Analysis of Doctor Blade Loading and Wear

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Abstract

Rotogravure printing is used to produce high speed, high quality printed product. One of the key parameters in controlling the process is the doctor blade. This removes ink from the non-image areas and meters the ink in the cell. The purpose of this paper is to evaluate the doctor blade performance and investigate the difference between the set and wipe angles. Doctor blades have been collected from commercial printing operations and cross sectional analysis performed to evaluate the blade tip. These results show the amount of wear undergone and from this the actual wiping angle can be obtained. The data has then been used in a simplified numerical model to evaluate the contact between the doctor blade and cylinder. The results show both the deflection of the blade and the sensitivity of the system to changes in the doctor blade load. A parametric study has been carried out on the doctor blade evaluating the doctor blade and process settings on the blade setting.

Introduction

Doctor blades are used in many printing, coating and paper applications including rotogravure, flexography, pad printing and paper creping. The purpose of the doctor blade changes between the different applications, from removing excess ink in rotogravure to sealing the anilox chamber in flexography. The focus of this paper will be with specific respect to rotogravure printing.

Rotogravure printing is a high speed, high quality printing process, shown schematically in Figure 1. An engraved cylinder carries the images. This rotates in an ink bath with the individual cells being filled with ink. This is metered with a doctor blade and the image is transferred to the substrate under impression. The doctor blade removes the excess ink in the non-image areas to prevent print faults such as hazing / scumming / streaks. In the image areas it meters the ink in the cells to ensure a consistent ink transfer. The pressure

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applied to the blade should be as low as possible to minimise wear on the rotogravure cylinder.

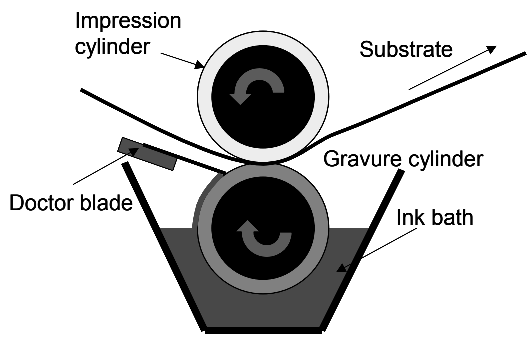

Figure 1 Schematic of the rotogravure process

The angle of the blade is important to obtain a quality print and is often one of the parameters that may be altered on the press to remove print faults. It is typically set at 60 degrees, but in many companies this is not measured and can vary between 55 to 70 degrees, Figure 2. If the angle is to steep problems such as chatter marks due to vibration. To low an angle can give rise to scumming and particles becoming caught under the blade, which is a cause of streaking. As with many manufacturing situations it is the interaction of all the components that determine the final product quality.

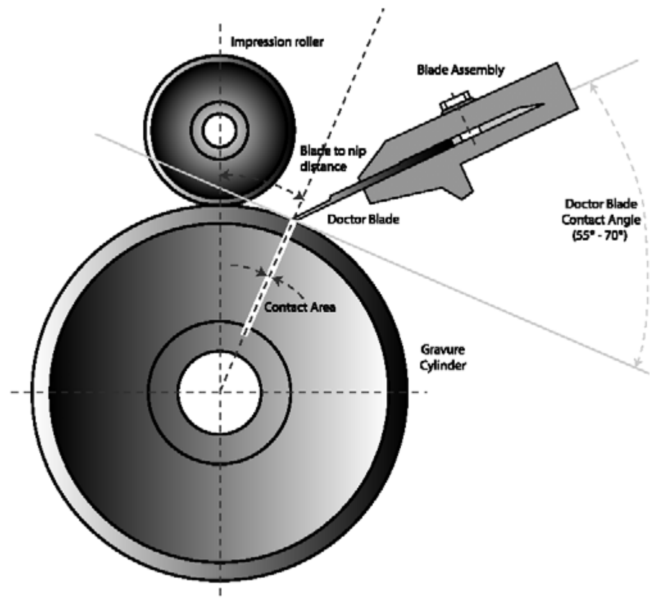

Figure 2 Doctor blade configuration

The doctor blades are mounted in a holder with a backing blade, which is used for stiffening, Figure 3. The set angle of the blade is different from the actual wiping angle. The exact positioning, backing blade and blade type vary between printers. Different blade types are used dependent on the application. These will vary from straight, bevelled through to lamella type, which also may have coatings to enhance the life of the blade.

