Advances in Roll Texturing for Surface-Critical Strip Applications

Grant McBain, Chris Childs

[1]Sarclad Limited
Unit 3-4 Evolution, Advanced Manufacturing Park, Whittle Way, Rotherham, S60 5BL, United Kingdom
Phone: +44 114 293 9300
Email: grant.mcbain@sarclad.com

ABSTRACT

The latest developments in roll texturing technology are reviewed including the introduction of digital servos and improved energy efficiency. The introduction of Multi-Servo Array (MSA) is pushing the boundaries of what is possible, allowing roll shops to produce textured rolls with higher peak counts and greater consistency in less time than ever before.

Detailed technical results are presented, which include Ra consistency, high peak count (Rpc) results including 3D surface topography analysis, and texturing time improvements.

Keywords: Electrical Discharge Texturing; EDT; Roll texturing; Surface texture; Peak count (RPc); Cold mill rolling; Automotive strip; Rolltex; Multi-Servo Array; MSA

INTRODUCTION

Electrical Discharge Texturing (EDT) is a well-established technology for producing textured rolls for automotive strip [1]. Performance is typically measured as a) RPc vs Ra envelope, b) texture consistency, and c) roll texturing time. The Rolltex MSA project set out to achieve significant improvements in all three of these performance metrics.

This paper details the technological developments that have been undertaken and presents the results with respect to established performance criteria.

The research presented here has been structured by first considering the established attributes of spark initiation and decay and then detailing the controllable process variables to effect improved control and performance of the spark erosion process.

There are many process variables that influence the performance of the EDT process. The primary variables are a) Current; b) Voltage; c) Spark duration; and d) Electrode-to-roll gap. Variables a), b) and c) are controlled by the power delivery system, and variable d) is controlled by the electrode positioning system. These two systems are critical for controlling the quality of textures produced by an EDT machine, and the programme of work presented here details how improved control delivers improved texture performance.

EXPERIMENTAL PROCEDURE

Power Delivery System

Until now EDT power delivery modules have assumed a constant plasma channel impedance, typically using current-limiting resistors to determine the current delivered. In fact, the impedance of the spark gap changes over time due to increasing gas bubble pressure leading to growth of the plasma channel [2]. Simple power delivery modules therefore provide nominal current selection only; the actual current delivered is not constant over time.

The Rolltex MSA Power Delivery module adapts itself to the impedance of the spark gap by monitoring the actual current delivered and adjusting its output continually to achieve closed-loop control. As can be seen in Fig. 1, the current waveform has a fast-settling time and a steady state.

Furthermore, the current delivered can be varied from 0.1A to 63.0A in steps of 0.1A.

Fig. 1: Closed-loop current waveform with changing spark gap impedance. x-axis is time (10µs/div); y-axes are (top) current (2A/div) and (bottom) voltage (50V/div).

Fig. 2: 63A Rolltex MSA Power Delivery module

For the highest quality textures, it is important to control the variables relating to energy delivered into the roll by each spark [3]. At the start of each spark, a potential difference is applied between the electrode and the roll. This can be positive polarity (electrode higher potential than the roll) or negative polarity (electrode lower potential than the roll) depending upon the texture requirements. The potential difference has a non-zero rise and fall time in practice. To maximize mean power, it is beneficial to have fast rise and fall times.

The Rolltex MSA Power Delivery module is designed to have minimal rise time to the full striker voltage as shown in Fig. 3. An active drain circuit ensures minimal fall time at the end of the pulse. Cable type, length, routing and printed circuit board (PCB) layout have been carefully designed to yield minimal output capacitance and inductance.

