

CHALLENGES IN REDUCING FRICTION AND WEAR IN SCRAPER CHAIN CONVEYORS: A REVIEW OF CONTEMPORARY RESEARCH

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Abstract. This paper reviews research published over the past two decades on reducing friction and improving the performance of chain-type scraper conveyors used at mechanized longwall faces. International, CIS, and Uzbek studies are analyzed in four research areas: optimization of scraper (flight) spacing as a function of material load; sprocket design; friction during conveyor advance and operation with a shearer; and operation in steeply dipping seams. The principal achievements, limitations, and unresolved research gaps are identified. The review shows that DEM/MBD-based optimization has achieved substantial reductions in energy consumption and moving mass, whereas adaptive selection of flight spacing, friction-oriented sprocket-profile optimization, direct measurement of trough-floor friction during advancing, and conveyor stability under steep-seam conditions remain insufficiently investigated.

Keywords: scraper chain conveyor, armoured face conveyor, scraper flight, sprocket, friction, wear, shearer, steeply dipping seam, DEM.

Introduction and Review Methodology

A chain-type scraper conveyor, commonly referred to as an armoured face conveyor (AFC), is the principal haulage system in a mechanized longwall face; it also serves as a guide for shearer travel and as an abutment for the powered supports [1, 2]. Friction in the chain, scraper flights, and conveyor trough is a major factor governing both energy consumption and wear [1, 24]. This review therefore focuses on four areas: (1) optimization of the number and spacing of scraper flights according to the material load; (2) sprocket design; (3) friction during conveyor advance and operation with a shearer; and (4) operation in steeply dipping seams.

The literature search covered English-, Russian-, and Uzbek-language sources published between 2005 and 2026. Sources were identified through the open web, publisher platforms (MDPI, Wiley, SAGE, Springer Nature), Zenodo, inLibrary, university repositories, and patent databases. Because subscription-based access to Scopus and Web of Science (WoS) was unavailable, the present review should not be

regarded as a PRISMA-compliant systematic review; the indexing status of individual journals should therefore be verified separately.

Source type	Language	Main search terms	Note
International journals	English	scraper conveyor; armoured face conveyor; friction; wear; sprocket; steeply dipping	Scopus/WoS status should be verified separately
Dissertations and thesis abstracts	Russian	забойный скребковый конвейер; износ цепи; звёздочка; крутые пласты	DonNTU, BNTU
Uzbek sources	Uzbek, Russian	zanjirli/qirg'ichli konveyer; Shargun; steeply dipping seam	Zenodo, inLibrary

Recommended Scopus query: TITLE-ABS-KEY("scraper conveyor" OR "armoured face conveyor") AND TITLE-ABS-KEY(friction OR wear OR sprocket OR "steeply dipping") AND PUBYEAR > 2005.

Friction: Theoretical Background

Friction occurs at several interfaces: chain/scraper flight-trough, coal-trough, trough-seam floor during advancing, shearer sliding surfaces-trough, and chain-sprocket engagement. Together with impact loading and variable chain tension, these interactions promote friction-fatigue wear and may ultimately lead to chain failure [19].

Moving mass and conveying capacity:

$$q_0 = q_{ch} + \frac{m_{fl}}{t_f}, \quad Q = 3,6 \cdot \rho \cdot B \cdot H \cdot \psi \cdot v \quad (1)$$

where q_0 is the linear mass, kg/m; m_{fl} is the mass of a scraper flight, kg; t_f is the flight spacing, m; Q is the conveying capacity, t/h; ψ is the filling coefficient; and v is the chain velocity, m/s. The drive power and specific energy consumption (objective function) are expressed as:

$$P = \frac{W \cdot v}{1000 \cdot \eta}, \quad e = \frac{P}{Q} \quad (2)$$

where W is the tractive resistance, N, calculated from the payload, chain weight, and resistance coefficients w_1 and w_2 ; and η is the drive efficiency. Reference [20] demonstrated friction-induced self-excited oscillations using a 200-lumped-mass elastic-chain model.