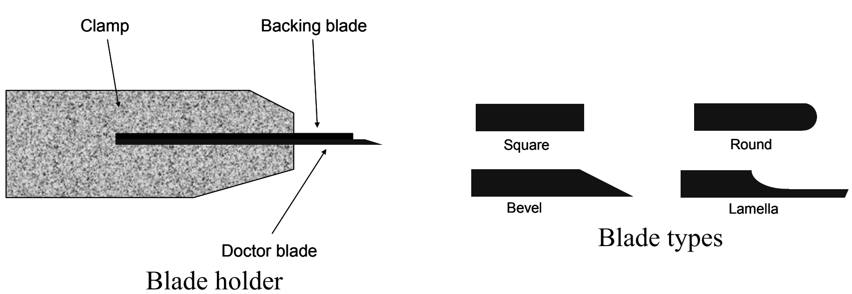

Figure 3 Doctor blade holder and types

The focus of the paper is to evaluate the doctor blade configuration, explore the actual angle that the blade is operating at and how this is affected by the set up.

This is achieved by numerical modelling the blade coupled with experimental evaluation of the tip profiles to measure the wiping angles.

Model background

Finite element modelling has been used to evaluate the blade deflection. Further details can be obtained from [1], [2]. The methods involved discretising the doctor blade and holding material into a number of small elements. The fundamental equations for the problem are those for displacement and force. These are solved for the individual elements and then across the whole problem to obtain a solution. The three sets of matrices used are shown below, with an exact solution being possible for the linear finite model.

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix} = \begin{bmatrix} \frac{\partial}{\partial x} & 0 & 0 \\ 0 & \frac{\partial}{\partial y} & 0 \\ 0 & 0 & \frac{\partial}{\partial z} \\ \frac{\partial}{\partial y} & \frac{\partial}{\partial x} & 0 \\ \frac{\partial}{\partial z} & 0 & \frac{\partial}{\partial x} \\ 0 & \frac{\partial}{\partial z} & \frac{\partial}{\partial y} \end{bmatrix} \begin{Bmatrix} \mathrm{u} \\ \mathrm{v} \\ \mathrm{w} \end{Bmatrix} \qquad \text{or,} \qquad \{\varepsilon\} = [\mathrm{B}]\{\delta\} \qquad \ldots 1$$

where $\{\varepsilon\}$ is the strain matrix, $[\mathrm{B}]$ the derivatives matrix and $\{\delta\}$ the displacement

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{xz} \\ \tau_{yz} \end{Bmatrix} = \frac{\mathrm{E}(1-\nu)}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1 & \frac{\nu}{1-\nu} & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ \frac{\nu}{1-\nu} & 1 & \frac{\nu}{1-\nu} & 0 & 0 & 0 \\ \frac{\upsilon}{1-\nu} & \frac{\nu}{1-\nu} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1-2\nu}{1-\nu} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1-2\nu}{1-\nu} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1-2\nu}{1-\nu} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix}$$

$$\text{or,} \qquad \{\sigma\} = [\mathrm{D}]\{\varepsilon\} \qquad \ldots 2$$

where $\{\sigma\}$ is the stress vector and $[\mathrm{D}]$ the stress strain matrix

$$[\mathrm{B}]^T \{\sigma\} = -\{f\} \qquad \ldots 3$$

where $\{f\}$ is the vector forces. These can be combined as shown below to eliminate both the stress and strain vectors, leaving the solution a function of the force and displacement.

$$\begin{aligned} [\mathrm{B}]^T \{\sigma\} &= -\{f\} \\ [\mathrm{B}]^T [\mathrm{D}] \{\varepsilon\} &= -\{f\} \\ [\mathrm{B}]^T [\mathrm{D}] [\mathrm{B}] \{\delta\} &= -\{f\} \end{aligned} \qquad \ldots 4$$

Experimental evaluation of doctor blades

It is important to be able to measure the actual working angle of the doctor blade, as this is different from the set angle. The objective of the experimental evaluation was to evaluate the magnitude of this angular difference. This could then be used as the start point in the numerical analysis. Samples were collected from actual print production with the blade set angle being recorded. These were collected from a number of print companies using different presses and doctor blade configurations.

