



Design and Development of a Smart Self Balancing Conveyor System for Uneven Load Transportation Using IOT

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How to Cite this Article:

Dukare, I., Ambadare, S., Dhumare, P., Sonkusare, S. & Chaudhari, P. (2026). Design and Development of a Smart Self Balancing Conveyor System for Uneven Load Transportation Using IOT. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(9), 1-9.

<https://doi.org/10.55041/ijcope.v2i9.216>

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<https://doi.org/10.55041/ijcope.v2i9.216>

angling a fixed-trough conveyor.

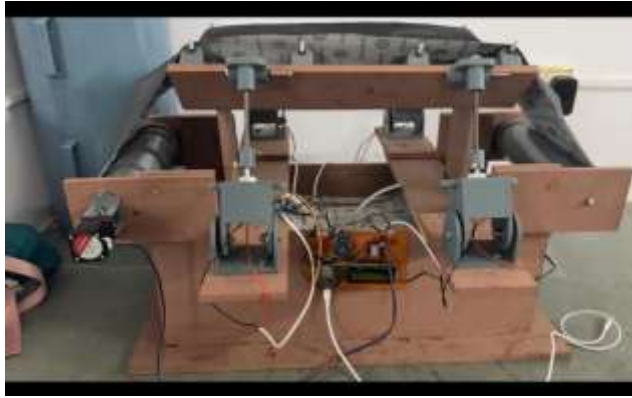
Keywords—*troughed belt conveyor; variable V-angle; scissor-screw jack; closed-loop control; auto-calibration; stepper motor; current sensing; load-adaptive control.*

1. INTRODUCTION

Belt conveyors remain the backbone of bulk-material transport in mining, agriculture, cement, and packaging industries because of their continuous handling capability and low per-tonne operating cost. Among available configurations, the troughed belt conveyor — where the belt is supported on idler rollers angled to form a V or U cross-section — is preferred for loose, granular, or lumpy materials, since the trough profile prevents spillage and increases the effective cross-sectional carrying area compared with a flat belt.

The optimum trough angle is not universal: it depends on the angle of repose of the material being handled, its lump size, moisture content, and belt speed, and in practice it also depends on how heavily the belt is loaded at a given moment. Most industrial conveyors are built with a fixed trough angle chosen at design time, which forces a trade-off whenever the plant needs to handle more than one type of material or a variable load. Manually re-angling the idler frames is time-consuming, requires the conveyor to be stopped and locked out, and is prone to inconsistent setting from one adjustment to the next. This work treats the trough angle — and, jointly, the belt speed — as motor-controlled, self-calibrating parameters rather than fixed mechanical settings, so that the conveyor itself keeps material contained under heavy load and runs efficiently under light load without operator intervention.

Abstract—Troughed belt conveyors are the standard means of bulk-material transport, and their carrying capacity and spillage resistance depend directly on the trough angle formed by the side idler rollers. Conventional conveyors are built with a fixed trough angle chosen at design time, forcing a compromise whenever a plant handles more than one material or whenever the load on the belt varies over time. This paper presents an auto-calibrating, variable V-angle troughed belt conveyor in which the trough angle of the wing idler rollers is varied on demand by a scissor-screw jack driven by a NEMA17 stepper motor and lead screw. A closed-loop control scheme combines two feedback paths: a rotary-encoder/limit-switch position loop that lets the controller reach and hold a commanded angle accurately regardless of backlash or missed steps, and an ACS712 current-sensing load loop that infers the instantaneous belt load and selects an appropriate angle and belt-speed target automatically. The system self-calibrates its zero and end-stop references at start-up, exposes a 5-button HMI with manual and automatic modes, and halts on an over-current or over-travel fault. The design is intended to reduce spillage under heavy load, improve throughput and reduce mechanical wear under light load, and remove the operator judgement and downtime associated with manually re-



II. LITERATURE SURVEY / EXISTING SYSTEMS

Conventional troughed conveyors use idler sets fixed at standard angles (typically 20°, 35°, or 45°) selected during plant design [2]. Some heavy-industry installations use hydraulically adjustable troughing frames, but these are costly, require a hydraulic power pack, and are generally justified only at large belt widths. Reported laboratory and academic prototypes have explored stepper- or screw-driven trough adjustment, but most rely on open-loop positioning — a fixed number of motor steps assumed to correspond to a given angle — which drifts over time due to mechanical backlash, belt-tension changes, and missed steps.