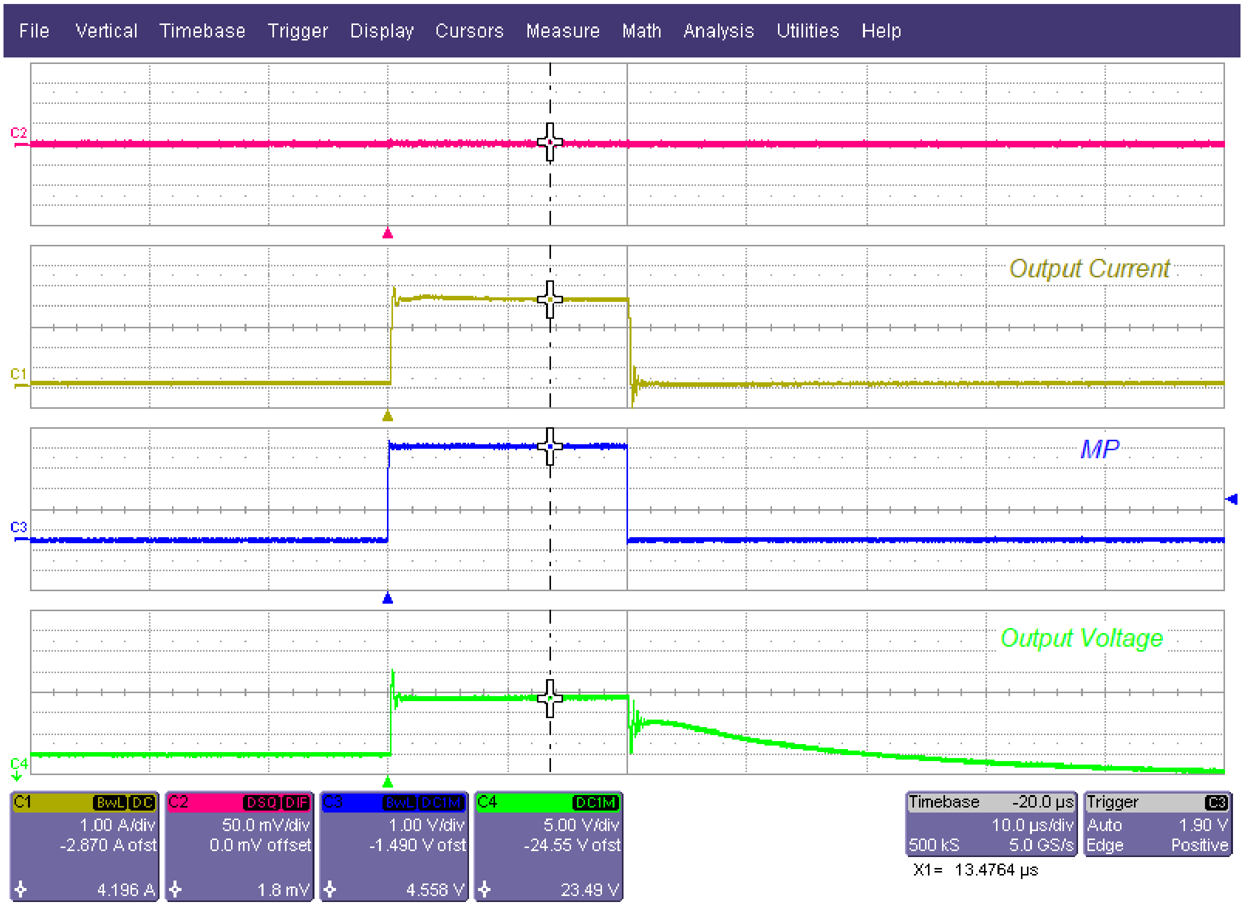


Fig. 3: Oscilloscope trace showing square waveforms of voltage and current with sharp transitions. x-axis is time (10µs/div); y-axes are (orange) current (1A/div) and (green) voltage (5V/div).

To allow the finest level of control, Rolltex MSA pulse duration is controlled in 0.01µs steps between 1.00µs and 1000.00µs. Furthermore, it is possible to operate in Isopulse mode, where the energy delivery is constant as the pulse duration is timed from the start of the spark. Isopulse ensures crater sizes are consistent, further improving texture consistency and repeatability [3].

Electrode Positioning System

Fig. 4: Rolltex MSA servo cartridge assembly

Rolltex MSA uses an array of servo cartridges (Fig. 4), each of which serves to independently position one electrode. Each cartridge in the array has a dedicated high-accuracy servomotor and servo drive. This allows every electrode to be positioned to the precise gap required, allowing the electrode array to achieve maximum efficiency.

The texture head is arranged so that the electrodes are presented to the roll via the top surface of the dielectric oil bath. This eliminates the requirement for any seals along the electrode positioning axis. The moving mass has been engineered to be as low as possible. Together these aspects allow faster and more precise positioning and control of the electrode-to-roll gap.

Rolltex MSA uses a servomotor and servo drive having high dynamic performance. Position feedback is achieved through an encoder integrated into the motor body.