The wiping angle was measured from the blade. A number of techniques were evaluated. The technique selected was to take cross sectional samples from the doctor blade. This was destructive but allowed the samples to be post processed by different methods from image processing through to SEM. The results presented in this paper have been derived from image processing.

The blades were cut into sections from the full strip at various locations across the width. These were then mounted in springs and cast in resin. The samples were lapped to expose the wiping angle. Typical results obtained from the views are shown in Figure 4. These clearly show the wear occurring on the blade and it is possible from this to calculate the wiping angle.

Figure 4 Cross sectional view of doctor blade

Results and discussion

A simplified blade model was used for the analysis of the effect of blade set up and performance on the wiping angle. The model represents a doctor blade that has been clamped in a holder with a backing strip supporting it, as shown in Figure 5. This also shows the mesh used within the finite element analysis at the blade tip. The boundary conditions are such that the doctor blade and backing blade were fixed in both the X and Y directions at the base. A load has been applied to the face of the blade tip to simulate the loading, Figure 5. The initial set angle of the blade used is 60^0. The figures for the positional and geometric measurements are given in Table 1. This is a typical configuration used in industry.

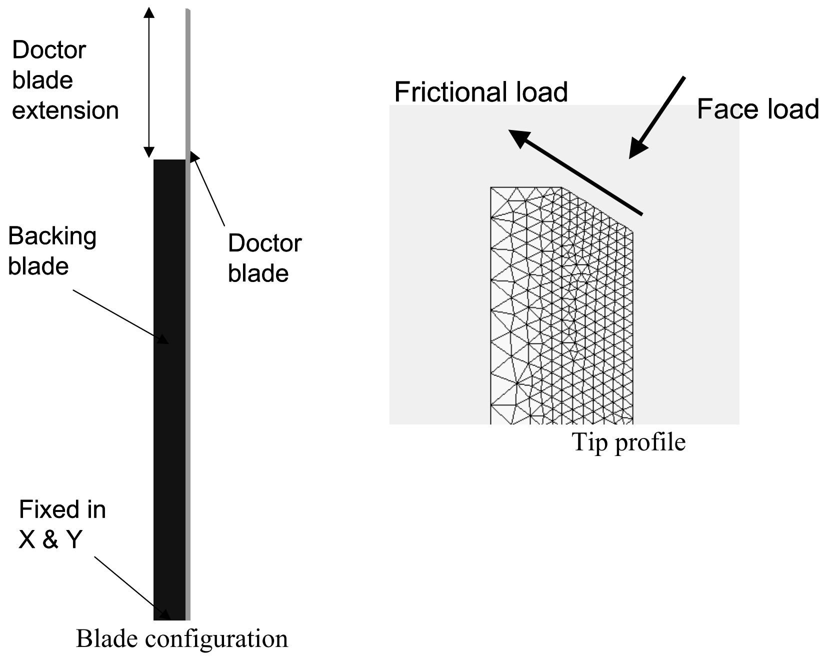

Figure 5 Doctor blade configuration

Parameter	Setting
Doctor blade thickness	0.15 mm
Backing blade thickness	1.0 mm
Doctor blade protrusion	5 mm
Backing blade length	15 mm
Initial set angle	60

Table 1 Doctor blade set up

A face load is applied to the tip. The working angle is defined by the angle at the tip. The load applied will cause a deflection in the doctor blade in both the x and y direction, Figure 6. In this analysis a normal face load has been applied. It is also possible to include a frictional tangential force if required. By analysing the position of the tip it is possible to calculate the angular displacement that the blade has undergone. From this information it is possible then to calculate the original set angle. This necessitates an iterative approach to obtaining the correct solution.