Closed-loop position feedback combined with an automatic start-up calibration routine, and a load-adaptive control layer that lets the system choose its own angle and speed targets from motor-current data rather than from a fixed operator setting, has not been widely implemented at the small-to-medium conveyor scale that this work targets. This gap between low-cost open-loop prototypes and costly hydraulic industrial units motivates the design presented here.

III. PROBLEM STATEMENT

Existing fixed-angle troughed belt conveyors cannot be reconfigured for different bulk materials or varying load conditions without manual mechanical intervention, leading to reduced flexibility, inconsistent trough geometry after re-adjustment, avoidable spillage under heavy load, unnecessary mechanical wear under light load, and downtime. There is a need for a conveyor system that can automatically and repeatably set its trough angle, verify that the commanded angle has actually been achieved, adapt the angle and belt speed to the load being carried, and detect abnormal loading conditions during operation — without depending on manual calibration or continuous operator judgement.

IV. OBJECTIVES

- Design a scissor-jack mechanism, driven by a lead screw and NEMA17 stepper motor, that varies the V-angle of the troughing idler rollers.
- Implement closed-loop angle control using rotary-encoder / limit-switch feedback so the commanded angle matches the actual mechanical position.

- Implement an automatic start-up self-calibration routine that establishes the zero and end-stop reference positions without manual intervention.
- Derive a load index from ACS712 drive-motor current sensing and use it to select target trough angle and belt speed automatically in AUTO mode, while also using the same signal for jam, stall, and over-travel detection.
- Provide a 5-button HMI for start/stop, mode selection, manual angle trim, and emergency stop, with live status on a display module.
- Validate the system's positioning accuracy and repeatability across repeated angle-change cycles.

V. PROPOSED SYSTEM DESIGN

A. System Architecture

The system is organised into three functional layers: sensing (rotary-encoder/limit-switch position feedback and ACS712 load current), decision (microcontroller calibration and control logic), and actuation (the V-angle scissor-screw mechanism and the belt-drive motor). Fig. 1 summarises the signal and power flow between the HMI, controller, sensing, and actuation blocks.

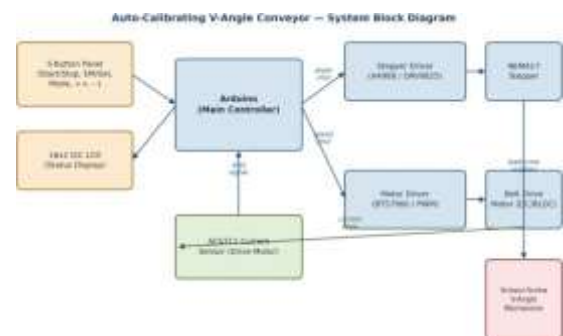


Fig. 1. System block diagram — signal and power flow between the HMI, controller, sensing, and actuation subsystems.

B. Mechanical Design — Scissor-Screw V-Angle Mechanism

The wing rollers that form the belt's trough are hinge-mounted at the edges of the centre idler frame, as in a standard troughed idler set. Instead of a fixed bracket angle, each wing roller is linked through a scissor (X-arm) linkage to a common lead-screw nut, the same working principle as an automotive scissor jack. A NEMA17 stepper motor turns a threaded lead screw at the base of the scissor assembly; as the nut travels up the screw, the scissor arms open and push the wing rollers upward and outward, increasing the V-angle, while reversing the stepper retracts the nut and lowers the angle. A single lead screw keeps both wing rollers mechanically synchronised, avoiding left/right angle mismatch and the cost of two independent actuators. Driving the mechanism with a lead screw, rather than a direct rotary actuator on the idler pivot, gives mechanical advantage, allows the jack to hold position without continuous motor



torque, and keeps the actuation hardware below the belt line, out of the material path.

