Limiting Contradictions In A Photographic Paper Manufacturing Process

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Introductions

Engineering systems, and particularly their associated production manufacture operations, are subject to limits in their fundamental capability. Understanding how and why these limits occur is an essential precursor to overcoming them. This article builds on previous work examining the limiting contradictions phenomenon and provides a graphic illustration of the dynamics of system evolution in action.

The focus of the article is the film coating process employed in the large-scale manufacture of photographic printing paper. The article plots the historical evolution of the process from its inception to the present day. Figure 1 provides a simplified summary of the overall process.

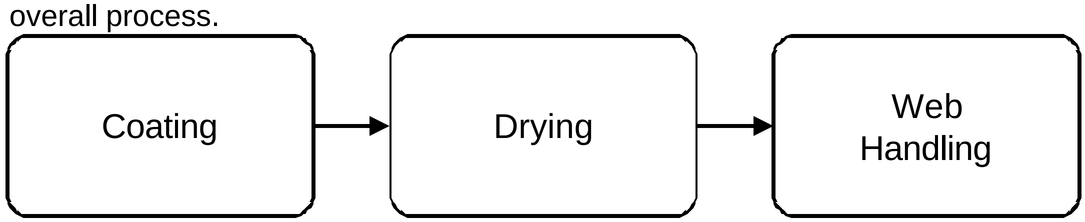


Figure 1: Paper Coating Process Summary

The process is described in more detail in Reference 1. The theme of that paper was to describe the evolution of this paper coating process through the lens of contradiction emergence and resolution. Rather than repeat the content of that work here, we merely need to review the idea that improving the output capability of the process happens through a series of different design generations. As suggested by Figure 2, these generations may be observed as a series of s-curves. The Figure 2 image – reproduced from Reference 1 – hides a considerable amount of detail. The aim of this paper is to expand the story of the evolution of the process by providing a more detailed analysis of how the system has changed since its initial inception.

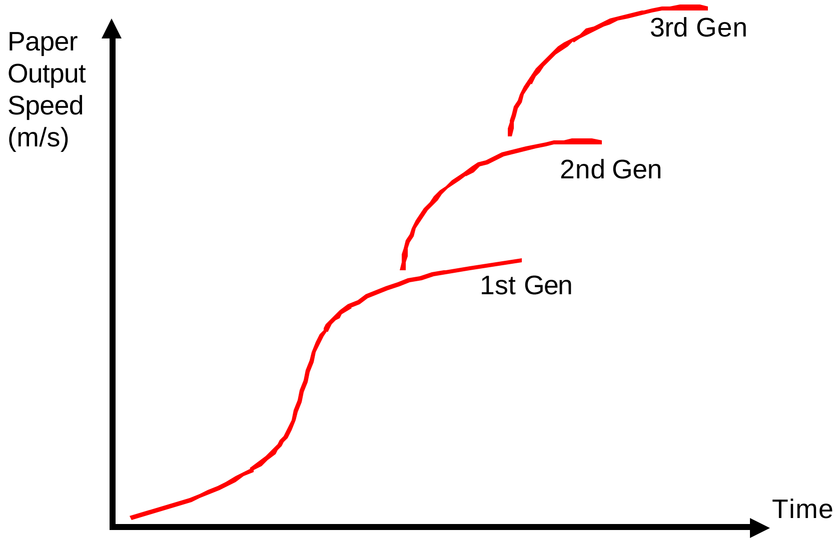


Figure 2: Paper Coating Process Summary

One of the main ideas of Reference 1 was that the evolution of the system happened through the resolution of a progression of different contradictions in which new ones emerge as existing ones become resolved. The story is complicated by the presence of the three different stages in the manufacture process. As is suggested by the history shown in the following table, it is possible to identify the speeds at which different parts of the process hit their respective limits.