Figs. 5 and 6 demonstrate the response time of the position control system in a classic step response test. Even such an atypically large movement of 50µm is completed and stabilized within 25ms.

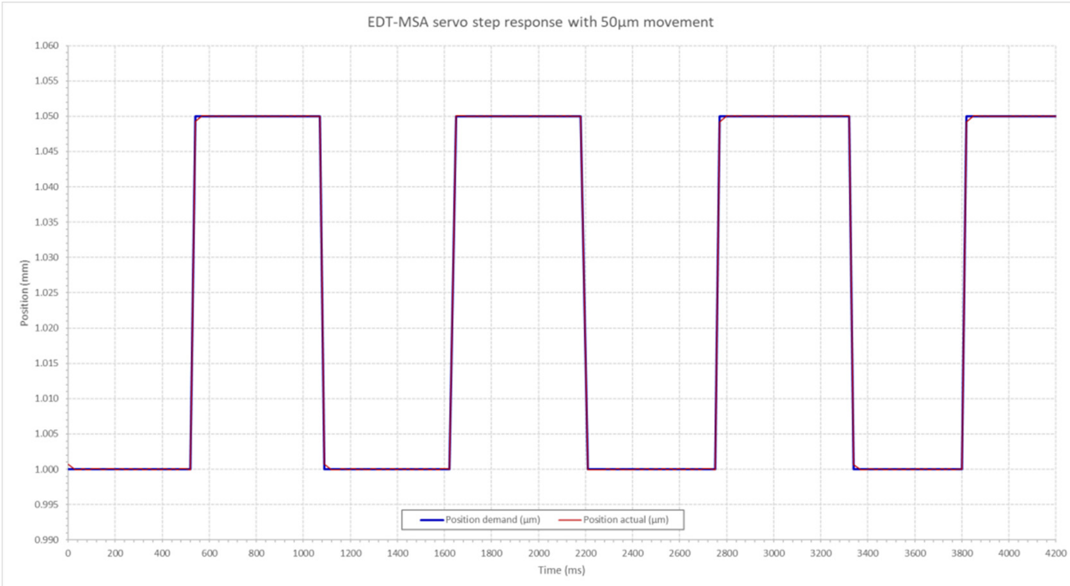


Fig. 5: Rolltex MSA texturing servo step response at 200ms time base

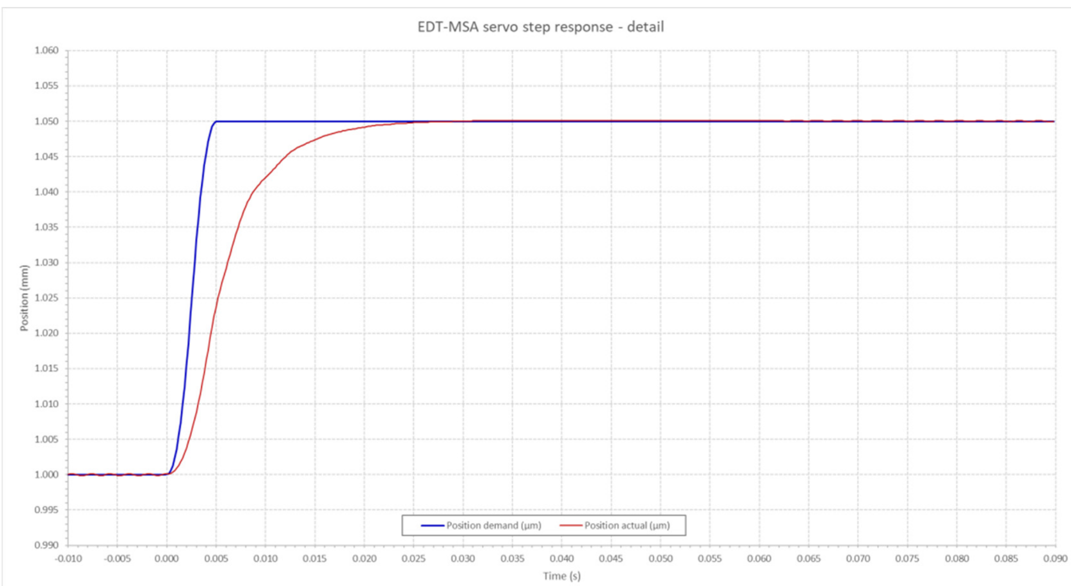


Fig. 6: Rolltex MSA texturing servo step response at 5ms time base

A custom controller PCB was designed, built and tested. Each controller PCB is responsible for the control and monitoring of a pair of electrode channels. The controller PCB directly accommodates socketed servo drives to further increase system integration and reduce cable lengths.

