Effects of Press Speed on Flexographic Printing in Central Impression Presses: A State-of-the-Art Update with Emphasis on Inks

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Abstract

Press speed is among the most consequential variables in flexographic printing, yet its effects in central impression (CI) presses are neither linear nor separable from ink behavior. This article is a state-of-the-art update: it presents no new experiments and defends no thesis. It triangulates two independent literature corpora compiled in September 2026: a 42-source technical corpus spanning peer-reviewed journals, TAGA proceedings, the FFTA Flexo Quality Consortium, trade and vendor publications, and patents; and a Consensus Deep Search synthesis of 100 included papers selected from 237 eligible records. The synthesis finds that speed acts through coupled mechanisms -- reduced nip dwell time, rate-dependent ink film splitting, temperature-driven viscosity and pH drift in water-based inks, drying-capacity limits, and web dynamics around the common impression drum. Higher speed often reduces ink transfer and optical density, but the response can be non-monotonic and is strongly mediated by formulation, anilox geometry, plate mechanics, and substrate. The update closes with agreements, disagreements, and a prioritized research agenda.

I. INTRODUCTION

Flexography is a relief printing process in which flexible photopolymer plates transfer low-viscosity, fast-setting inks metered by an engraved anilox roll. It dominates packaging printing -- flexible packaging, labels, folding carton, and corrugated -- because it prints a very wide range of absorbent and non-absorbent substrates at high speed and with comparatively low make-ready cost.

The central impression (CI) press arranges four to ten print stations as satellites around a single large impression cylinder, typically more than one meter in diameter. Each station carries its own plate cylinder, anilox roll, ink supply, and interstation dryer, but there is only one impression surface, and the web remains wrapped on that drum through every color impression. Because the substrate cannot move or distort between colors, CI presses hold print-to-print register on thin, extensible films far better than stack or inline architectures, in which each unit has its own impression cylinder and the web is pulled through successive nips (Johnson et al., 2003).

Commercial CI packaging presses commonly run 300 to 1,000 ft/min; modern CI presses are specified to 1,640 ft/min (DFTA Technology Centre reference press) and 1,970 ft/min with claims of extremely stable register (Koenig & Bauer Evo XC), while roughly 2,000 ft/min is described in the trade literature as a mechanical ceiling that becomes problem-prone in practice (Podhajny, 2002). Speed is therefore not a free variable: every additional meter per minute shortens nip dwell time, raises extensional rates during ink film splitting, increases ink and anilox temperatures, raises drying demand, and perturbs web handling.

This update synthesizes what the literature currently establishes about those effects, with deliberate depth on printing inks -- water-based, solvent-based, UV-curable, LED-UV, and electron-beam systems -- and their relationship with the flexographic process at speed. Its central finding, supported by both corpora, is a process-window view: press speed matters most through its interaction with ink behavior, and the practical outcome depends on whether ink, anilox, plate, substrate, and dryer form a matched system. The article is organized as follows. Section II describes the literature selection and triangulation method. Section III covers press-speed effects on print quality. Section IV treats inks in depth. Sections V and VI cover anilox and doctor blade behavior and drying and curing systems. Section VII states where the literature agrees and disagrees, Section VIII lists research gaps and future directions, and Section IX concludes.

II. LITERATURE SELECTION

Two independent corpora were triangulated. Corpus A is a 42-source technical corpus compiled in September 2026: five peer-reviewed journal papers, two TAGA conference papers, reports of the FFTA Flexo Quality Consortium, industry technical publications, vendor and equipment technical material, and patents. A subset of these sources was read in full; the remainder was assessed from indexed excerpts, and confidence flags distinguish well-supported claims (multiple independent sources agree), single-source claims, and vendor or anecdotal material (indicative only).