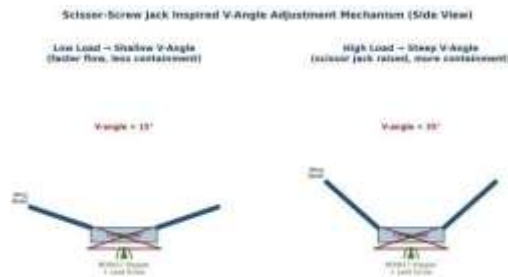


Fig. 2. Scissor-screw jack mechanism at a shallow angle under light load (left, $\approx 15^\circ$) and a steep angle under heavy load (right, $\approx 35^\circ$).

- Self-locking: the lead-screw thread pitch is chosen so the mechanism holds its angle under belt vibration without motor holding torque, reducing power draw and heat.
- Bounded travel: mechanical end-stops / limit switches define the nominal 15° – 45° physical range; firmware also enforces this range in software.
- Low interference: the actuation hardware sits below the belt line, keeping it clear of the material path.

C. Electrical / Electronic Subsystem

Table I lists the principal electronic building blocks. The controller reads position feedback and load current, and drives the angle actuator and belt-speed control accordingly.

Function	Component	Notes
Controller	ESP32 / STM32 (Arduino-class)	Calibration routine, closed-loop control, HMI handling
Angle actuator	NEMA17 stepper + lead screw	Drives the scissor-jack mechanism
Stepper driver	A4988 / DRV8825	Microstepping for smooth, precise angle steps
Position feedback	Rotary encoder / limit switches	Authoritative angle reference and calibration
Belt drive motor	12/24 V DC gear motor or BLDC	Sized to conveyor load capacity
Speed control	BTS7960 / L298N (PWM)	PWM speed control of the belt-drive motor
Load sensing	ACS712 current sensor	Drive-motor current as a load proxy; jam/stall detection
HMI input	5× tactile push buttons	Start/Stop, EM/Set, Mode, Angle ++, Angle —
Display	OLED / 16×2 I2C LCD	Mode, angle, load %, belt speed, fault status
Power	SMPS 12/24 V + 5 V regulator	Isolated logic and motor supplies recommended

Using the drive motor's current draw as the load signal is a deliberate simplification: it avoids mounting load cells under the belt structure, needs only one low-cost sensor, and correlates with the torque the motor must deliver, which rises with both material weight and — if the angle is too shallow — with material spillage and friction. It is a proxy rather than a direct weight measurement, and its calibration against known no-load and rated-load currents is treated as a design item to be validated on the bench before AUTO mode is enabled.

D. Start-Up Auto-Calibration

On power-up, the controller runs a self-calibration sequence before accepting angle commands. The scissor jack is driven toward its mechanical limit switches at reduced speed to establish the true zero (minimum trough angle) and maximum-angle reference points, and the corresponding encoder counts are stored as the working range for that session. Because the encoder / limit-switch reading is the authoritative position reference and the stored step count is only a coarse estimate refreshed at every calibration, this removes accumulated positioning error from backlash, missed steps, or thermal expansion of the lead screw over long-term operation.

E. Load-Adaptive Angle and Speed Control (AUTO Mode)

In AUTO mode, the controller samples drive-motor current through the ACS712 on every control cycle (e.g., every 500 ms), applies a moving-average filter to remove PWM switching noise, and maps the filtered current into a Load Index between 0% and 100%, bounded by the motor's known no-load and rated-load current values. The Load Index is looked up in a target table (Table II) to obtain a target V-angle and a target belt speed. The controller then commands the closed-loop position stage described in Section V-D to approach that target angle, and ramps the belt-speed PWM toward the target speed.