All of the control features are carried out in hardware by a field-programmable gate array (FPGA). A Profinet interface enables the central programmable logic controller (PLC) of the EDT machine to set overall texturing parameters and monitor feedback during the texturing process.

Pilot Studies – 4-Electrode EDT Machine

An adapted lathe (Harrison M500) was used as the basis of the Rolltex MSA prototype. A cluster of 4 electrodes in a 2x2 array was designed and built to validate the Power Delivery and Digital Servo Control systems.

Textures were produced at a typical Ra range and analyzed with a Mahr MarSurf CM mobile 3D surface measurement microscope.

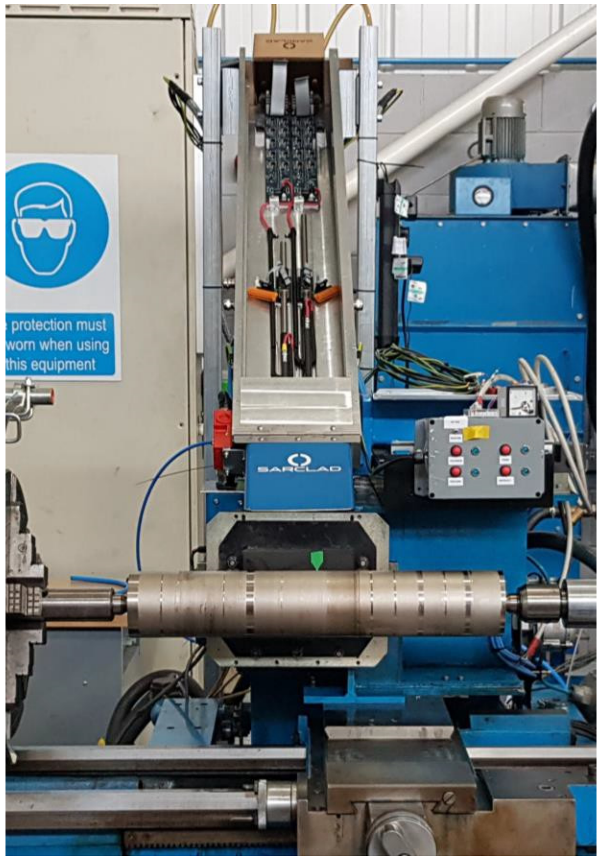


Fig. 7: 4-electrode Rolltex MSA test setup

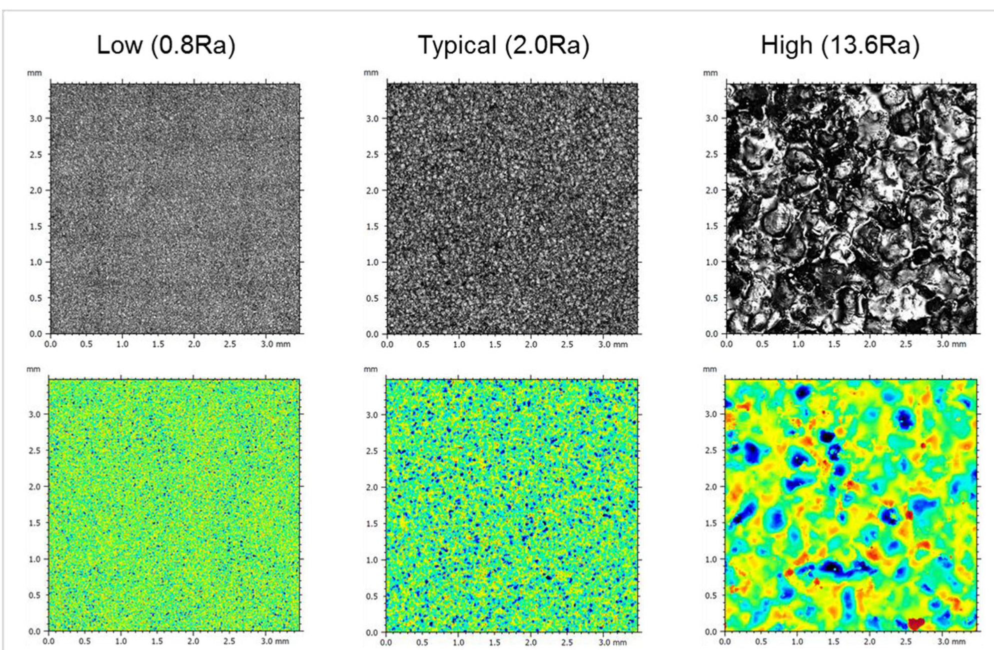


Fig. 8: Typical surface texture range produced by Rolltex MSA

36-Electrode EDT Machine

A full-size single-station EDT machine was designed and built in a 6x6 configuration. The purpose of this machine is to validate texturing performance at full scale and to demonstrate texturing full-size mill rolls for potential customers.