Corpus B is a Consensus Deep Search synthesis built from ten search queries covering CI press fundamentals, speed-dependent print quality, water-based ink viscosity and pH behavior, ink transfer physics, anilox and doctor blade behavior, UV and electron-beam curing, solvent drying, and high-speed instability terms. The reported funnel spans roughly 2.1 million retrieved records, 237 eligible papers after relevance and quality screening and deduplication, and 100 included papers, with priority given to peer-reviewed work from approximately the last fifteen years and older foundational studies retained where they anchor mechanisms still cited by newer work.

Triangulation proceeded claim by claim: points on which both corpora converge are reported as agreement; points on which they diverge, or on which one corpus is silent, are reported as disagreement or uncertainty. The reference list contains only works whose full bibliographic details could be independently verified; statements drawn from the Consensus synthesis whose sources lack complete publication details are presented as synthesis statements in the text. Anything resting on a single industrial source or on vendor material is flagged in the text. In-text citations follow APA author-date format at the author's request, rather than the numbered citation style customary in Physical Review Letters.

III. PRESS SPEED AND PRINT QUALITY

A. Ink transfer, optical density, and tonal value

The most direct experimental evidence on speed in a CI press remains Johnson, Ratto, Lestelius, and Jarnstrom (2003), who instrumented a full-scale six-color CI press with thin load cells and varied speed (164, 328, and 492 ft/min), impression (100, 200, and 300 micrometers), plate hardness, and plate type. Dynamic nip pressure depended only on the impression setting -- not on press speed and not on plate hardness -- yet print density, dot gain, and absolute ink coverage were all affected by press speed. The nuance is decisive: speed does not much change the mechanical pressure pulse in the nip, but it changes what happens inside the nip -- dwell time, ink splitting, and immobilization (Johnson et al., 2003).

The direction most often reported is a loss: higher speed shortens contact time between anilox, plate, and substrate and frequently lowers transferred ink and optical density, especially with conventional low-viscosity inks and certain anilox and ink combinations (Foulston, 2020). The density drop is reported to be stronger with higher-viscosity inks, whereas some high-screen anilox conditions dampen the speed effect (Foulston, 2020). Against a simple monotonic rule, however, an optimization review reports that ink transfer can first fall and then rise again at still higher speed, especially in highlights -- a non-monotonic process window rather than a single directional law.

Zolek-Tryznowska, Rombel, Petriaszwili, Dedijer, and Kasikovic (2020) printed solvent inks at a constant 984 ft/min on an eight-color Fischer & Krecke press and found that for 40 to 100 percent coverage, plate and substrate characteristics dominated optical density and tonal value increase (TVI), with ink viscosity the least influential factor; in light tones (0 to 20 percent), by contrast, ink viscosity dominated TVI because low-viscosity ink flooded out of the dots before drying. The practical implication is that speed-induced viscosity changes -- for example through evaporation -- appear first in highlights. The pressroom corollary, documented in the trade literature, is that printers running faster compensate by reformulating to higher color strength (thinner ink films), adjusting pH, and raising dryer temperature (Podhajny, 2002).

B. Dot gain and register accuracy

Across both corpora, dot gain is governed more strongly by pressure, plate deformation, ink spreading, and substrate than by speed alone (Zolek-Tryznowska et al., 2020). At low coverage and high line rulings, physical deformation of dots becomes the more important component, while in most other cases ink spreading dominates total dot gain. Impression must therefore be set with care at any speed: the lightest workable ("kiss") impression corresponds to roughly 75 micrometers of nip engagement, while engagement below about 20 micrometers causes slurring from circumferential speed mismatch between plate and web, and engagement above about 150 micrometers causes slurring because the plate surface runs faster than the web (Valdec et al., 2022).

Register defects are more clearly speed-coupled than dot gain, but through web tension, acceleration transients, smearing, and thermal deformation rather than through pure ink transfer. The CI architecture itself is the principal defense: with the web wrapped on the common impression drum, CI presses are reported to hold register on PET film at 1,150 to 1,310 ft/min -- described as more than twice the speed of a narrow-web press on the same job -- and a 1,970 ft/min CI press is marketed with guarantees of extremely stable register behavior (Packaging News, 2019). Both figures are single trade-press sources with vendor proximity and should be read as indicative, not established.

