High Quality Printing with CFD

Uteco Converting S.p.A. is the world leader in the production of printing machines designed for the most diverse flexible packaging applications.
Uteco offers innovative solutions through its broad range of flexographic and rotogravure printing machines, laminating machines and high-tech machines with special configurations, while constantly focusing on research and innovation.

Introduction

High production rate and printing quality are not alternative choices when talking about Uteco printing machines. These are pre-requisites that are met by the adoption of the most advanced technologies in the fields of research, design, production and services. Among these technologies Uteco has decided to apply Computational Fluid Dynamics to support the design of its printing machines. In particular CFD simulation has been applied to study and improve the printing and the ink drying processes.

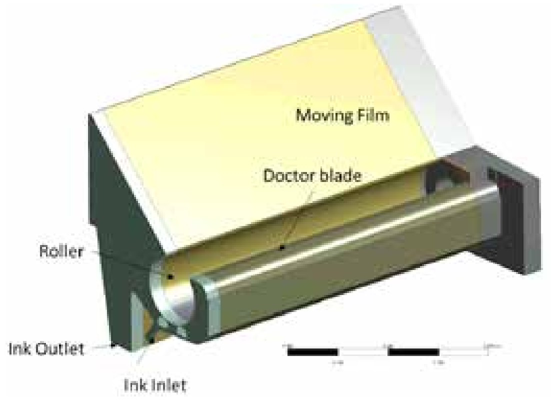

Figure 1 – 3D CFD model of the Rotogravure Press

High Quality Printing at High Rate

When printing at high speed with Rotogravure Presses (Figure 1) the printing quality might be affected by air entrainment, that is mainly due to two distinct phenomena. The first type of air entrainment is due to air drag associated to the high rotational speed of the roller. The second type of air entrainment is due to ink splashing produced by the drag of the roller onto the ink (Figure 2).

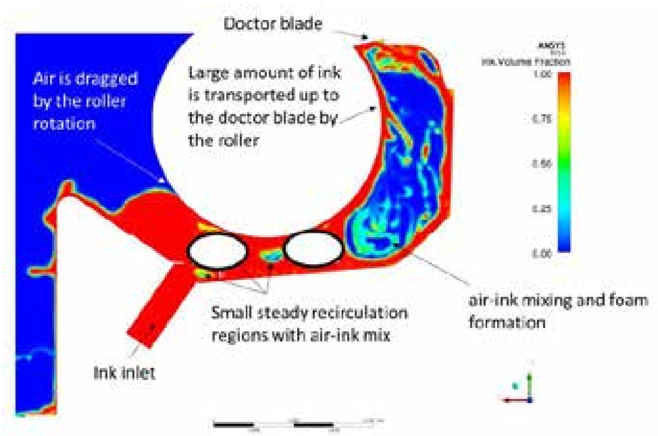

Figure 2 – 2D slice showing in red the ink distribution and the ink spalshing due to the roller drag and the effect of the doctor blade

Both the two phenomena increase their negative effect on the printing quality as the production rate increases, and both of them can be managed by adopting appropriate design solutions.
Regarding the air dragged by the rotating roller at the interface with ink, Uteco developed solutions based on specific devices, that are located below the roller and that reduce the amount of entrained air.
In this case CFD simulation was used to understand the phenomenon and to design the geometry that reduce to a minimum the risk of having printing defects.
The ink splashing is instead something that was initially less clear and intuitive. What was clear is that that the printing defects were due to air bubbles inside the ink volume, but the question was: "Where do the bubbles come from?".
What is actually visible looking at the printing machine is just foam at the ink free surface. Uteco and also customers perceive foam as something to be avoided and associate foam to potential printing defects.

In reality foam is only a symptom of the real source of printing defects, that is ink splashing.
Ink splashing takes place in the rear, hidden area of the machine, where ink is lifted up by the roller and then suddenly put to a halt by the "doctor blade". The consequence is that ink tends to fall and splash at high velocity, thus mixing with air and generating foam. Foam is generated in this hidden part of the machine and then moves together with the main ink stream and it is made visible in the front part of the machine.
So foam is produced by ink splashing, but it is not the cause of printing defects. As a matter of fact ink splashing produces also air entrainment and air bubbles growth inside the ink volume just beneath the roller. This is what must be avoided or limited.
The CFD modeling of the Rotogravure printing process allowed to understand these kinds of phenomena and once the source of the problem was known, finding the solution was quite easy.
A new system was implemented to minimize ink splashing and mixing between air and ink. Air bubbles in the ink volume are prevented from reaching the printing area and at the same time foam generation is limited.