Fig. 9: 36-electrode Rolltex MSA machine

Texture Head
The texture head is designed for maximum performance, with the servomotors closely coupled to the electrodes with minimal moving mass to achieve high dynamic behaviour. The power delivery cables are as short as possible to minimize output capacitance and inductance. The systems are mounted on water-cooled plates to achieve temperature stability in a wide variety of ambient conditions.

Improved Texture Station
The texture station design has been further improved to ease operation and maintenance tasks (Fig. 10). The upper half of the texture station houses the array of 36 servo cartridges (Fig. 11), while the power and control electronics (Fig. 12) are directly below within the lower section. This arrangement retains minimum cable length while allowing easy access to servo cartridges and control electronics.

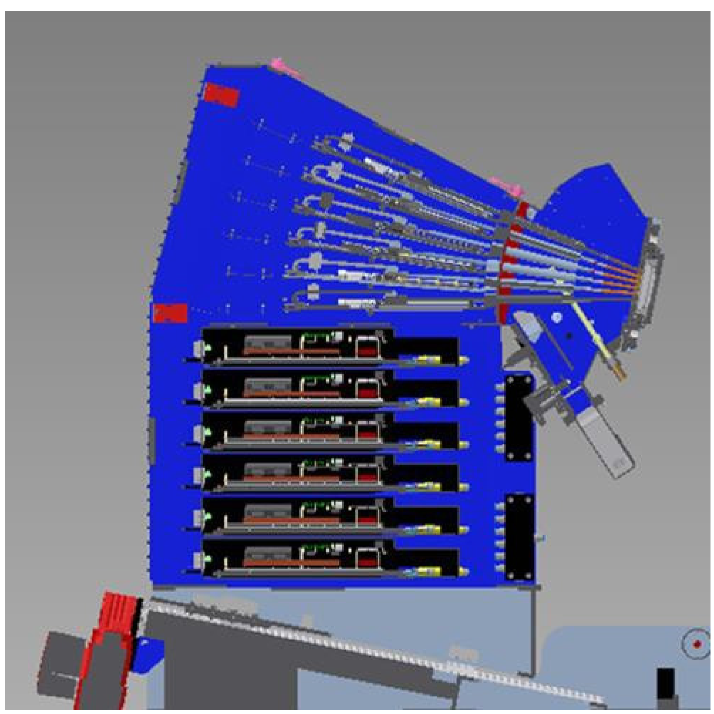
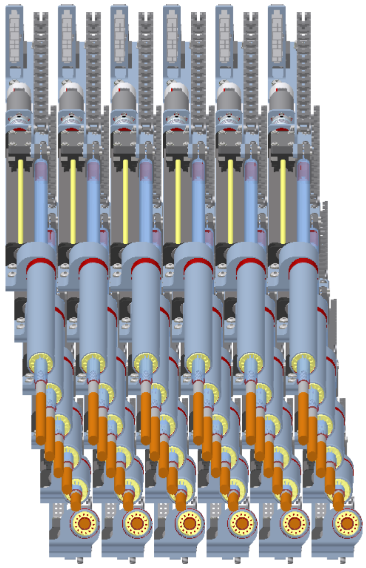