International and CIS Research by Theme

Optimization of Scraper Flights According to Material Load

Reducing the flight spacing increases the moving mass and no-load power demand (Eq. (1)); however, increasing the spacing intensifies material back-slippage

and decreases the filling coefficient ψ . The optimum spacing is therefore a compromise between these competing effects. Using DEM, Ref. [9] employed a 6p-8p-6p arrangement and reduced the number of scraper flights by 11.1% and the mass of the chain system by 26.2% (72 fewer flights and a 6,358 kg mass reduction for a 400 m conveyor). Reference [12] reported a nonlinear relationship between chain velocity and flight spacing, with an optimum spacing of 303 mm at chain velocities of 0.9-1.5 m/s. Using the NSGA-II algorithm, Ref. [10] reduced energy consumption by 33.7%; however, the area fraction of large coal particles decreased by 27.7%, indicating a trade-off between energy efficiency and coal degradation. Reference [6] found coal-particle size to have the strongest influence on impact damage, although many published studies remain limited to single-factor analyses.

Sprocket Design

Chain engagement with a sprocket, typically having 5-7 teeth, produces the polygonal (chordal) effect, whereby chain velocity fluctuates during each tooth-engagement cycle [1]. The amplitude of this fluctuation decreases markedly as the tooth number z increases (Fig. 1). Reference [3] proposed a shape-from-focus method for measuring volumetric sprocket-tooth wear. Reference [13] reported that austempered ductile iron (ADI) exhibited greater wear resistance than L35GSM steel. According to manufacturer data, the GR sprocket can increase mechanical efficiency from 93% to 97% [16]; however, no independent experimental confirmation of this claim was identified.

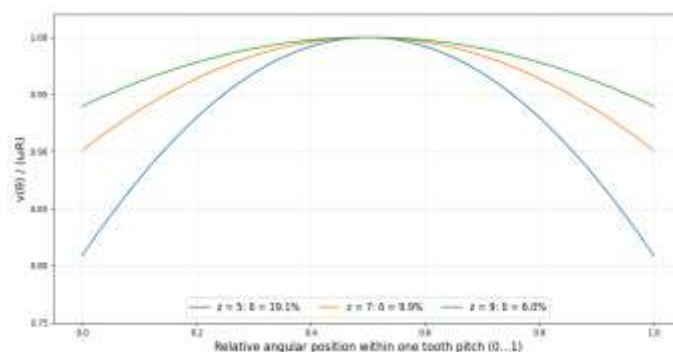


Figure 1. Polygonal effect: normalized chain velocity at the chain-sprocket engagement point ($z = 5, 7, 9$).

Friction During Conveyor Advance and Shearer Operation

The shearer frequently discharges coal directly onto the conveyor trough, producing a time-varying load [1, 2]. A related patent emphasizes the need for real-time measurement of frictional forces [19]. Proposed engineering solutions include modifying the geometry of the lower trough section to increase the effective contact area [16], dynamically reducing the initial chain pretension from approximately 30-40 t to below 10 t [18], and replacing sliding friction with rolling friction, as demonstrated in a mine trial [11]. CIS studies have investigated independent control of the two

conveyor drives [21], dynamic protection under jamming conditions [22], and resonance in traction chains [23]; however, these studies are largely at the master's-thesis level and do not incorporate DEM analysis.

Operation in Steeply Dipping Seams

For steeply dipping seams, two distinct phenomena should be considered: sliding of the conveyed material and displacement of the conveyor itself. For an unanchored trough, the safety factor against sliding is:

$$k_s = \frac{f_p \cdot \cos \alpha}{\sin \alpha} \quad (3)$$

where f_p is the trough-floor friction coefficient and α is the seam dip angle. Under Shargun conditions (40-48°), even at $f_p = 0.7$, $k_s < 1$; thus, the conveyor cannot remain stable without an additional restraining force or anchorage. Reference [14] treated downward conveyor displacement at a 36° dip as a problem coupled with shield-support sliding and overturning and proposed an arc-shaped longwall-face layout. Reference [15] reported a critical overturning angle of 27.8° and a sliding angle of 16°. An earlier patent [17] described the risk of coal fragments sliding without effective scraper restraint on steep inclines and being ejected from the upper strand. Reducing conveyor dimensions while maintaining the same capacity Q requires a higher chain velocity v , which in turn increases acceleration associated with the polygonal effect. No study directly addressing this size-velocity trade-off was identified.

Research by Uzbek Scientists

Coal production in Uzbekistan is concentrated primarily at Angren (surface mining) and Shargun/Boysun (underground mining). A mechanized longwall complex is used at the Shargun mine, where seam dips are typically 40-48°.