Load index	V-angle target	Belt speed target
0–30% (light)	15° – 22° (shallow)	100% of rated speed
30–65% (moderate)	22° – 32°	80–95% of rated speed
65–85% (heavy)	32° – 40°	60–80% of rated speed
85–100% (overload)	40° – 45° (max)	40–60% of rated speed + warning

Angle and speed targets are approached gradually — one microstep and one PWM increment per control cycle rather than an instant jump — so the belt never lurches and the scissor linkage is never slewed faster than it can safely move. A small hysteresis band around each Load Index threshold prevents the mechanism from hunting back and forth when the load hovers near a boundary. The simplified control loop is summarised below.

```

loop every 500 ms (AUTO mode, not e-stopped):
    i_raw    = read(ACS712)
    i_filt   = movingAverage(i_raw)
    loadIndex = clamp(map(i_filt, I_NO_LOAD,

```



```
I_RATED, 0, 100), 0, 100)
  targetAngle = lookupAngle(loadIndex) // Table
II
  targetSpeed = lookupSpeed(loadIndex) // Table
II
  if |targetAngle - encoderAngle| >
HYSTERESIS_DEG:
    stepAngleToward(targetAngle,
maxStepsPerCycle) // closed-loop, Sec. V-D
    rampSpeedToward(targetSpeed,
maxPwmStepPerCycle)
    updateDisplay(loadIndex, encoderAngle,
speedPct, mode)
```

During any commanded motion, the ACS712 reading is also monitored independently for a current spike beyond a configured threshold; this is interpreted as a jam or mechanical obstruction, halts the motor immediately, and forces the controller to re-run the calibration routine of Section V-D before resuming.

F. Human-Machine Interface

The operator panel is intentionally limited to five tactile buttons — Start/Stop, EM/Set, Mode (Auto/Manual), Angle ++, and Angle — — to keep the shop-floor interface simple. In MANUAL mode the operator sets the trough angle directly and the belt runs at a fixed default speed; in AUTO mode the controller sets both angle and speed from the Load Index, and the ++ / — buttons are disabled (or optionally used as a small trim offset on the auto-calculated angle) so that manual and automatic control never conflict. An OLED or 16×2 I2C LCD continuously shows the operating mode, current angle, load percentage, and belt speed.

G. Emergency Stop and Safety

A long press on the EM/Set button, or an over-current fault detected during motion, triggers an Emergency Stop: belt-drive PWM is cut to zero immediately (a hardware relay cut is recommended in addition to PWM=0 for a true fail-safe), the stepper holds its current angle without further motion, and the display shows the fault reason where known. The system requires an explicit Start press to resume — it never restarts automatically — and re-runs calibration before returning to normal operation.

VI. VALIDATION PLAN AND EXPECTED OUTCOME

The prototype is intended to demonstrate: (i) repeatable start-up self-calibration that converges to consistent zero and end-stop references across power cycles; (ii) closed-loop angle positioning within an acceptable tolerance of the commanded value, verified against the encoder rather than the assumed step count; (iii) a current-sensing calibration curve (no-load and rated-load current) validated on the bench before AUTO mode is enabled; and (iv) correct AUTO-mode behaviour in which the trough angle and belt speed track the Load Index table of Section V-E across light, moderate, heavy, and overload conditions, with graceful, non-jerky transitions between bands. Jam detection and Emergency-Stop recovery are to be validated by deliberately obstructing

the scissor mechanism and confirming an immediate, safe halt followed by a full re-calibration before resumption.

VII. APPLICATIONS

- Material handling in mining, cement, and aggregate-processing plants handling varied bulk materials.
- Agricultural produce and grain-handling conveyors that need different trough profiles for different crops.
- Packaging and warehousing lines that switch between product types with different flow characteristics.
- Laboratory-scale bulk-material handling test rigs for research and academic demonstration.

VIII. CONCLUSION AND FUTURE SCOPE

This paper has presented a practical, closed-loop approach to variable-trough-angle belt conveying that combines a scissor-screw jack actuator with sensor-based auto-calibration, encoder-verified position control, and current-based load-adaptive angle/speed selection. By replacing manual mechanical adjustment with a self-referencing, microcontroller-driven system, the design aims to improve setup consistency, reduce spillage and downtime, and extend the range of materials and load conditions a single conveyor installation can handle efficiently. Future work includes finalising the scissor-linkage geometry and the corresponding angle-versus-steps calibration table against the physical wing-roller geometry, bench-validating the current-sensing calibration curve, evaluating a load-cell fallback where the current-load relationship proves too noisy in practice, and extending the prototype from a single conveyor section to a multi-section pilot line.

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