Fig. 10: Rolltex MSA texture station cross-section



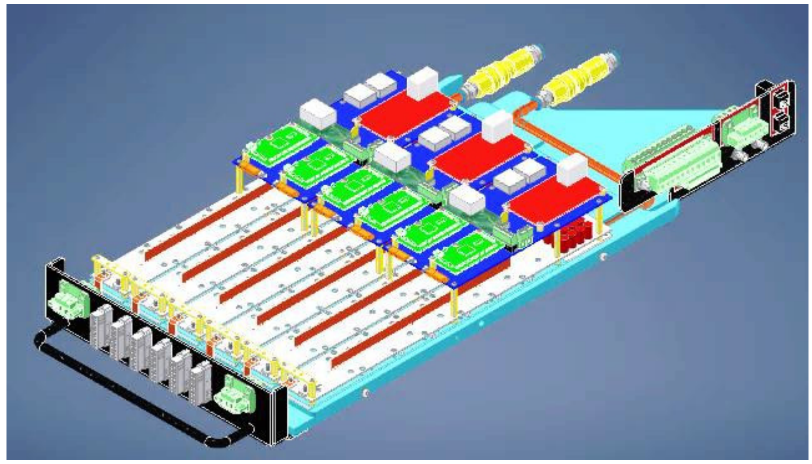


Fig. 11: 36-electrode servo array Fig. 12: Power and control electronics assembly

RESULTS AND DISCUSSION

The MSA was launched in 2022 and has already been selected that these flagship facilities:

Steel Dynamics Inc. – Sinton, Texas (2023)

AMNS India – Hazira (2024)

JiangyinRunYuan – China (2025)

Peak Count (RPc)

Test bands were textured using a range of texturing parameters. Results were measured using a Mahr PS10 stylus instrument at a cutoff of λc=2.5mm and bandwidth of 1µm (C1=C2=0.5µm) as stipulated by EN10049:2013 for measurements of textured automotive strip [4].

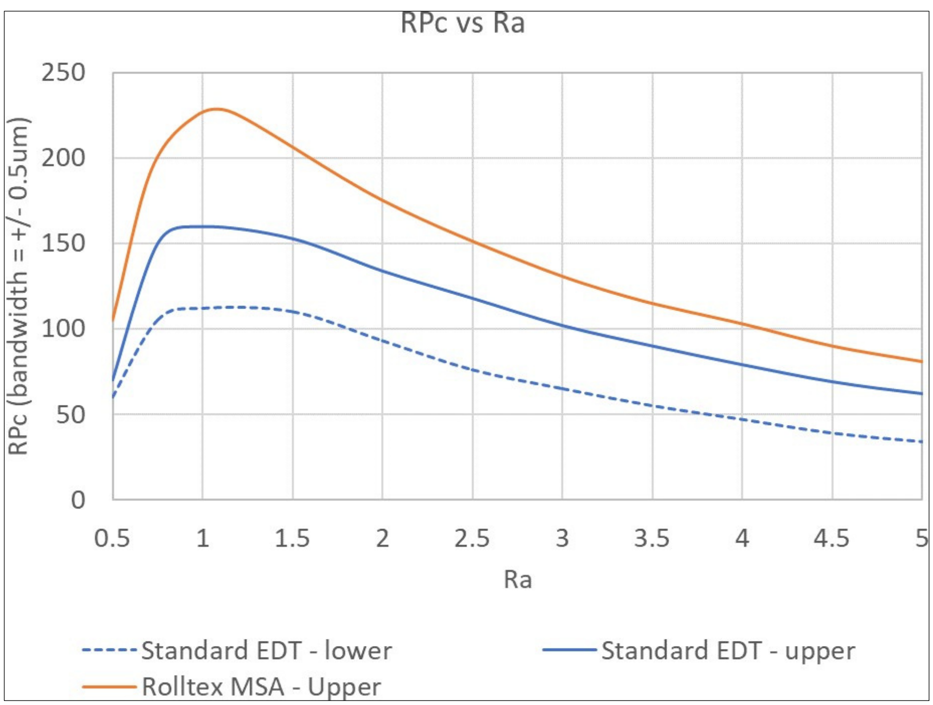


Fig. 13: Chart of RPc vs Ra

The particular shape of the RPc vs Ra curve is due to two factors. Firstly, there is a natural inverse relationship between Ra and RPc; larger craters result in higher roughness amplitude and fewer peaks per unit length. This effect dominates the shape of the curve at the medium-to-high Ra range. Secondly, with decreasing Ra, the effect of RPc bandwidth eliminates an increasing proportion of peaks, shaping the curve downwards to tend towards zero in the lower Ra range.

Rolltex MSA textures show a significant increase in highest RPc in the lower Ra range, peaking at around 1.0Ra. By further optimizing the machine setup and texturing parameters, RPc is significantly increased in the mid-range Ra, where rolls for automotive strip are typically produced at 2.5-3.0Ra. In this region, Rolltex MSA can provide an increase in highest RPc of +30% compared to standard EDT. Further work is ongoing in this area to realize the performance gains possible by Rolltex MSA technology.