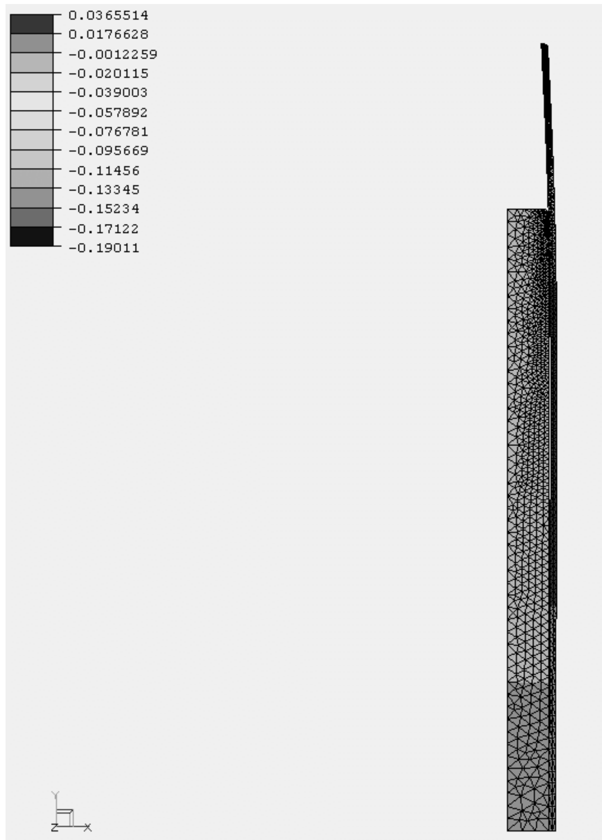

Figure 6 Deformation of the doctor blade

The analysis for the parameters outlined in Table 1 was carried out for a low fixed face load. This resulted in a working angle of 55.9 degrees, a difference from the set angle of 4.1 degrees. This a typical deflection of the blade based on the experimental data, if slightly at the low end. The effect of changing the doctor blade extension and the backing blade length are shown in Figure 7. The results indicate that for both an extension of the blade or a longer backing blade the wiping angle is further reduced from the set angle of 60 degrees. In the case of the blade extension the effect is non linear with increased angular deflection as the distance is increased. The figure clearly shows that it is the setting of the blade extension that is the critical parameter when setting the blade to ovoid problems associated with the incorrect wipe angle.

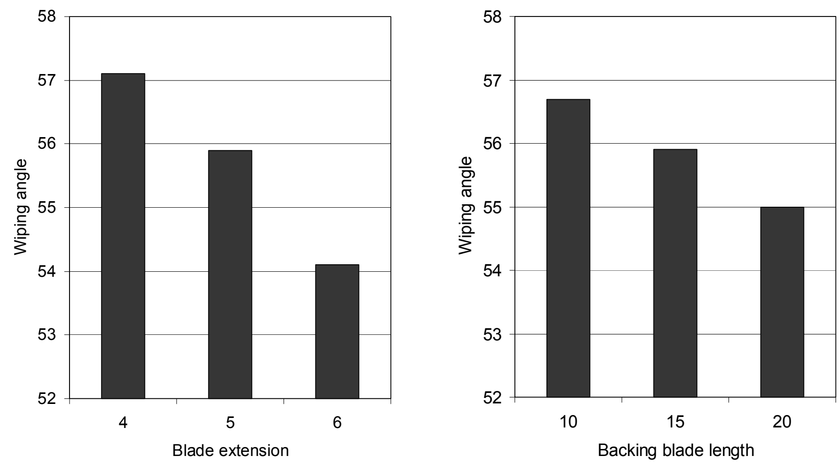

Figure 7 Effect of length changes

The influence of the thickness of the blade and backing blade are shown in Figure 8. These calculations are all carried out for the same contact area and load. Typical doctor blade thicknesses vary between 0.1 and 0.15 mm for flat doctor blades, while a thickness up to 0.25 mm can be used with lamella blades. A reduction in the thickness of the doctor blade has a dramatic change in the performance of the wiping, with a 12-degree reduction in angle. This bears out commercial practice with a much lower pressure needing to be applied. For the same deflection the load is reduced to 37% of the original load. The typical backing blade used appears close to the optimal with little variation when increased in thickness, while at the same time as the width is decreased there is a decrease in the wiping angle.