Process Speed (m/min)	**Coating**	**Drying**	**Web Handling**
5	Air Blade	Festoon	Manual joins
6	Air blade	Festoon	Manual Joins Contradiction
6 8	Air Blade Air Blade	Festoon Festoon Contradiction	Twin Turret Contradiction solved Twin Turret
8	Air Blade	Spiral Contradiction solved	Twin Turret
10	Air Blade Contradiction	Spiral	Twin Turret
10	Slot Coating Contradiction solved	Spiral	Twin Turret
15	Slot Coating	Spiral Contradiction	Twin Turret
15	Slot Coating	Flat Bed Air Impingement Contradiction Solved	Twin Turret
20	Slot Coating	Flat Bed Air Impingement	Twin Turret Contradiction
20	Slot Coating	Flat Bed Air Impingement	Semi Auto Join Contradiction solved

25	Slot Coating Contradiction	Flat Bed Air Impingement	Semi Auto Join
25	Cascade Coating Contradiction solved	Flat Bed Air Impingement	Semi Auto Join
60	Cascade Coating	Flat Bed Air Impingement	Semi Auto Join Contradiction
70	Cascade Coating	Flat Bed Air Impingement	Automated Join Contradiction solved
120	Cascade Coating	Flat Bed Air Impingement Contradiction	Automated Join
150	Cascade Coating	Air Impingement Folded Contradiction Solved	Automated Join
200	Cascade Coating Contradiction	Air Impingement Folded	Automated Join
250	Curtain Coating Contradiction solved	Air Impingement Folded	Automated Join
280	Curtain Coating	Air Impingement Folded Contradiction	Automated Join
300	Curtain Coating	Air Flotation Folded Contradiction Solved	Automated Join
330	Curtain Coating	Air Flotation Folded	Automated Join Contradiction
350	Curtain Coating	Air Flotation Folded	Moving Web Contradiction solved
400	Curtain Coating	Air Flotation Folded Contradiction	Moving Web

The table highlights the fact that each of the three different parts of the process has at one time prevented further increases in the speed of the process due to the emergence of a conflict – there was a desire to increase the speed of the process, but something fundamental prevented that increase. In each case, further overall process speed increases only became possible once the emergent contradiction had been solved.

As reported in Reference 1, by way of example, when the process hit its limit at 8m/min, the drying process had hit its limiting contradiction as the length of building required to hold the festoons of paper became insufficient. The only way to obtain further increases in speed was if the contradiction could be solved. As shown in Figure 3, the contradiction was solved by evolving a spiral-form dryer arrangement.

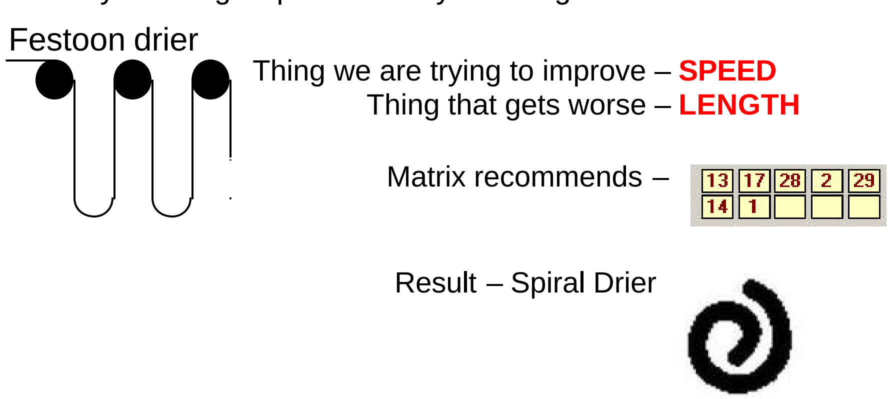


Figure 3: Emergence And Resolution Of The Festoon Dryer Contradiction

In order to better illustrate the dynamics of the evolution of the manufacture process it is helpful to see the process via an animation.