Consistency

36 measurements of each texture were taken according to a standard measurement protocol [5]. Standard deviation of Ra measurements was calculated from the results, as shown in Fig. 14.

Consistency of Ra measurements results falls within ±3% standard deviation typical 1-6µm Ra range, as shown in in Fig. 14. This represents a significant improvement in Ra consistency, 25% better than the more usual ±4% standard deviation.

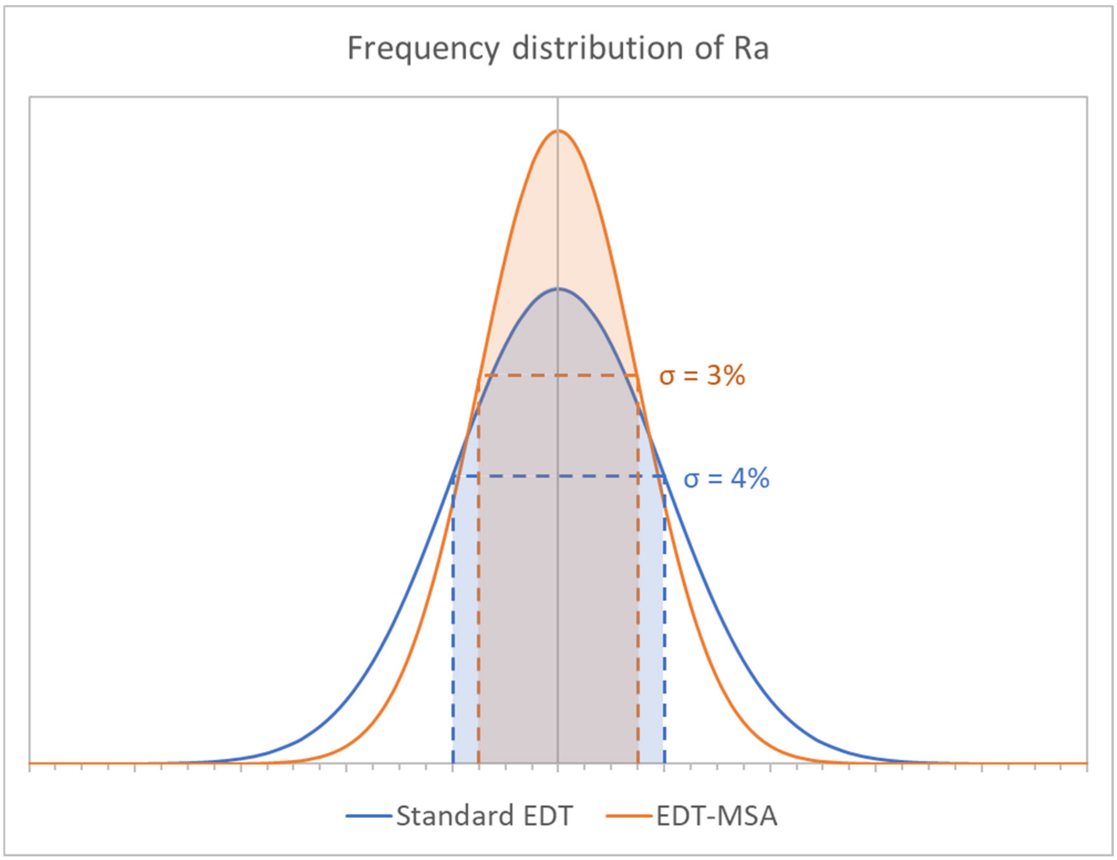


Fig. 14: Frequency distribution of Ra

Texturing Time and Removal of Grinding Defects

Due to the high current capability of the Power Delivery module and optimized arrangement of the texture station, it is possible to texture relatively low Ra textures at high current compared with standard EDT. In this way it is possible to increase the sparking frequency and thereby reduce the texturing time. It was observed that texturing time varies according to the magnitude of defects in the ground roll surface.