The CFD simulations of the Rotogravure Press were developed both using 2D and 3D models. The 2D model was helpful to understand the physical phenomena associated to the ink-air interaction and to verify the efficacy of the new system in terms of air entrainment reduction. The same 2D models allowed also to understand that it is fundamental to dispose the air bubbles by facilitating air movement from the area close to the roller to less risky areas away from roller. The 3D CFD models allowed to calculate and visualize the extension of the air bubbles underneath the roller in different geometrical configurations. It is quite evident from the results that the new system reduces the dimension of the air bubbles and creates a pressurization of the ink volume, that helps to decrease air entrainment also at the sides of the roller, where most of the printing defects are located.

The 3D model clearly demonstrated also the improvements in terms of ink flow distribution towards the ink recirculation system, that is located in the visible area of the machine (Figure 3). This aspect, together with the limited foam formation, can be regarded also as an "aesthetic improvement" of the machine fluid-dynamic behavior and is perceived as a proof of high quality printing from the customer's perspective.

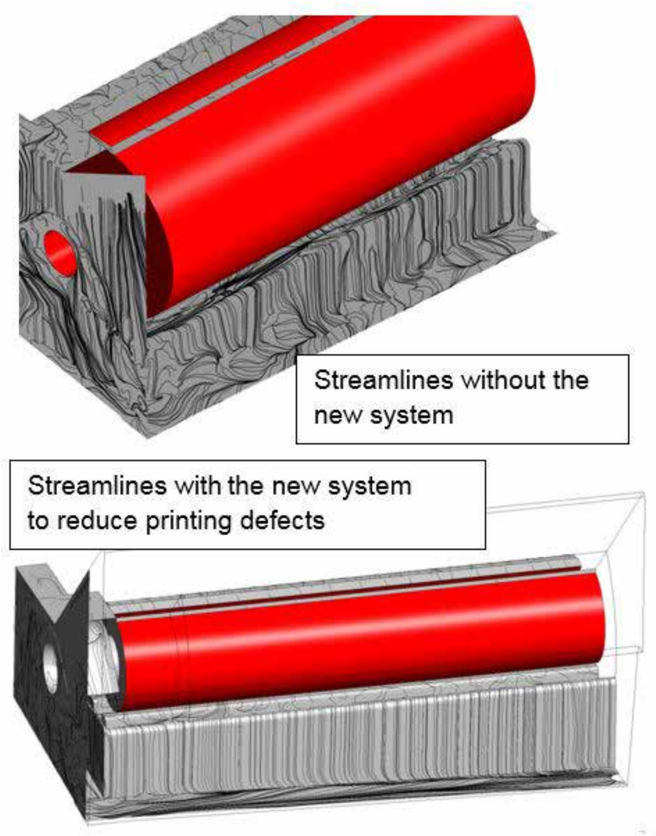

Figure 3 – comparison of ink streamlines without (upper picture) and with (lower picture) the new system to reduce printing defects

Efficient Ink Drying

After the printing phase, the volatile part of ink has to be evaporated. The volatile part might be water or chemical solvents. The first challenge about ink drying is to fully evaporate the volatile part on a fast moving film. The second one is to prevent the vapor

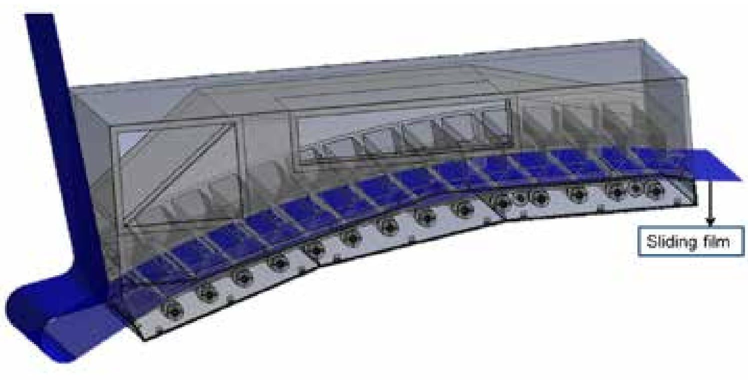

Figure 4 – Large air box with multiple nozzles

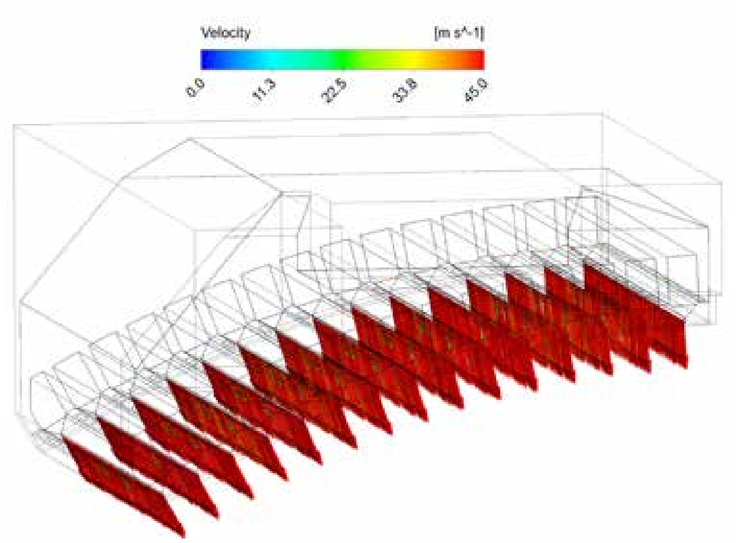

Figure 5 – Air velocity vectors, showing uniform air flow impinging on the moving film