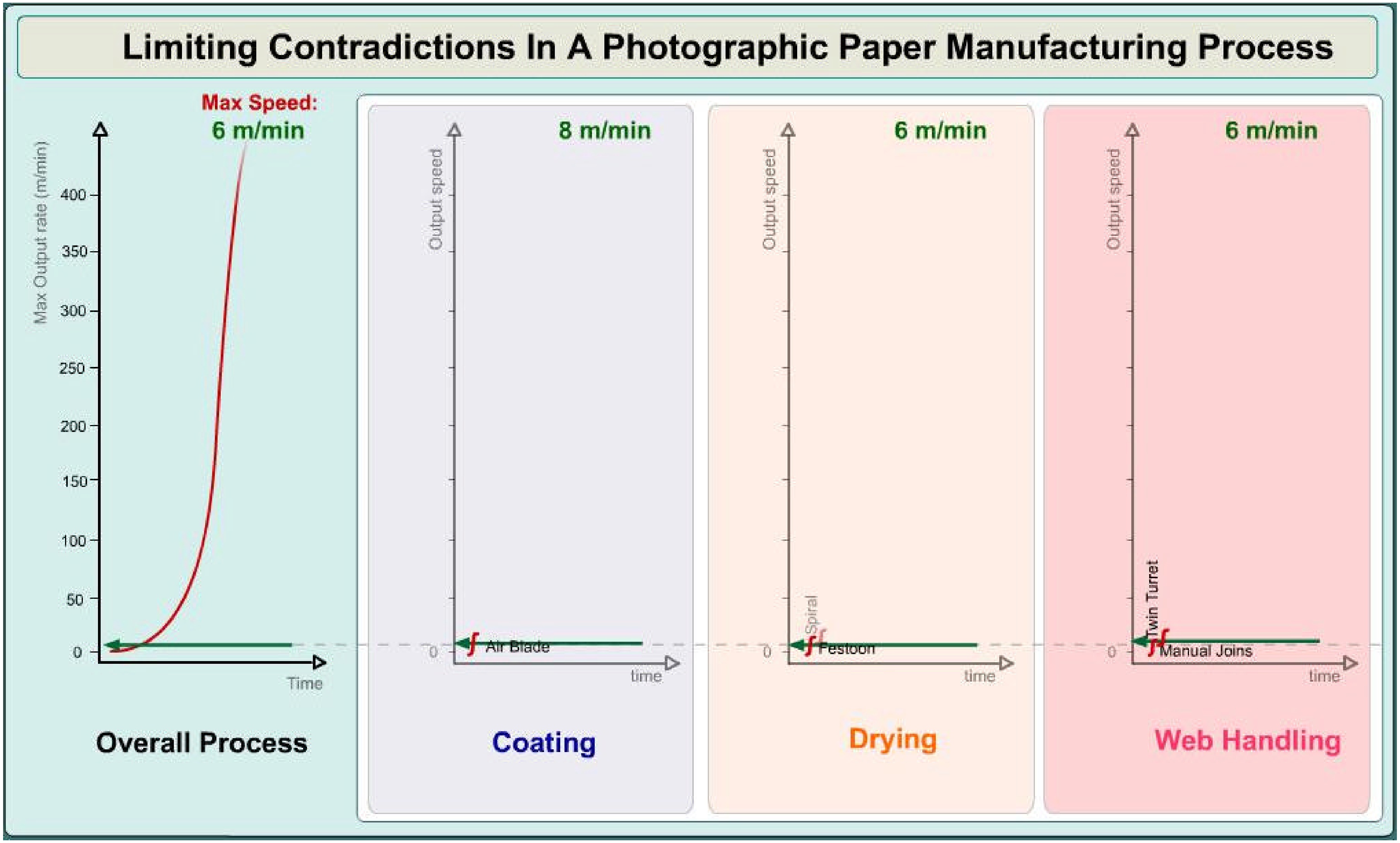
Illustrations can be observed at the end of this paper.

Essentially, the animation shows how different technologies reached their fundamental limits (reached the top of their s-curve), and how a new s-curve emerged once the limiting contradiction was resolved. This animation illustrates and provides the main purpose of this article.