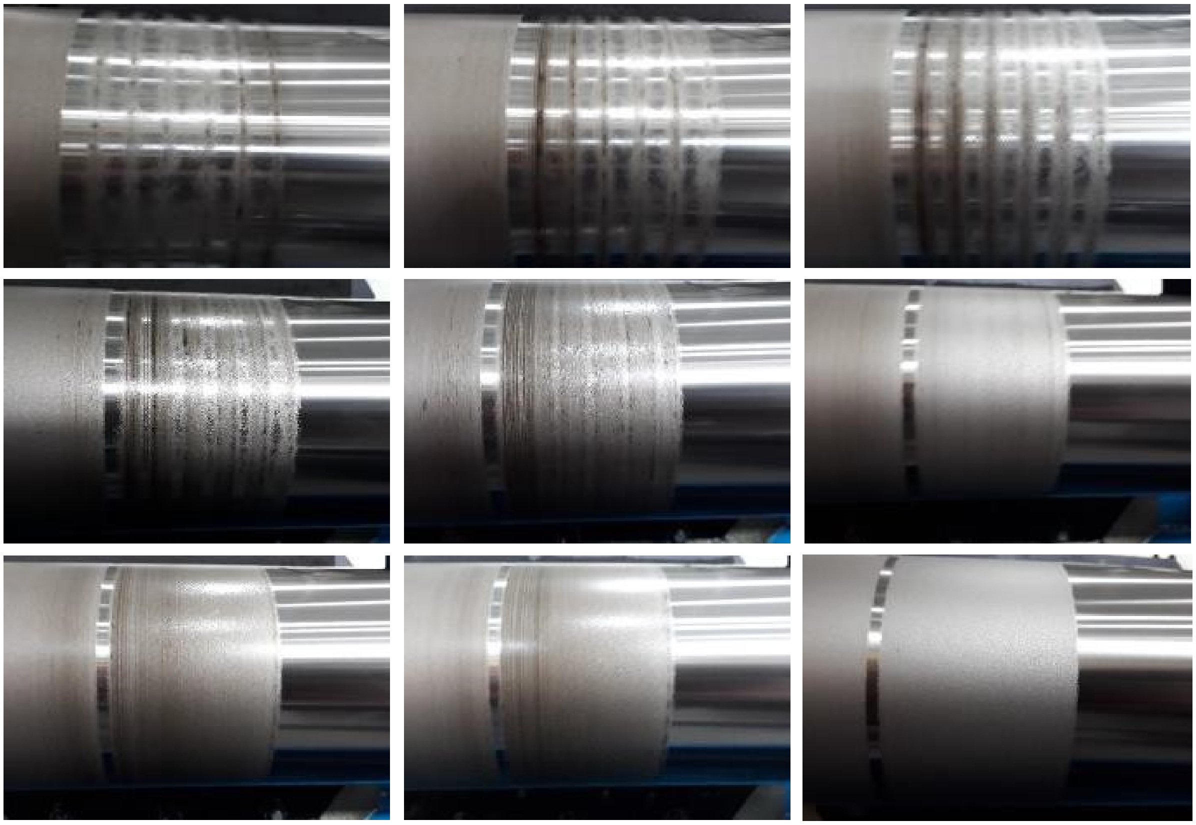


Fig. 15: Sequence showing traverse/feed lines being removed from the start of texturing (top-left) to the end (bottom-right).

CONCLUSION

A new Power Delivery module controls voltage, current and spark duration better than ever before. Independent positioning of every electrode using precision servomotors and a new Digital Servo Controller ensures absolute control of electrode-to-roll gap. Together these fundamental improvements to EDT technology combine to provide significant performance improvements.

RPc is shown to be at least 30% higher RPc than standard EDT. Standard deviation of Ra measurements is shown to be at least 25% better than standard EDT.

Rolltex MSA technology offers EDT users operational benefits in addition to quality benefits. The ability to detect and remove grinding defects improves roll shape, avoiding these defects producing costly issues with strip quality in downstream rolling processes.

REFERENCES

1. Benati, F., Effect of Surface Topography upon the Quality of Autobody Panels, Brunel University, UK, 2003.
2. Descoeudres, A., Characterization of electrical discharge machining plasmas, Lausanne, CH, 2006.
3. Toma, E., Simion, C., Electrical Efficiency of EDM Power Supply, Nonconventional Technologies Review, Romania, September 2004.
4. BS EN 10049:2013, Measurement of roughness average Ra and peak count RPc on metallic flat products, ISBN 978 0 580 81440 2.
5. Sarclad Rolltex EDT Technical Specification, Sarclad, UK, 2023.