Source	Content	Relevance to the conveyor problem
Makhmudov et al., 2022 [25]	Mechanized extraction of thick, steeply dipping (40-48°) seams at Shargun; longwall system; block dimensions 80 x 800 m; seam thickness 5 m	Addresses the technological-complex level; no analysis of friction or scraper-flight parameters
Ziyotov and Haqberdiyev, 2026 [26]	Historical development of steep-seam extraction, Shargun practice, and longwall-face design principles	Focuses on equipment coordination; no conveyor-friction calculations

No dedicated open-source study by Uzbek authors was identified that specifically addresses friction in scraper conveyors, optimization of scraper-flight number or spacing, or sprocket design. The available studies primarily focus on coal-seam extraction technology. Within the reviewed literature, this therefore represents a potentially original direction for dissertation research.

Achievements, Limitations, and Recommendations

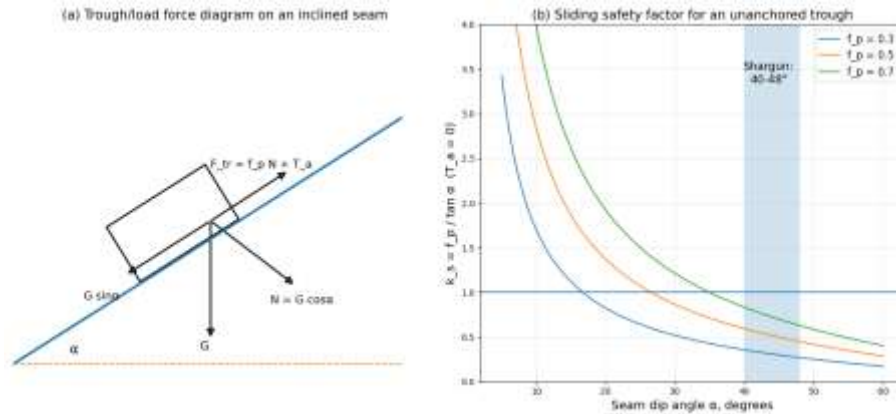


Figure 2. (a) Force diagram for a conveyor/load system on an inclined seam; (b) safety factor against sliding, $K_s(\alpha)$, for an unanchored trough according to Eq. (3).

Research area	Achievement	Limitation / research gap	Recommendation
1. Scraper flights	The effects of flight spacing and chain velocity have been quantified using DEM [9, 10, 12]	No load-adaptive selection based on throughput (t/h); most studies are single-factor	DEM-based optimization minimizing $e(tf)$; variable spacing similar to Ref. [9]
2. Sprocket	Polygonal effect, tooth-wear measurement method [3], and ADI material [13]	Limited tooth-profile optimization specifically targeting friction reduction	Parametric optimization of z and tooth profile; wear mapping
3. Advancing / shearer operation	Trough geometry, dynamic pretension control, and rolling-friction concepts [11, 16, 18]	Trough-floor friction has not been measured directly under mine conditions	Real-time friction measurement [19]; dynamic control of initial chain pretension
4. Steeply dipping seams	Mechanics of shield-support sliding and overturning [14, 15]	The conveyor itself (material sliding, conveyor dimensions) is insufficiently studied	Field measurements under Shargun conditions; DEM analysis of the size-velocity trade-off
Uzbekistan	Technological justification for Shargun conditions [25, 26]	No dedicated conveyor-friction research identified in the reviewed open literature	Integrate tribological testing, DEM/MBD, and mine trials; target Scopus/WoS-indexed publication

Conclusions

- Scraper-flight spacing and chain velocity have been investigated extensively using DEM/MBD approaches, with reported reductions of up to 33.7% in energy consumption and 26.2% in chain-system mass. Nevertheless, load-adaptive parameter selection and comprehensive multi-factor optimization remain insufficiently developed.

- The polygonal effect and methods for measuring sprocket wear are well established, but optimization of sprocket tooth profiles specifically aimed at reducing friction and wear remains limited.

- Trough-floor friction during conveyor advancing and the stability of the conveyor itself in steeply dipping seams have not been investigated as independent research problems to a sufficient extent.

- Within the reviewed open literature, conveyor-friction research in Uzbekistan remains limited, creating a promising research niche for dissertation work that combines tribological testing, DEM/MBD simulation, and mine-site validation.