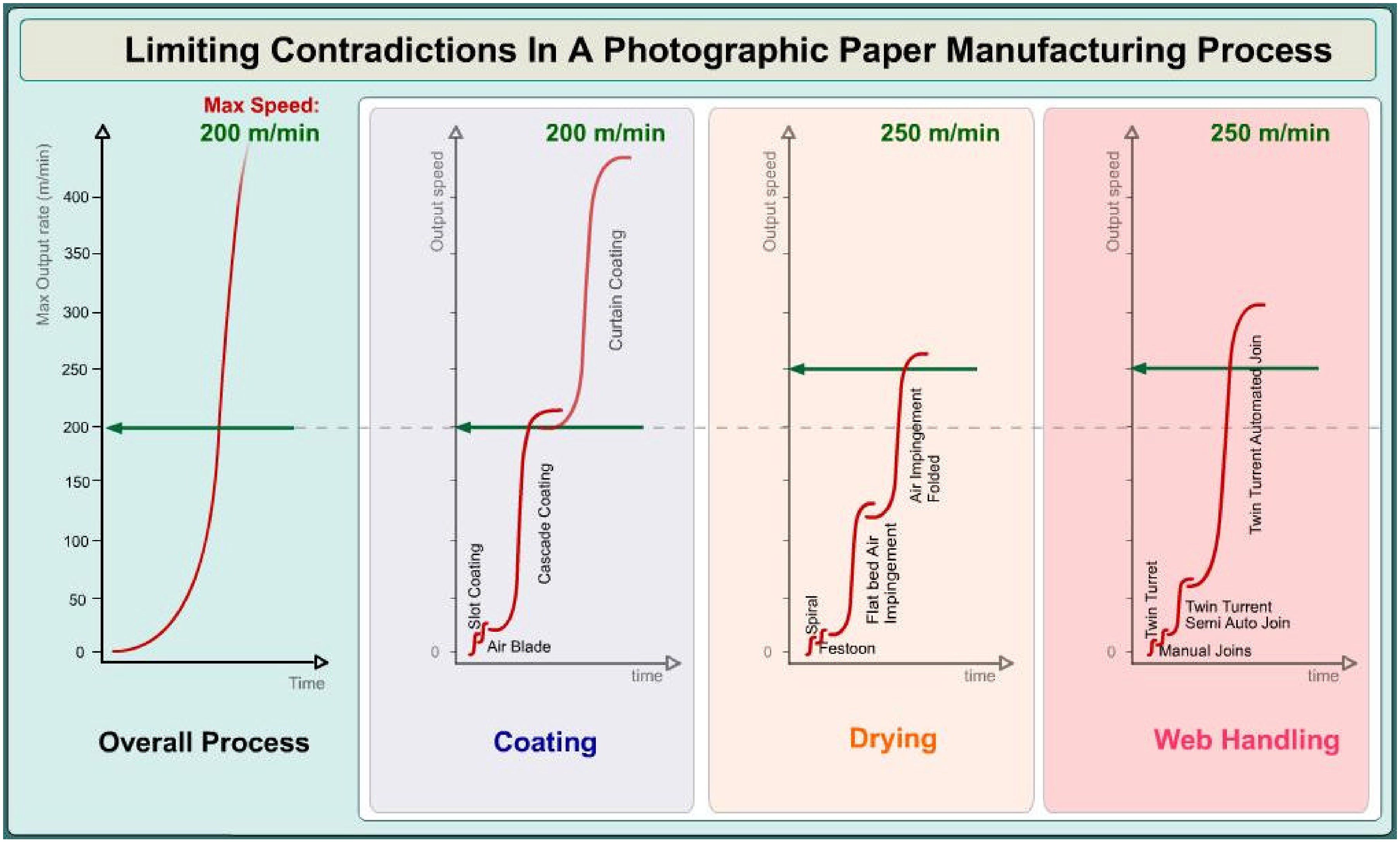
As suggested by the final entry in the table, the current limit on the system is again back with the drying part of the process. Again also, the limiting contradiction is related to the length of the facility required to accommodate the current folded air-flotation design style. Anyone interested in examining possible next evolution steps may wish to explore some of the Inventive Principles illustrated in Figure 3.