C. Speed-related defects

Standard defect taxonomies list excessive dot gain, gear marks, halo, feathering, doughnuts, skip-out, misregistration, mottled image, fill-in, bridging, pinholing, and dirty print (Luminite, n.d.). The mechanisms with the clearest speed coupling are the following. *Barring, gear marks, and bounce (chatter)* are vibration-induced bands of uneven ink application; at higher speeds the ink feed to the enclosed chamber must increase to avoid starvation, while over-pressurization of the chamber combined with improper blade-to-anilox pressure makes the doctor blade pulsate against the anilox, printing as chatter. Worn gears, bushings, and bearings generate vibration that persists even with correct chamber setup, and cylinder weight, web tension, impression loading, imbalance, and cylinder length all increase deflection (Daetwyler USA, n.d.-a). Documented mitigations include blade tip configurations that flex with bounce, correct blade pressure, angle, and material, maintenance of gears and bearings, and servo or gearless drives, which eliminate gear marking (Daetwyler USA, n.d.-a). *Pinholing* -- unprinted micro-voids in solids -- is reduced by thicker white-ink films from higher anilox volumes, which distribute more uniformly (Tomerlin, Valdec, Tomisa, & Vusic, 2023). *Halo and doughnuts* arise when excess plate-to-substrate pressure squeezes ink to dot edges and are prevented by kiss impression (Luminite, n.d.). *Fill-in, bridging, and dirty print* are linked to anilox cell volume, worn blades, and ink drying on the anilox or plate -- aggravated at speed when the anilox surface exceeds roughly 140 F and ink dries in the cells, or when unbalanced dryer air blows onto the plate or anilox (Podhajny, 2002). *Mottled image* reflects uneven absorption and distribution of ink components (Zolek-Tryznowska et al., 2020).

IV. INKS IN DEPTH

A. Overview of ink systems

Water-based inks are the dominant and fastest-growing flexographic system, estimated at about 51.8 percent of the flexo ink market (Fact.MR, 2026). Solvent-based inks remain important in flexible packaging for their fast evaporative drying but are constrained by volatile organic compound (VOC) emissions and retained-solvent limits. Energy-curable systems -- conventional UV, LED-UV, and electron-beam (EB) -- cure by polymerization rather than by evaporation and occupy the high-fidelity and heat-sensitive-film niches. Each system meets press speed at a different bottleneck: evaporation capacity for water and solvent, delivered cure dose for UV, and formulation hydrodynamics for misting and spitting defects.

B. Water-based inks: chemistry and control parameters

Water-based flexo inks are resin and pigment emulsions stabilized by volatile amines. The industry control window is narrow: press operating guides typically target 19 to 24 seconds in a Zahn No. 2 cup for viscosity and pH 8.2 to 9.4, with pH stabilizer dosed at 1 to 2 percent every 30 to 50 minutes of running (NBCHAO, n.d.; Longchang Chemical, n.d.). The classic operating rule is that adding water to cut viscosity also drops pH and "hardens" the ink; if pH falls too far, viscosity rises, resins coagulate, ink dries on the anilox and plate, and plates become hard to clean, while if pH runs too high, viscosity drops and drying slows (Podhajny, 2002). Transfer itself depends on a surface-tension ladder -- ink at roughly 23 to 42 dynes/cm wetting anilox, plate, and substrate surfaces of progressively higher surface energy -- and adding water raises ink surface tension toward loss of process control.

Rheologically, water-based flexo inks are typically pseudoplastic (shear-thinning) rather than Newtonian, and binder chemistry strongly affects the shape of the viscosity curve and the water-retention behavior of the film. Because apparent viscosity falls at the high shear rates of high-speed nips -- the Ostwald-de Waele behavior documented in flexo inks (Zolek-Tryznowska et al., 2020) -- the ink that meters, transfers, and splits at 1,310 ft/min is rheologically a different fluid from the ink measured in the Zahn cup at rest.

