High-Performance Charging Unit for Liquid Electrophotographic Presses

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Abstract

The HP Indigo presses dominate the commercial printing market with more than 50% market share using Liquid Electrophotography technology with superb print quality, high productivity and wide paper gamut. The new HP Indigo 7000 Digital Press introduced in Drupa08 runs at a marking speed of 2.15 m/s and places about three quarter of a billion dots on the paper per second. The new press incorporates many breakthrough improvements, including a new charging system featuring a charge roller. This unique charge roller unit is the first such technology used in a production digital press and supports by far the highest process speed of any offset-quality electrophotographic press. The single charge roller replaces the three scorotron units used in the previous generation Series II presses with improved charging uniformity and reduced cost per page. The charge roller is also much easier to maintain and is a "green" solution with minimal ozone generation. In this paper we discuss the multiple challenges that had to be overcome to meet or exceed the initial charge roller unit design objectives. This includes a useful life of over a half million impressions, which is far longer than other charge rollers.

Introduction

The HP Indigo digital presses dominate both the commercial and industrial digital printing markets with a wide portfolio of offerings. The HP Indigo marking engine is based on liquid electrophotography (LEP) using HP Indigo ElectroInk® [1,2]. A Series II marking engine [3] is shown in Fig. 1. As in a typical EP process, the photoconductor (PIP) is first charged, here to ~-950V using three double scorotrons. The image area is subsequently discharged to ~-50V by the laser writing head. In the 3rd step ink is placed onto the image areas with the developer units. The pattern is then electrostatically transferred to the hot blanket where the imaging oil is removed. The ink remaining meanwhile transforms into a tacky, uniform layer, which is mechanically transferred to the substrate in the final step using heat and pressure.

The first Indigo LEP press [4] was introduced at IPEX 93 with a process speed of 0.61 m/s as indicated in Fig. 2. The liquid ink technology has the potential for running at a very high press speed, free of the limitations of the dry electrophotography (DEP). By 1999 the Indigo Series II presses with double the process speed at 1.22 m/s were unveiled [3]. These incorporated the binary ink development (BID) technology [5], which removed electrophoresis as the rate-limiting step in development. HP Indigo continues to utilize the high speed capabilities of the ElectroInk® with the introduction of the latest generation Series III presses at Drupa08, which run at a process speed of 2.15 m/s. The series III marking engine possess many technology breakthroughs, including a new innovative charging unit based on a charge roller that replaced the three doubled scorotrons. This is the first charge roller system to be implemented in a high-end digital press with a speed, charging uniformity and lifespan needed for the market and exceeds by far the capabilities of any other charge roller in the market.

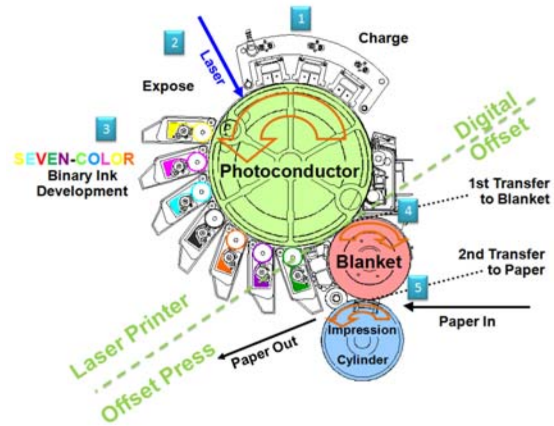

Figure.1. HP indigo marking engine in series II presses.

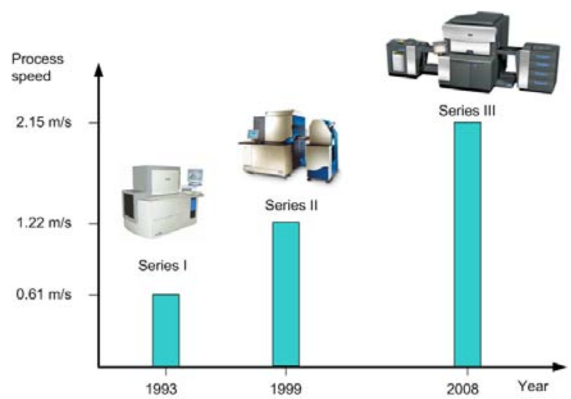

Figure.2. HP indigo LEP marking engine process speed since 1993.

Key challenges

To implement a charge roller in the HP Indigo press, many challenges had to be addressed including:

- *Charging level* – the single charge roller had to be designed with sufficient capability to charge the PIP to ~-1400V, allowing for a 40% safety margin for the Series III speed of 2.15 m/s and room for potential future increases.
- *Charging uniformity* – the charging spatial uniformity should fall within ±1% to maintain < ±0.5% variation in the halftone dot area.
- *Charge roller current* – the roller should support a net DC current of 1.5 mA, more than 10x higher than most charge rollers, which are commonly in office laser printers and laser-based multi-function printers.