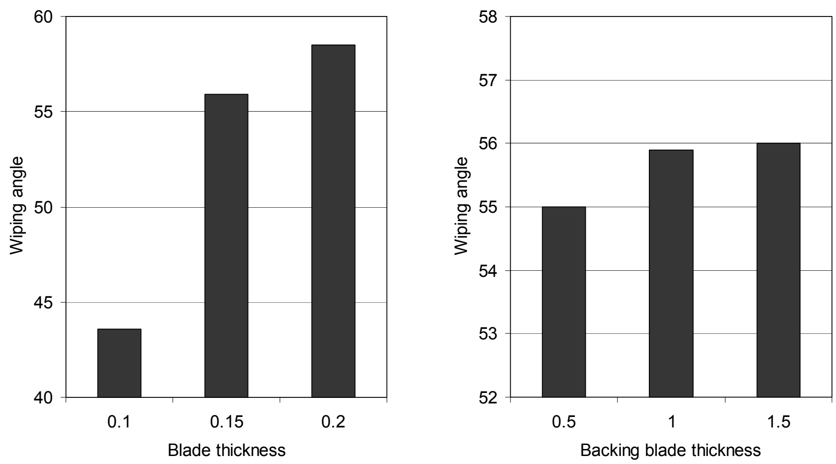

Figure 8 Effect of thickness changes

The load applied to the tip has been altered for the main operating conditions, Figure 9. These results show an increasing large and non-linear deflection as the load is increased. The loads evaluated cover a wide range of those found in commercial applications from the analysis of the difference between both the set and wiping angle.

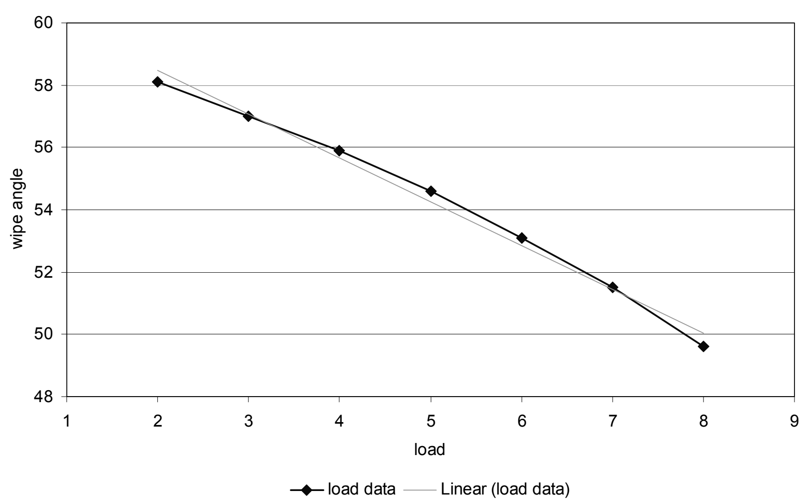

Figure 9 Effect of load

Conclusions

The difference between the set and wipe angle has been measured experimentally. A model has been successfully developed to simulate the loading conditions of a doctor blade. The experimental data has been used as the boundary conditions for the numerical model to evaluate the effect of changing blade settings. A parametric study has then been carried out to establish the sensitivity of the blade settings with respect to the wiping angle. The results can be summarised as:

- As the blade thickness is reduced it reaches a minimum past which unacceptable bending occurs.
- The correct and consistent doctor blade extension is critical to consistent printing as this has a large effect on the wipe angle.
- Changes in the backing blade properties have a much smaller effect than those made on the doctor blade.
- Increasing the load decreases the wipe angle in a non linear manner

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