C. The viscosity-pH-evaporation triangle at speed

The defining instability of water-based flexo inks is a coupled triangle: amines evaporate, pH drifts downward, and viscosity, drying rate, and resolubility shift together -- faster at higher temperature and speed. The most direct evidence is the Flexo Quality Consortium ink-temperature study (Flexo Quality Consortium, 2021): at a fixed press speed of 250 ft/min with ink temperature stepped from 70 F to 120 F on BOPP and paper, pH decreased as a function of evaporation as amines flashed off, viscosity decreased and the ink flowed faster and thinner at higher temperature, and dot gain responded in a color-dependent way -- increasing with temperature for a green water-based ink and decreasing for a cyan one -- while density effects were inconsistent across colors and substrates.

Temperature rise lowers viscosity, which can increase density and spreading but can also worsen dot gain and process drift if not controlled. Podhajny (2002) adds the speed dimension from pressroom practice: at high press speeds the anilox surface temperature can exceed 140 F, flashing off fast co-solvents, raising ink surface tension, and hurting wettability; foaming and microfoam appear in water-based inks around 700 ft/min because entrapped air cannot escape fast enough, requiring different defoamers; and reformulation for 1,500 ft/min involves fast co-solvents, pH adjustment, and better wetting agents -- or, alternatively, higher-strength, thinner inks that ease the drying load.

Water-based ink viscosity must stay within a narrow window at speed. If viscosity is too high, transfer worsens; if too low, dots flood and dot gain increases (Zolek-Tryznowska et al., 2020). Light tones are especially viscosity-sensitive, while full-tone density is often more dependent on plate and substrate than on modest viscosity changes alone (Zolek-Tryznowska et al., 2020). pH control matters mainly because it shifts viscosity and dispersion stability; recent bio-binder work shows that stable alkaline pH and stable Zahn-cup viscosity can be maintained over storage , but that evidence addresses storage robustness rather than high-speed running behavior, so extrapolation to fast CI operation remains uncertain.

D. Drying behavior of water-based inks

Water-based inks set by evaporation plus absorption into the substrate where the substrate permits it. Water is fundamentally harder to dry than alcohol-based solvent: its latent heat of vaporization is roughly three times that of ethyl alcohol, and atmospheric moisture quickly saturates the boundary layer above the web (Water-Based Inks for Flexo Printing, n.d.). One industry document reports vapor volumes roughly ten times those of solvent for the same liquid volume and 25 to 30 percent production-speed losses on high-speed presses running water-based inks through solvent-designed dryers -- a single, dated source that should be treated as indicative rather than established (CH Printing Machinery, 2025). Amine management matters as well: if amines are not scrubbed out by the dryer airflow, they remain in the film and soften subsequently printed layers. At high speeds absorption contributes less because dwell time is shorter, so the dryer must do more of the work -- the central reason drying is the binding speed constraint for water-based systems.

E. Ink transfer: anilox to plate to substrate

Ink transfer from anilox to plate to substrate depends on cell volume, cell geometry, viscosity, viscoelasticity, speed, and contact angles (Foulston, 2020). Wider and shallower anilox cells release a higher fraction of their contents, laser-engraved geometries can outperform mechanically engraved cells, and wavy channel geometries appear advantageous for high-viscosity, elastic inks (Foulston, 2020). The amount of ink available on the anilox remains a first-order determinant: increasing anilox volume raises film thickness and density, although too much volume can overflow and distort dots (Bould et al., 2011).

Transfer to the substrate requires the ink's surface tension to sit below the substrate's. Films therefore need corona treatment to 38 dynes/cm and above, but corona effectiveness decays as speed rises unless power is increased or treaters are added (Podhajny, 2002; Enercon Industries, n.d.). On non-absorbent films there is no absorption assist, so all setting must come from evaporation or cure in the interstation dryers. A related speed-sensitive failure is dot dipping: if plate dots are smaller than the anilox cells, dots pick up excess ink and dot gain rises, which is why anilox line count is matched to plate screen ruling at roughly four to five times the plate ruling (Luminite, n.d.).