- *Lifespan* – our goal was to exceed 500,000 impressions to meet the cost-per-page (CPP) and ease-of-use goals. Typical lifespan of charge rollers on the market is 20,000 impressions.
- *Interaction with the seam of the PIP drum* – HP Indigo uses a photoconductor foil rather than belt or a coated drum. This PIP design has many operational advantages but creates a seam where the ends of the foil meet. As a result, mechanical and electrical compensation systems were needed to properly charge the PIP seam and to keep the roller clean of seam residues to ensure high image quality. Our charge roller design can now support both seam and seamless drums.
- *Plasma flux* – the plasma created during the roller charging process differs from that of the scorotron's and interacts with the PIP differently. For best press performance the charge roller upgrade included a system-level improvement for the marking engine.

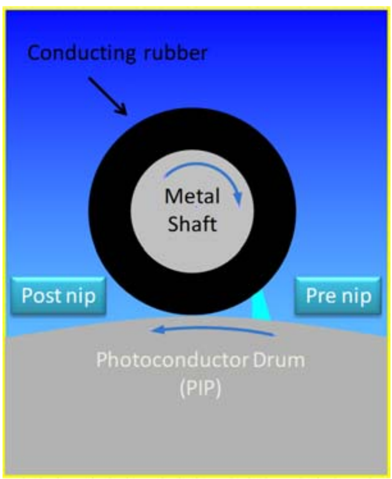

Figure.3. Charge Roller operation.

The principles of a charge roller

Charge roller operation is well understood and explained in detail by Kawamoto, et al. [6]. A typical roller adjacent to the PIP is illustrated in Fig. 3. The roller usually consists of metal shaft surrounded by a conductive rubber. When the shaft is biased to a sufficiently high voltage (V_s), the roller surface in the pre-nip surpasses the electric field for Paschen air breakdown. This creates charge pairs which separate, sending negative charges to the PIP and counter-charges to the roller. The minimum critical voltage, known as Paschen threshold (V_{th}), depends mainly on the surrounding gas, its pressure, and the gap between the electrodes. Typical threshold between parallel electrodes for air at atmospheric pressure was numerically calculated at HP Labs and is shown in Fig. 4 [7].

The charge generation process differs somewhat depending on the operational mode. In DC the PIP is continuously charged to $V_{PIP} = V_s – V_r - V_{th}$ where V_{PIP} is the PIP voltage, V_s the charge roller shaft voltage, V_r the voltage drop of the rubber and V_{th} the Paschen threshold needed for a specific configuration.

In AC with $V_s = V_{dc} + V_{ac}{\cdot}\sin(2\pi ft)$ (if $V_{ac} > V_{th}$), the PIP is charged to $V_{dc} – V_r$ through intermittent charging and discharging near the peak of the sine wave. Charging and discharging occurs in a period of 1/f even after photoconductor has reached desired charge level V_{dc}. AC generates better charging uniformity and accuracy but requires more complicated and expensive electronics design. As such, the AC mode is more common in high-end presses.

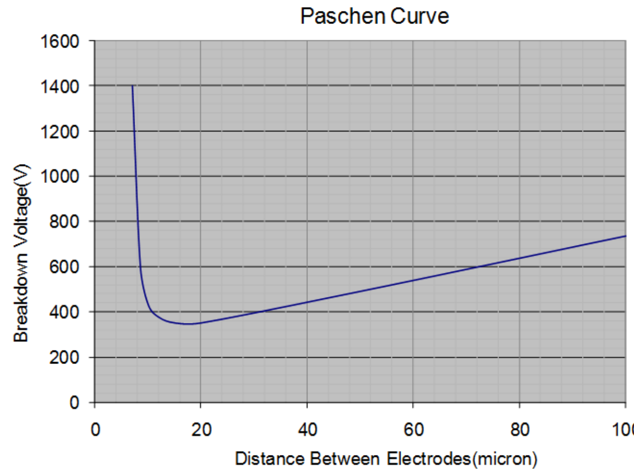

Figure 4 Paschen threshold curve for atmospheric air. Threshold was numerically calculated at HP Labs [7].

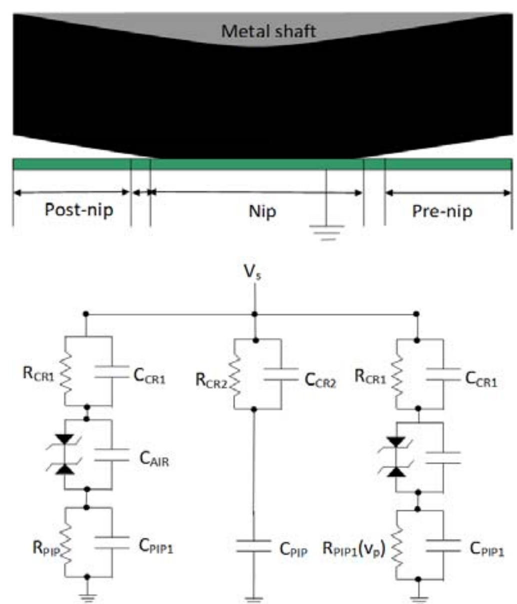

Figure 5 A lumped-circuit model of a charge roller and a photoconductor during operation [8].

