1 Introduction

1.1 Background

This thesis is the result of the coalescence of the long-term goals of the Dutch government and the Dutch paper and board industries at the end of the 20th century. Over the last years the following trends could be observed that still seem to continue today:

- Additional requirements regarding the paper quality caused by the increasing importance of the appearance of products and a wide spread use of new printing techniques such as laser and colour printing (Bublinski et al. 2002; Danby 1998; Farell et al. 2002; Oittinen and Saarelma 1998; Ravary 1999; VOITH 2002).
- Decreasing quality of base material because of the continuous search for cost reduction and increasing recycle rates.
- Increasing energy prices, making high dry contents before the drying section desirable, whereas fear for quality decrease due to increased wet-pressing prevents papermakers from increasing the outgoing dry content after wet-pressing.

For the above reasons the Dutch paper and board industries have been looking for ways to increase profit by decreasing costs, for example by increasing energy efficiency and increasing revenues by increasing product quality. Therefore, the Dutch paper and board producing industry was interested to learn more about the influence of wet-pressing on final paper quality. Currently, this information is available only for a given machine, stock, and product combination.

At the same time the Dutch government, bound by the Kyoto treaty, was looking for ways to reduce the emission of greenhouse gasses. The paper and board industry, being an energy intensive industry, raised the government’s concern.

In the eighties the Dutch research organisation TNO carried out several reports on energy saving potential of the Dutch paper and board mills, among others a huge energy saving potential was identified in the wet-pressing section i.e. a cost reduction for the industry. By 1999 a considerable energy efficiency increase was realised, but the alleged potential for increase of energy-efficiency in the press section was not realised. Fear of quality loss prevented papermakers from implementing the suggestions made in the TNO report. Due to the strong interaction between the press section and paper properties, measures cannot be taken in the press section without
affecting the properties of the final product. The current wet-pressing models are strictly dewatering models and therefore do not provide the required information to allow for optimisation of the total wet-pressing performance.

The question is what is the additional information required to allow for both a reliable prognosis of dewatering rates and of paper properties, and how can this be modelled?

1.2 Aim

The starting point of this thesis work was the wet-pressing model developed at TNO by Riepen, Mulder and Sinon, which was (and still is) a state of the art dewatering model that had proven it’s validity in difficult applications such as predicting the moisture and temperature distribution in a wet sheet during Condebelt or Impulse Drying (Riepen 2000).

At first the aim of this thesis was to provide the TNO dewatering model with a more scientific base by replacing the empirical relations by general applicable engineering relations.

Therefore we explored the field by verifying a number of publications using simple experimental techniques. Evaluation of the experimental results raised the insight that the current dewater theory was insufficient to incorporate the effect of wet-pressing on paper quality in any dewatering model. Therefore the aim was focussed on understanding of the observation that an extended nip press (ENP) or shoe press yields for some furnishes a lower density than a roll nip press at equal outgoing moisture ratio. Based on this we developed the hypothesis that fibre dewatering is the key to understanding this phenomenon. Therefore we focussed from then on the development of a double continuous model allowing for the explicit calculation of the rate of fibre dewatering, including a new mechanical model of the wet web differentiating between the deformation of the network and the fibres.

1.3 Outline

A short introduction to pulp production and paper making is given in chapter 2. In addition a description is given of the different size scales at which wet-pressing can be studied.
Chapter 3 looks at the scale effects related to the difference in scale between the pore radii and the sheet thickness. Assumptions that have to be made to apply macro-scale equations to the flow in the pores, i.e. to micro-scale processes, are verified. The understanding of this theory is of crucial importance to the interpretation of experimental data.

Wet-pressing compacts paper. Chapter 4 gives an overview of the present understanding of which wet-pressing variables determine the effect of the wet-pressing on the final degree of compaction of the dried sheet. Some experimental results are presented, these show that the outgoing moisture ratio strongly influences the way wet-pressing affects the final density of the sheet, in addition it shows the effect of wet-pressing on other properties than the density. This chapter also describes our experimental equipment in detail.

Chapter 5 is dedicated to rewet theory. The Differentiated Permeability Surface Layer (DPSL) rewet theory suggested in 2000 (I’Anson and Ashworth 2000) is put to the test.