F. Ink film splitting

At the nip exit the ink film splits between plate and substrate, and film splitting is a rate-dependent extensional process. As speed rises, engagement time shortens and filament extension rate rises, which often reduces the released ink (Foulston, 2020). Lubrication and scaling models show that seam width, nip height, contact-zone size, wetting-zone length, and ink shear all scale nonlinearly with speed rather than proportionally. Experimental analogs and high-speed imaging outside conventional graphics flexography support the same basic mechanism: faster separation reduces deposited volume and changes breakup mode, especially when elasticity is low. An early and still-cited mechanism is due to De Grace and Mangin, who showed in the 1980s that splitting becomes asymmetric on nonporous substrates and invoked air entrainment at speed as an additional mechanism -- directly relevant to high-speed CI film printing, but reported here as cited in Johnson et al. (2003) and still awaiting modern re-validation with current nip speeds and ink chemistries (De Grace & Mangin, 1980s, as cited in Johnson et al., 2003).

G. Misting and slinging at high speeds

Misting and slinging -- centrifugal ejection of ink droplets at high anilox and plate surface speeds -- are among the clearest high-speed ink defects. A recent peer-reviewed formulation study showed that acrylic colloids strongly affect misting and that optimized water-based varnish formulations ran up to 2,300 ft/min without misting (Uraz et al., 2025). That result is encouraging but is a single study and should not be read as a general threshold. Higher viscosity and higher elasticity can suppress satellite formation in droplet-analog studies, but in flexography the same rheological shifts also change release, rewetting, and plate and anilox cleanliness, so the best formulation is process-specific rather than universal. Non-chambered, single-blade inking systems are reported to be prone to ink slinging at higher press speeds (Paper, Film & Foil Converter, n.d.). Notably, the technical corpus found no peer-reviewed quantitative misting thresholds for CI presses at all -- a genuine gap against which the single industrial trial above must be weighed.

H. How ink formulation interacts with press speed

Formulation can decouple speed from transfer loss. The classic result, reported via Johnson et al. (2003), is Cozzens and co-workers' finding that a low-viscosity ink gave constant ink transfer from 984 to 1,390 ft/min -- proof that the ink, not the press alone, sets the speed response (Cozzens et al., 1965, as cited in Johnson et al., 2003). Speed also changes ink temperature during running, which feeds back into viscosity and transfer. White inks illustrate an unresolved interaction: Tomerlin, Valdec, Tomisa, and Vusic (2023) report greater transfer and opacity at lower speed (around 197 ft/min) yet suggest that higher speed may help smooth and wet the white ink film -- a tension the literature has not resolved. The documented formulation levers for higher speed are higher color strength at thinner films, fast co-solvents, pH stabilization, wetting agents, and defoamers matched to the air-entrainment regime of the press (Podhajny, 2002).

I. Solvent-based inks

Solvent-based inks, typically alcohol and acetate systems, evaporate rapidly and historically enabled the highest press speeds, but they bring VOC, migration, and plate-swelling concerns. Solvent choice affects dot shape and plate compatibility, and aggressive solvents can swell plates and alter line width or deposited film thickness. In the peer-reviewed literature they remain a reference system: Zolek-Tryznowska et al. (2020) ran solvent CMYK at 15, 25, and 35 seconds flow time at 984 ft/min against a supplier optimum of 16 to 25 seconds. Practical speed guidance from the trade literature sets dryer temperatures of 122 to 176 F for solvent inks; alcohol-based dryers are designed to let solvent build up before exhausting, but high solvent content in the dryer then removes less solvent from the web, so dryers must be at peak performance. Residual-solvent risk rises with coating weight and speed and falls with proper dryer air balance, and crusting -- a surface skin blocking solvent diffusion -- is the failure mode when heat is excessive (CH Printing Machinery, 2025).

