International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 05 May 2026
Page No: 3025-3029
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0382

Safety Enhancement of Screw Conveyor Using Lid-Activated Automation Mechanism

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Abstract
Screw conveyors are extensively used in industries for material handling, but they pose serious safety risks when operated with open lids or during maintenance, as accidental contact with the rotating screw can cause severe injuries. This paper focuses on the safety enhancement of a screw conveyor using a lid-activated automation mechanism to eliminate such hazards. The proposed system employs a limit switch or proximity sensor mounted on the conveyor lid, which continuously monitors its position and automatically cuts off power to the motor when the lid is opened. This interlocking mechanism ensures that the conveyor operates only when the lid is securely closed, thereby preventing human error and accidental access to moving parts. The system is simple, cost-effective, and easy to retrofit into existing conveyor setups without affecting productivity. Overall, the implementation significantly improves operator safety, reduces accident risks, and supports compliance with industrial safety standards.

Keywords: *Screw conveyor, Safety enhancement, Lid-activated automation, Limit switch, Interlocking mechanism.*

1. Introduction
Industrial automation and mechanized material handling systems have significantly improved productivity and operational efficiency in manufacturing and processing industries. Among these systems, screw conveyors are widely used for the transportation of bulk materials due to their simple construction, compact design, and continuous operating capability. However, despite their advantages, screw conveyors pose serious safety hazards to human workers, particularly during operation, cleaning, inspection, or maintenance activities. One of the most critical and frequently reported accidents involves the entrapment of a human hand or limb in the rotating screw mechanism, often resulting in severe injuries, amputations, or even fatalities. In many small- and medium-scale industries, safety measures around screw conveyors are either inadequate or improperly implemented. Workers often interact closely with these machines due to manual feeding, blockage removal, or routine maintenance, increasing the risk of accidental contact with moving parts. Factors such as the absence of proper guarding, lack of interlock systems, insufficient warning mechanisms, and limited safety awareness further contribute to the occurrence of such accidents. The present paper focuses on the design and development of a safety system aimed at preventing human hand entrapment in screw conveyors. The core objective of the paper is to detect unsafe human interaction near the conveyor and immediately stop or restrict the operation of the screw mechanism before an injury occurs. By integrating suitable sensing elements, control logic, and mechanical or electromechanical safety features, the proposed system intends to minimize the risk of accidents without significantly affecting productivity. This paper aligns with the growing emphasis on occupational health and safety, as well as the principles of safe machine design.

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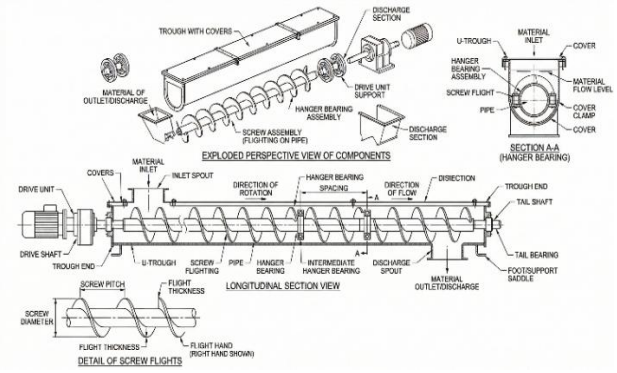

Figure 1 Screw Conveyor Nomenclature

2. Literature Review

Screw conveyors [6] are extensively used in industries such as agriculture, cement, food processing, pharmaceuticals, chemical processing, and mining for the transportation of bulk materials. Their compact structure [13], enclosed design, and ability to handle a wide range of materials make them an essential component of industrial material handling systems. However, the rotating helical screw presents a severe mechanical hazard [7][8], particularly to workers operating near feed openings or performing cleaning and maintenance tasks.

According to OSHA [1], [4], [5] safety analyses, a significant proportion of conveyor-related injuries occur when workers attempt to clear blockages, manually feed material [11] [12], or service the equipment while it is in operation. Mechanical guarding has been widely reported in the literature as the first line of defense against screw conveyor accidents. Fixed covers, grates, and mesh guards over feed points are effective in preventing accidental contact with the rotating screw [9] [10]. However, studies indicate that in many industrial settings, guards are removed to improve accessibility or are bypassed due to frequent choking of material. To address the limitations of conventional guarding, researchers have proposed the use of interlocked guarding systems. Interlocks ensure that the conveyor cannot operate unless all access covers are properly closed. Recent advancements in industrial automation have shifted research focus toward sensor-based and intelligent safety systems. Smart safety systems integrated with programmable logic controllers (PLCs) or microcontrollers have been shown to improve reliability and response time in industrial safety applications. [16]

Updated versions of ISO 12100[2] and ISO 14120[3], along with recent CEMA and OSHA guidelines, emphasize hazard identification, risk assessment, and the implementation of inherently safe design and protective systems. The reviewed literature clearly establishes that screw conveyors pose a high risk of severe hand and limb injuries, advocating the integration of intelligent, sensor-based safety systems that can detect unsafe human interaction and prevent accidents proactively.

