorter Speed** | 0.5 to 3.0 m/s | Higher throughput potential, shorter induction windows. | Lower throughput, longer induction windows, easier timing. |
| **Track Encoder Resolution** | 1000 to 10000 pulses/revolution | More precise position tracking, tighter induction control. | Less precise tracking, wider induction windows needed. |
| **Induction Conveyor Speed** | 0.8 to 4.0 m/s | Faster article release, shorter transfer time. | Slower article release, longer transfer time, potential for article roll-back. |
| **Induction Window Size** | 10 to 80 mm (along track) | More tolerance for timing errors, less precise placement. | Less tolerance for errors, more precise placement, higher risk of mis-induction. |
| **Article Length** | 50 to 1000 mm | Requires larger clear space on carrier, affects induction timing. | Smaller clear space needed, simpler placement. |

## 13. Additional Implementations

[0021] The disclosed system can be extended to include multiple induction points along the same sorter loop, each operating with its own induction controller (24) but all synchronized to the global carrier position data from the carrier position processor (22). This allows for distributed induction capabilities. Furthermore, the system can integrate with upstream article identification systems (e.g., barcode scanners, OCR readers) to assign each inducted article (14) to a specific carrier (12) and track its journey through the sorter. The carrier position processor (22) can maintain a manifest for each carrier (12), associating it with the article (14) it is transporting. For systems handling a wide range of article (14) sizes, the induction controller (24) can dynamically adjust the induction window and release profile based on real-time article (14) dimension data, ensuring optimal placement for very small or very large items. This might involve adjusting the acceleration profile of the induction conveyor (16) or the angle of article (14) release. The carrier position processor (22) can also monitor the health of individual carriers (12). For example, if a specific carrier (12) consistently fails to report as empty after discharge, or if its on-board sensor (30) reports a fault, the system can automatically mark that carrier (12) as unavailable for induction until it is inspected or repaired, routing articles (14) to subsequent carriers (12).

## 14. Figures

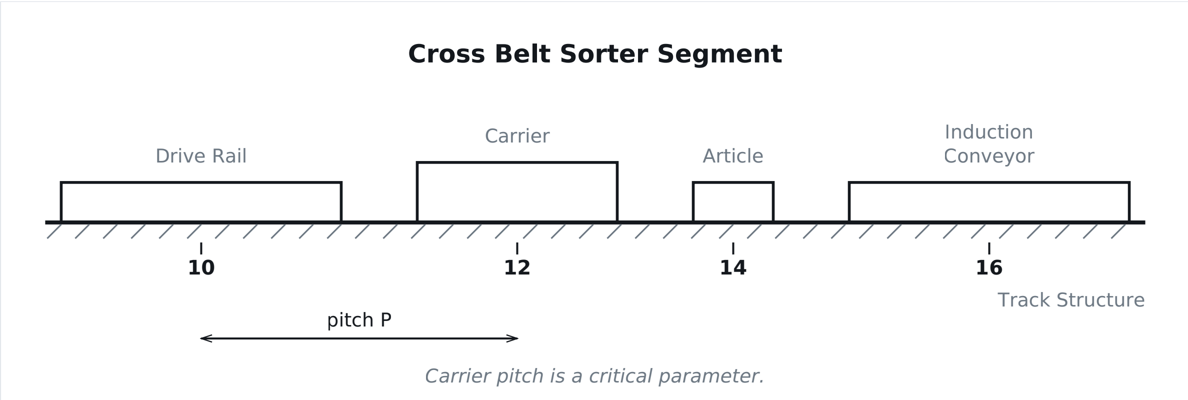


**FIG. 1** An elevation view of a section of a cross belt sorter showing carriers and induction. PNG

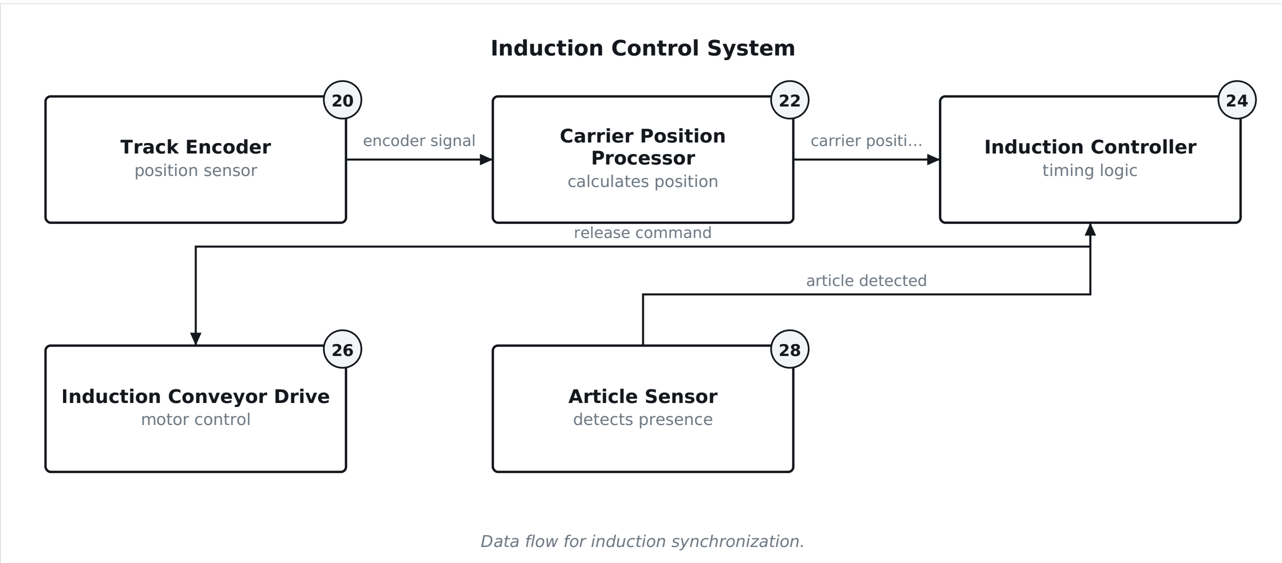


**FIG. 2** A block diagram illustrating the components of the induction control system. PNG

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