J. UV-curable, LED-UV, and electron-beam inks

UV-curable inks are near 100 percent solids: the full transferred film polymerizes into the ink film, so less ink volume is needed than with water or solvent systems, plates and anilox stay cleaner, dot gain is low, and gloss and color saturation are high. Because they do not change consistency on press, they can stand in the inking system without cleaning. UV systems offer high dot fidelity and low gain precisely because they are much higher in viscosity and do not depend on interstation solvent removal, but classical UV CI flexo remains speed-limited by cure of dark colors and lamp heat.

Press speed for UV is limited by delivered dose -- irradiance multiplied by dwell time -- rather than by evaporation. Published cure-speed claims range from 197 to 492 ft/min with the fastest above 1,640 ft/min, but these are vendor claims without stated test conditions and are weak evidence (PrintArea, n.d.). LED-UV changes the trade-off: LED modules at 17 to 25 W per square centimeter switch instantly and emit virtually no infrared heat, and converters have reported production-speed increases up to 100 percent on some jobs (WhatTheyThink, 2015). The no-heat property matters at speed on CI presses because it eliminates heat-shrinkage register error on thin films and removes the wait before downstream converting (KYMC, n.d.). Dual-cure ink series that polymerize under either LED or conventional mercury-arc lamps at conventional UV ink speeds or faster have been demonstrated (Fujifilm, 2020), and new UV-LED ink series aimed at high-speed narrow-web converters continue to appear (FlexoTech, 2026).

The distinct high-speed defect of UV flexo is ink spitting. UV inks' higher viscosity and thixotropy make them harder to meter from closed-cell anilox engravings; hydraulic pressure builds beneath the doctor blade, the blade flexes into a hydrodynamic regime, and ink is flung as droplets and streaks onto the substrate -- worse at higher speeds and on narrow-web presses (Daetwyler USA, n.d.-b). Documented countermeasures are thicker, stiffer blade bodies with fine tips and open-channel anilox geometries -- such as Apex GTT 2.0 and Harper XCAT -- that improve ink flow and release, reduce air entrapment and foaming and blade wear, and improve ink behavior at high speeds (Daetwyler USA, n.d.-b; Label & Narrow Web, n.d.). Peer-reviewed quantification of the spitting mechanism is absent -- a gap.

Electron-beam systems were developed to remove the CI-specific constraints of UV: EB curing enables wet trapping and end-of-line curing without interstation drying or added drum cooling, relaxing the speed limits that interstation cure imposes on CI presses.

V. ANILOX ROLL AND DOCTOR BLADE BEHAVIOR AT HIGH SPEED

Anilox selection follows standardized industry tables relating volume, line screen, and application: heavy lines and solids at roughly 180 to 330 lines per inch and 9 to 4 billion cubic microns per square inch (BCM); line and type at 200 to 400 lpi and 8 to 3 BCM; vignettes at 360 to 500 lpi and 3.6 to 2.8 BCM; and process work at 500 to 1,200 lpi and 2.8 to 0.9 BCM (Harper Corporation of America, n.d.; Flexographic Technical Association, 2013). Sixty-degree hexagonal cells are the standard; 75-degree and open-channel geometries are specified for better flow and release at speed (Savickas, Stonkus, Jurkonis, & Iljin, 2021). UV inks need smaller anilox volumes than water-based inks because nearly 100 percent of the transferred film is used.