Table1 Accident Statistics and Causes Table of Screw Conveyor / Auger Systems [14], [15]

S. No.	Parameter	Statistical Value/ Condition	Description
1	Total analyzed accident cases	167 incidents	Auger entanglement cases in confined agricultural spaces (1964–2013 dataset)
2	Fatality rate	32.30%	Nearly one-third of recorded incidents resulted in death
3	Gender distribution	~98% male victims	Indicates high exposure of male workers in auger operations
4	Most affected age group	21–45 years	Highest number of injuries among active workforce
5	Most common injury type	Lower limb amputation	Caused by stepping into exposed screw/auger

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6	Primary accident mechanism	Entanglement in rotating auger	Occurs due to contact with energized screw
7	Major accident location	Confined spaces (grain bins, silos)	High severity due to difficult rescue conditions
8	Leading cause of exposure	Cleaning / removing residual material	Workers interact with running conveyors
9	OSHA recorded cases	>238 documented cases	Includes fatalities, amputations, and injuries involving screw conveyors
10	Recent fatal incidents	Multiple fatalities reported (e.g., 2025 cases)	Indicates ongoing risk despite regulations
11	Common OSHA injury types	Amputation, crushing, entanglement	Frequently reported in industrial conveyor accidents
12	Unsafe condition factor	Unguarded conveyors	Many accidents involve missing covers/guards

3. Methodology and Proposed System

3.1.Problem Statement

Screw conveyors pose serious safety risks during operation, inspection, cleaning, and maintenance. One of the major safety concerns is the exposure of rotating screw components when the protective lid or cover is opened while the machine is still running. Since the screw rotates at high speed and generates significant torque, accidental contact with moving parts can lead to severe injuries such as cuts, fractures, crushing, or even fatalities. The lack of an automatic safety interlock system between the screw conveyor lid and the motor creates a critical safety gap. Without such a mechanism, the machine can continue running even when the lid is open, directly exposing rotating components [11-12]]

3.2.Working of screw conveyor system

The machine operates as a hopper-based material handling system integrated with a vibrator and screw conveyor. It is designed to store, control, and transfer bulk materials such as powders or granules in a smooth and continuous manner. Initially, the raw material is loaded into the hopper from the top, acting as a temporary storage unit and guiding the material toward the bottom outlet using gravity. A vibrator generates controlled mechanical vibrations that loosen the material, break blockages, and ensure free and uniform movement toward the discharge outlet. At the bottom of the hopper, a screw conveyor (feeder) driven by an electric motor and gearbox transports the material at a controlled and continuous rate into a connected pipeline or processing unit. [13-14]

3.3.Proposed Lid-Activated Automation Mechanism

To overcome the safety risks associated with screw conveyors, an automated lid-activated safety mechanism can be implemented to ensure operator protection and prevent accidents. The proposed solution focuses on eliminating human dependency and introducing automatic machine shutdown whenever unsafe conditions occur.

- Limit switch is mounted on the conveyor lid and connected to the motor control circuit.
- When the lid is in a closed position, the switch remains engaged, allowing normal operation of the conveyor.
- As soon as the lid is opened, even slightly, the switch is triggered and immediately interrupts the power supply to the motor, stopping the rotation of the screw.

To further enhance safety, the system can be integrated with a programmable logic controller (PLC) or relay-based control system, ensuring precise control, faster response time, and reliable operation. The conveyor will not restart automatically once the lid is closed; instead, a manual reset or start command is required. [15-16]

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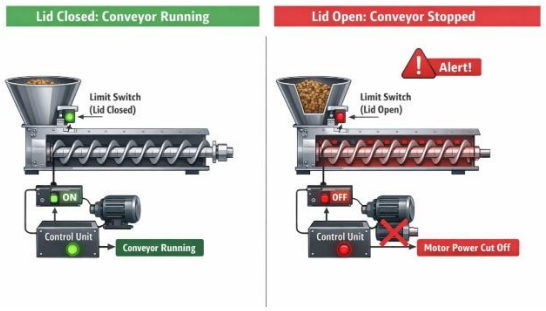

Figure 2 Used Lid Activated Mechanism System

4. Advantages and Drawbacks

4.1.Advantages

- The limit switch mechanism on lid provides enhanced protection against human injury.
- It provides proactive and automatic safety response.
- It reduces dependence on human judgment.
- It provides improved safety during maintenance and cleaning.
- There will be minimal impact on productivity.
- It makes improved workplace safety culture.

4.2.Drawbacks

- It increases initial cost due to additional sensors, interlocks, wiring, and control systems.
- It may require regular maintenance and calibration of interlock switches to ensure reliable operation.
- It may subject to environmental sensitivity dust, moisture, vibration, or corrosion can affect performance of limit switch[16]

5. Results and Discussion

The implementation of a lid-activated automation mechanism in a screw conveyor system resulted in significant improvements in operational safety, efficiency, and reliability. The primary outcome observed was the elimination of the risk of accidental contact with the rotating screw, which is a common source of injury in conventional conveyor setups. By integrating a lid sensor that automatically stops the conveyor when the lid is opened, the system ensured that operators cannot access the moving parts while the machine is in operation, effectively preventing accidents and reducing the likelihood of serious injuries.

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