References

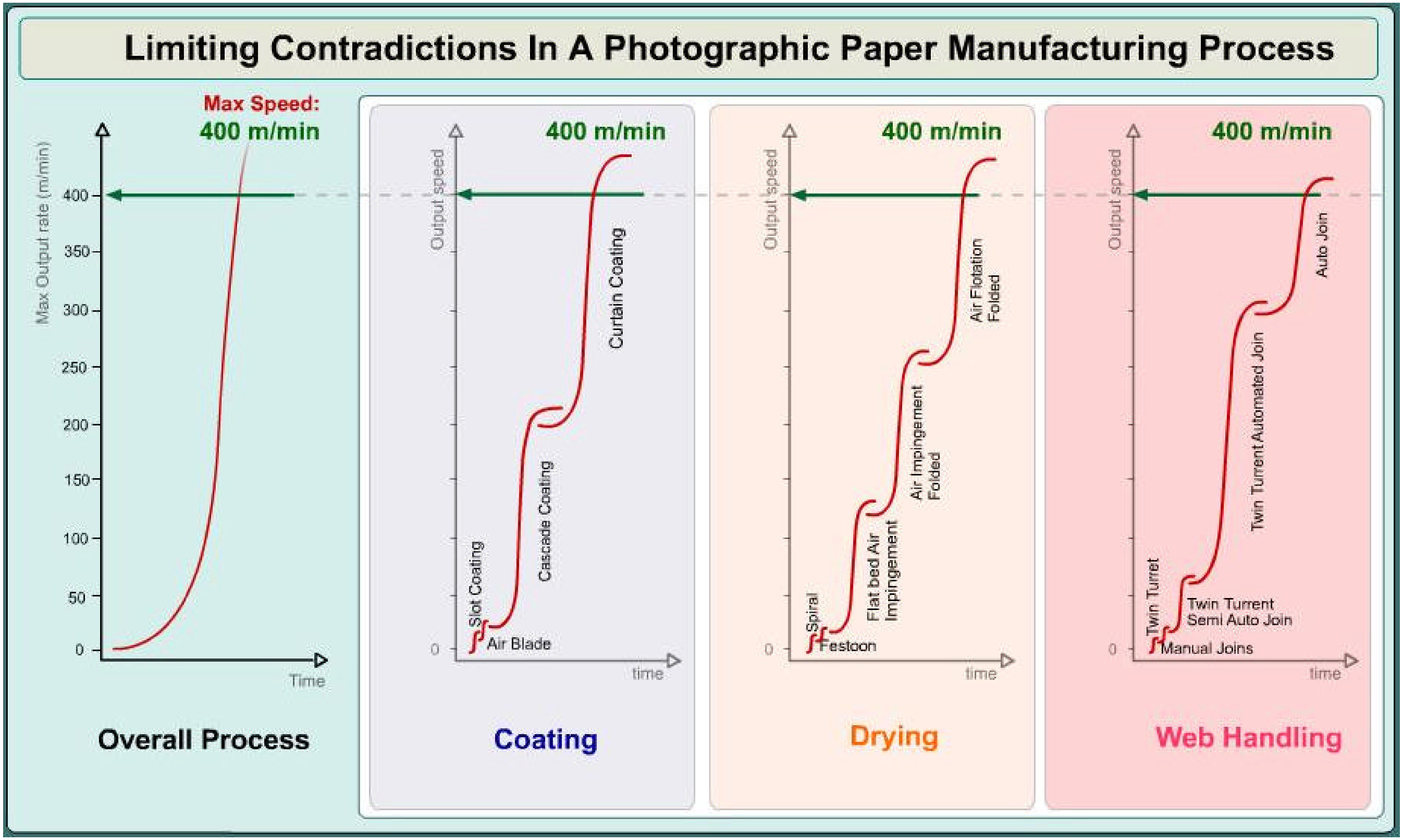
1) Mitchell, I., Mann, D.L., 'Overcoming Limiting Contradictions In a Continuous Manufacturing Process', ETRIA TRIZ Future conference, Strasbourg, November 2002 (copies available from D.L.Mann upon request).



Limiting Contradictions In A Photographic Paper Manufacturing Process
Max Speed:
6 m/min
Max Output rate (m/min)
400
350
300
250
200
150
100
50
0
Time
Overall Process
8 m/min
Output speed
0
Air Blade
time
Coating
6 m/min
Output speed
0
Spiral
Festoon
time
Drying
6 m/min
Output speed
0
Twin Turret
Manual Joins
time
Web Handling



Limiting Contradictions In A Photographic Paper Manufacturing Process
Max Speed:
200 m/min
Max Output rate (m/min)
400
350
300
250
200
150
100
50
0
Time
Overall Process
200 m/min
Output speed
Curtain Coating
Cascade Coating
Slot Coating
Air Blade
0
time
Coating
250 m/min
Output speed
Air Impingement Folded
Flat bed Air Impingement
Spiral
Festoon
0
time
Drying
250 m/min
Output speed
Twin Turrent Automated Join
Twin Turret
Twin Turrent Semi Auto Join
Manual Joins
0
time
Web Handling



Limiting Contradictions In A Photographic Paper Manufacturing Process
Max Speed:
400 m/min
Max Output rate (m/min)
400
350
300
250
200
150
100
50
0
Time
Overall Process
400 m/min
Output speed
Slot Coating
Air Blade
Cascade Coating
Curtain Coating
time
Coating
400 m/min
Output speed
Spiral
Festoon
Flat bed Air Impingement
Air Impingement Folded
Air Flotation Folded
time
Drying
400 m/min
Output speed
Twin Turret
Manual Joins
Twin Turrent Semi Auto Join
Twin Turrent Automated Join
Auto Join
time
Web Handling