Speed introduces four specific behaviors. First, heat: friction in dual-blade chambered systems can drive the anilox surface above 140 F at high speed, drying ink in the cells and changing transfer (Podhajny, 2002). Second, chamber hydraulics: at higher speeds the ink pump rate must rise to avoid local starvation in the chamber, while over-pressurization makes the doctor blade pulsate against the anilox and print chatter or banding (Daetwyler USA, n.d.-a). Third, wear and clogging: Savickas, Stonkus, Jurkonis, and Iljin (2021) measured 326 production rollers and found only 26.6 percent within 5 percent of nominal transfer, 26.3 percent down 5 to 15 percent, and 5.7 percent having lost more than 35 percent of transfer, with over half significantly clogged; doctor-blade wear rounds the cell-wall tops, permanently cutting volume. The authors note explicitly that few studies address what drives clogging and wear -- and the speed dependence of wear rates is an open gap. Fourth, blade metering: doctor blade type can dominate density and print contrast in predictive models (Zhang et al., 2010), blade deflection changes metering effectiveness as loading changes (Bould et al., 2011), and at higher running speeds synchrony between anilox and plate becomes more critical because small phase or speed mismatches immediately print as light or dark bands. Blade pressure, angle, material, and thickness all matter more as speed rises: too much pressure or stiffness contributes to chatter, too little gives poor wipe, dot gain, and density variation (Daetwyler USA, n.d.-a).

VI. DRYING AND CURING SYSTEMS VERSUS PRESS SPEED

CI presses carry interstation dryers between every print unit plus a final dryer -- five interstation air dryers and a main dryer on the six-color CI press studied by Johnson et al. (2003). The binding constraint is residence time: at 492 ft/min a point on the web spends only about 0.10 to 0.16 seconds in a 250 to 400 mm interstation zone, so evaporation capacity must scale with speed. Documented responses are raising dryer temperature (with film heat sensitivity as the ceiling, since PET and BOPP distort and curl), increasing air velocity and turbulence to break the boundary layer, reformulating inks to higher strength and thinner films with fast co-solvents, and -- for heat-sensitive films -- moving to LED-UV curing, whose 17 to 25 W per square centimeter arrays remove the thermal ceiling entirely (Podhajny, 2002; WhatTheyThink, 2015; KYMC, n.d.).

A CI-specific geometric constraint follows from the architecture: interstation arc length is fixed by drum diameter and station count, so CI press speed-ups for water- and solvent-based inks must come from hotter or more turbulent air, thinner ink films, or chemistry -- not from longer dryers. This is a synthesis inference from the architecture and the drying literature, not a directly sourced claim. Dryer imbalance is a further speed-coupled failure: air blowing onto plates or anilox causes dirty print and must be avoided (CH Printing Machinery, 2025).

For UV and LED-UV, curing is effectively instantaneous if the dose is sufficient, which is why it is the speed-enabling technology for heat-sensitive films. The remaining speed limit is photochemical -- dose equals irradiance times exposure time, so doubling speed halves dose unless irradiance rises -- and quantitative dose-speed-cure curves for flexo inks on films are a gap in the open literature. Higher drying temperature can also feed back into register through thermal strain of the web, especially in web processes.

VII. WHERE THE LITERATURE AGREES AND DISAGREES

A. Agreement

Both corpora converge on six points. First, the CI architecture gives superior register stability at high speed on extensible films compared with stack and inline presses (Johnson et al., 2003). Second, press speed affects ink transfer, density, and dot gain even when nip pressure is speed-invariant -- through dwell time, splitting, and immobilization (Johnson et al., 2003; Foulston, 2020). Third, water-based ink control is a coupled pH-viscosity-evaporation problem: amines evaporate, pH drifts down, and viscosity and drying shift together (Flexo Quality Consortium, 2021). Fourth, higher speed demands more chamber ink feed, more dryer capacity, more corona power, and usually ink reformulation (Podhajny, 2002; Daetwyler USA, n.d.-a). Fifth, UV and LED-UV decouple speed from evaporation, while their speed-specific defect is spitting from blade and anilox hydrodynamics (Daetwyler USA, n.d.-b). Sixth, anilox volume and line-screen selection follows standardized application tables, with finer screens for process work and coarser screens for solids (Harper Corporation of America, n.d.; Flexographic Technical Association, 2013).