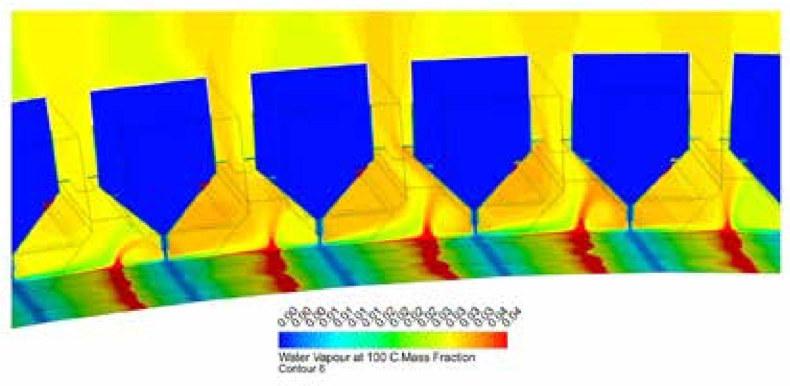

Figure 6 – Vapor concentratuion in the evaporation and suction areas

from escaping into the external environment, where operators are located and might smell chemical solvents.
The drying process is done through air boxes with multiple nozzles that impinge hot air on the moving film (Figure 4 and Figure 5).
The design of ink drying systems has been heavily supported by CFD with multiple objectives, like evenly distribute the air flow at the nozzles, assure the total ink evaporation, reduce the pressure losses in the air boxes, evaluate the minimum suction or flow rate to prevent solvent escape.
In few words the aim is to evaporate the ink with the minimum energy and in a safe way.

The first and most important design objective is to make sure that each nozzle is fed with the same amount of air and that the velocity along the linear nozzle is uniform (Figure 5). If this target is reached, then the evaporation rate will be uniform on the moving film.
But this is not enough, the total volatile matter evaporation must be guaranteed before the exit of the film from the drying area. For this reason the CFD models, in addition to predicting the velocity distribution, must be able to explicitly simulate evaporation and the transport and diffusion of vapor.

Specific models have been implemented to predict the evaporation rate both for water and chemical solvents. The same models allow also to estimate for each type of solvent the minimum operating temperature to guarantee total evaporation (Figure 7). This kind of information is of paramount importance both for the printing quality and to minimize energy consumption, that are two of the reasons why customers purchase Uteco printing machines.
After the evaporation, vapor suction must be guaranteed for safe operation. This is done by reducing the area where solvent vapor can escape to the external environment and by creating a proper suction effect. Also in this case CFD modelling allows to predict vapor escape and to calculate the minimum suction level that assures total vapor capture with the minimum energy consumption.

Conclusions

In the search for quality and innovation Uteco Converting makes extensive use of Computational Fluid Dynamics, mainly to guarantee and improve printing quality, with minimum energy consumption and in safe conditions for the operators.
CFD has been applied to the simulation of Rotogravure Presses to prevent printing defects and improve the fluid-dynamic behavior of the presses. It has also been applied to the ink drying process, where the high production rate, the energy consumption and safety aspects make the solvent evaporation a real challenge.

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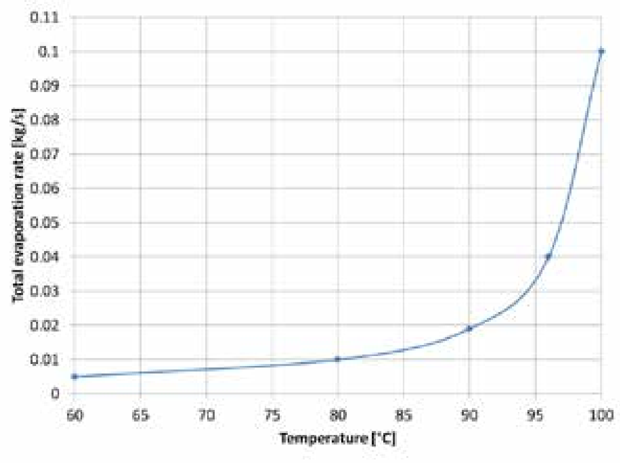

Figure 7 – Ink evaporation from the moving film versus operating temperature