References

1. Li et al. Tension characteristics analysis of scraper chain of heavy-duty scraper conveyor with time-varying loads. Shock and Vibration. 2024. Art. 5589346. DOI: 10.1155/2024/5589346.
2. Wang D. et al. Crack initiation characteristics of ring chain of heavy-duty scraper conveyor under time-varying loads. Advances in Mechanical Engineering. 2019. Vol. 11(9). DOI: 10.1177/1687814019880366.
3. Ding H. et al. Volumetric tooth wear measurement of scraper conveyor sprocket using shape from focus-based method. Applied Sciences. 2019. Vol. 9(6). Art. 1084.
4. Wang X. et al. The transporting efficiency and mechanical behavior analysis of scraper conveyor. Proceedings of the Institution of Mechanical Engineers, Part C. 2018. DOI: 10.1177/0954406217734002.
5. DEM-based study on the wear mechanism and wear regularity in scraper conveyor chutes. Mathematical Problems in Engineering. 2019. Art. 4191570.
6. Impact damage to the middle trough of a scraper conveyor based on EDEM and orthogonal matrix analysis. PLOS ONE. 2022. DOI: 10.1371/journal.pone.0266831.
7. Analysis of scraper conveyor chain dynamics under falling coal impact conditions. Machines. 2024. Vol. 12(9). Art. 648.
8. Study on the rigid-discrete coupling effect of scraper conveyor under different chain speed-load conditions. ScienceDirect. 2024.
9. Mining scraper conveyors chain drive system lightweight design: DEM and topology optimization. Computation. 2025. Vol. 13(9). Art. 225.
10. Dynamic coal flow-based energy consumption optimization of scraper conveyor. Applied Sciences. 2025. Vol. 15(13). Art. 7366.
11. Energy consumption optimization of scraper conveyors adopting rolling friction. ScienceDirect. 2025.

12. Scraper spacing-conveying efficiency DEM study. ResearchGate, publication 372734409.
13. Possibilities of increasing the durability of chain wheels of armoured-face conveyors (ADI cast iron). Zenodo.
14. Research on the stability of support structures in steeply dipping coal seam working face. Scientific Reports. 2026.
15. Research on stability control of shields at working face with large dip angle. Energies. 2023. Vol. 16(15). Art. 5813.
16. Cat PF6 armored face conveyors / AFC catalog. Caterpillar Global Mining.
17. US Patent 4,364,470. Scraper-chain conveyor (for use in inclined mine workings).
18. US Patent 9,422,112. Systems and methods for controlling a conveyor in a mining system.
19. US Patent 11,440,740. Frictional force monitoring system for middle troughs of scraper conveyor.
20. Osichev O.V., Tkachenko A.O. Influence of friction in the chain of an armoured face scraper conveyor on dynamics and energy efficiency. NTU 'KhPI', 2021. [In Russian].
21. Bogdanov A.N. Investigation of dynamic processes in a scraper conveyor. Master's thesis. DonNTU, 2011. [In Russian].
22. Terentyev D.Yu. Investigation of the dynamic characteristics of a scraper conveyor under jamming conditions. DonNTU, 2013. [In Russian].
23. Rudenko S.A. Resonance in traction chains: dissertation abstract. DonNTU, 2007. [In Russian].
24. Calculation of parameters of an armoured face scraper conveyor (UDC 622.112). BNTU. [In Russian].
25. Makhmudov D.R. et al. Justification of mechanized extraction of thick, steeply dipping coal seams under the conditions of the Shargun deposit. Universum: Technical Sciences. 2022. No. 5(98). [In Russian].
26. Ziyotov S.A., Haqberdiyev A.L. Mechanized extraction of steeply dipping coal seams using a mechanized complex. Development and Innovations in Science. 2026. 5(3). DOI: 10.5281/zenodo.18937738. [In Uzbek].
27. Conveyor transport used in mining enterprises. Eurasian Journal of Academic Research. 2022. 2(13). DOI: 10.5281/zenodo.7430740. [In Uzbek].
28. Open-pit mining operations (KNK-270 steep-incline conveyor). Navoi Mining and Metallurgical Company. [In Uzbek].
29. Friction coefficient of scraper chain conveyors on the floor. OSTI/ETDEWEB. 1980 (historical source; outside the 20-year review window).