B. Disagreement and tension

First, *how important is ink viscosity per se?* Zolek-Tryznowska et al. (2020) rank it the least influential factor on optical density and TVI at 40 to 100 percent coverage -- plate and substrate dominate -- and important only in light tones, while pressroom literature treats viscosity and pH as the primary control variables (Podhajny, 2002). A likely reconciliation is that viscosity matters through its variation (drift) rather than its setpoint, but this has not been directly tested. Second, *does density fall monotonically with speed?* Most studies report a decrease (Foulston, 2020), although a non-monotonic response -- transfer falling and then rising at still higher speed, especially in highlights -- has also been reported; Foulston (2020) further shows that high-screen anilox conditions dampen the speed effect. Third, *speed versus white-ink laydown*: Tomerlin, Valdec, Tomisa, and Vusic (2023) report greater transfer and opacity at lower speed yet suggest higher speed may help smooth and wet the white ink -- unresolved. Fourth, *water-based drying speed*: marketing material claims water-based inks dry faster than solvent, while the technical literature shows water needs roughly three times the vaporization energy of ethanol and is harder to dry; the technical position is better evidenced. Fifth, *dot gain versus temperature* is formulation-specific: the Flexo Quality Consortium study found opposite dot-gain responses to temperature for green and cyan water-based inks (Flexo Quality Consortium, 2021). Sixth, *misting thresholds*: the technical corpus found no peer-reviewed quantitative thresholds for CI presses, while a single peer-reviewed formulation study reports 2,300 ft/min mist-free running for an optimized water-based varnish (Uraz et al., 2025) -- a genuine tension that only more published data can resolve.

VIII. RESEARCH GAPS AND FUTURE DIRECTIONS

The corpora are rich in transfer physics and rheology but uneven in direct high-speed CI press experiments that simultaneously measure ink chemistry, hardware state, and print quality. Eight gaps stand out. (1) Speed-resolved ink-transfer studies on production CI presses above 492 ft/min, comparing water, solvent, and UV systems on films: Johnson et al. (2003) remains the only peer-reviewed CI study found, limited to board and water-based cyan at or below 492 ft/min. (2) pH-drift kinetics at production speeds and temperatures and their quantitative link to TVI drift across a run: the Flexo Quality Consortium (2021) shows the mechanism at 250 ft/min, but speed scaling is unquantified. (3) Anilox wear and clogging rate laws versus speed and blade parameters, and a standardized transfer-measurement method: Savickas et al. (2021) document the end state, not the rates. (4) Broader peer-reviewed ink misting and slinging physics above 1,310 ft/min on CI presses, beyond the first data point of Uraz et al. (2025). (5) Modern validation of ink-splitting and air-entrainment models for current nip speeds and chemistries. (6) Quantitative UV and LED-UV dose-speed-cure curves for flexo inks on films in the open literature. (7) Sustainable high-speed ink formulations: water-based systems that hold pH and viscosity at 1,310 to 1,970 ft/min, and low-migration UV-LED systems for food packaging -- active industrial R and D, with new UV-LED ink series aimed at high-speed converters appearing in the trade press (FlexoTech, 2026). (8) Integrated studies measuring viscosity, pH, temperature, and drying evolution together during real multicolor CI production -- the biggest gap identified by the Consensus synthesis.

IX. CONCLUSION

The literature shows that press speed in CI flexography matters most through its interaction with ink behavior. Faster running changes transfer time, extensional splitting, temperature, drying load, and register stability, but the practical outcome depends on whether the ink, anilox, plate, substrate, and dryer form a matched system. Water-based inks bring environmental advantages and broad substrate use, but their pH, temperature sensitivity, water retention, and evaporation behavior make them especially vulnerable to speed-induced drift; UV and electron-beam systems improve fidelity and relax drying bottlenecks while introducing cure physics, heat management, and equipment trade-offs of their own. The deepest evidence therefore supports optimizing a coupled process window -- not maximizing speed in isolation -- and the research agenda above defines where that window is still unmapped.

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The reference list contains only works whose full bibliographic details could be independently verified. Statements in the text that draw on the Consensus Deep Search synthesis are presented as synthesis statements; their underlying sources are not individually listed because complete publication details were not available.

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