The electrical challenges for the AC mode are tougher when addressing the unprecedented speed of 2.15m/s in Series III Indigo press. A special power supply was developed and implemented. In addition, a lumped-circuit model was constructed to understand the high frequency behavior. Figure 5 shows the complete model of the charge roller and photoconductor system in motion. The charging region is divided into the pre-nip, nip, and post-nip parts in the process direction. The charge roller is modeled as a leaky capacitor, the air back-to-back Zener diodes in parallel with a capacitor, and the photoconductor also as a leaky capacitor.

The model reflects charge roller performance only if values are accurately assigned. Here the charge roller impedance is just that measured at the high frequency used in the press. The Zener diode values are pegged to the threshold of Paschen breakdown (Zener breakdown voltage is equal to V_{th}). The pre- and post-nip photoconductor resistances represent charges being transported through the region and are hence process-speed dependent. At the nip, no resistor is needed for the photoconductor model because there is no charging current. The impedance ratio of charge roller to photoconductor eventually determines relative voltage drop in the rubber. The fractional DC voltage drop across the roller is ~ $R_{CR1}/[R_{CR1} + R_{PIP1}(v)]$. For AC, it is ~ $C_{PIP1}/(C_{PIP1} + C_{CR1})$.

Current status and summary

The new Series III marking engine with our advance charge roller unit is shown in Fig. 6. This new engine forms the core of the two recently introduced HP Indigo presses – the sheet-fed HP Indigo 7000 and HP Indigo WS6000 industrial web press, which have already been installed in many customer sites. The presses are shown in Figs. 7 and 8.

Our new charge roller assembly replaced the scorotrons unit, producing the following impressive benefits:

- Uniform and consistent charging at a process speed of 2.15 m/s – by far the highest process speed of any offset-quality electrophotographic press.
- Only one charge roller is needed. It is markedly smaller than the three Scorotrons in the HP Indigo series II presses.
- The charge roller assembly is significantly less expensive to manufacture than the multiple Scorotrons.
- Cost per page is improved.
- Less maintenance, increasing the customer “ease of use.”
- Ozone generation is lower by three orders of magnitudes, reducing requirements for ozone filtration and makes our presses even more environmental friendly.
- The charge roller life exceeds the initial design objectives and has a useful life of over half a million impressions, far longer than other charge rollers.

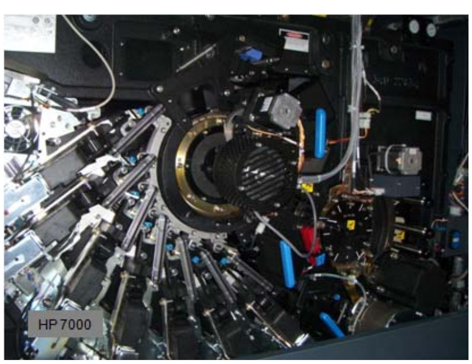

Figure.6. HP Indigo Series III marking engine.

Acknowledgements

The authors thank the many researchers from HP Labs and the HP Divisions for their many innovations and contributions that made this advanced charge roller system possible. These include Quang Lam, Paul Matheson, Bill Holland, Dr. Eric Hanson, Dr. Daihua Zhang, Dr. Gadi Oron, Dafna Shunary, Nir Mosenson, Dr. Mark Sandler, Doron Avramov, Zvika Cohen, Dr. Erez Faraggi, Dr. Albert Teisheb, Uri Tovim, Dr. Yoram Sorek, John Thompson, Bruce Jackson, Dr. Tom Camis, Pete Gysling, and Dr. Shirley Lee.

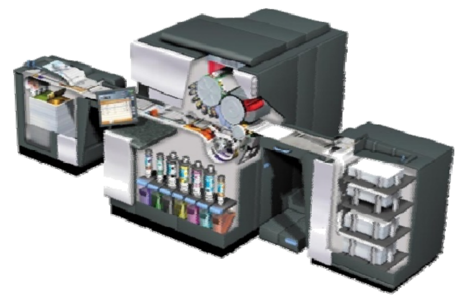

Figure.7. HP Indigo 7000.

Figure.8. HP Indigo WS6000.

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Author Biography

Omer Gila joined HP Labs in 2001 has been managing the Digital Commercial Printing Project since 2003 working mainly on Indigo-related technologies. From 1994 to 1999 he worked at Indigo in Rehovot, Israel before it was acquired by HP. He holds a B.Sc. (1989) in Physics and Mathematics from the Hebrew University (Jerusalem, Israel) and M.Sc. (1992) in Applied Physics and Electro-optics from the Weizmann Institute of Science (Rehovot, Israel) with honors in both.