Fibre dewatering occurs under certain conditions during wet-pressing. Chapter 6 presents a method for determining the part of the fibre dewatering potential as a function of the applied pressure.

Chapter 7 presents experimental results that show the effect of wet-pressing on the inter-fibre pore radius. This is relevant to wet-pressing performance since the pore size distribution has a significant effect on the permeability of the furnish to water.

Chapter 8 describes the deformation stresses that may occur in a wet web during compaction. An attempt is made to bring the description of these deformation stresses in line with common deformation physics.

In chapter 9 the results of the different chapters are used to improve the insights obtained by the existing wet-pressing models. Using this new insight a new approach is suggested to evaluate the difference between roll nip presses and so-called shoe nip or extended nip presses on the paper properties.

1.4 Vocabulary

In this work some words have a specific meaning, that may differ from normal English usage. Below is a short dictionary of words the specific meaning of which may not be immediately clear from the context:
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Material made of fibrous vegetable material deposited from an aqueous suspension. In this thesis paper is used as a general term for the finalised product independent of base weight, i.e. including board.</td>
</tr>
<tr>
<td>Board</td>
<td>Paper of a high base weight, normally &gt; 170 g/m².</td>
</tr>
<tr>
<td>Web</td>
<td>During the production process of paper, a continuous web is formed in the sieve section at the start of the paper machine. In the subsequent process steps this web is dewatered and the surface of the web is prepared for specific applications. The web remains unbroken and is wound on the winder at the end of the paper machine. Therefore, we use the word web to indicate the paper while it is being produced on the machine.</td>
</tr>
<tr>
<td>Hand sheet</td>
<td>A piece of paper made on a laboratory sheet former, i.e. instead of a continuous web a single sheet is formed. Hand sheets are used to study on a laboratory scale, i.e. before pilot tests, the effect of changes to the pulping process and/or the paper machine on the final paper quality.</td>
</tr>
<tr>
<td>Sample</td>
<td>Piece of web or hand sheet before it is dried, as used in the wet-pressing tests described in this thesis.</td>
</tr>
<tr>
<td>Furnish</td>
<td>Reference to the composition of the paper. For example the sentence: “We used different furnishes”, means that we used samples differing in the type of pulp.</td>
</tr>
<tr>
<td>Freeness</td>
<td>The freeness of a pulp is an indication of it’s dewaterability. Two methods exist to measure freeness: the Schopper-Riegler test, with the result expressed in SR units, and the Canadian Standard Freeness test, with the result expressed in CSF units.</td>
</tr>
<tr>
<td>Machine width</td>
<td>Width of the paper machine, also referred to as cross direction (CD).</td>
</tr>
<tr>
<td>Machine direction</td>
<td>Machine direction (MD) is the direction parallel to the length of the paper machine. In most fast producing paper machines</td>
</tr>
</tbody>
</table>
the fibres are aligned parallel to this direction.

**Nip**
Contact area between paper, roll and felt(s), location in the press where pressure is applied to the paper.

**Nip length**
The nip covers an area. The dimension in MD is called the nip length and the dimension parallel to the CD is called the machine width.

**Line pressure**
The pressure at mid-nip if the nip was the line of contact between the two rolls forming the nip, i.e. load applied to the axes of the rolls divided by the machine width. In practice the line of contact widens to a contact area, providing the nip with a length and a width.

**Press impulse**
The pressure applied in the nip integrated over the time during which the pressure was applied. According to conventional dewatering theory the degree of dewatering of a certain furnish remains constant if the press impulse remains constant. The press impulse can be calculated as the ratio of the line pressure over the machine speed.

**Strain**
Distortion of a material by forces acting on it. The strain is the ratio of the deflection to the dimension of the material before distortion and is therefore without unit.

**Stress**
The (reaction) forces per unit area within a material tending to change the material's dimensions. Stresses are the result of forces acting on a material.

**Hydraulic pressure**
The pressure exerted by water on its surroundings. Hydraulic pressure decreases to zero when the forces acting on the water decrease to zero, i.e. when the flow resistance met by the water decreases to zero or when the applied load is removed.

**Structural pressure**
Part of the stress in the material that causes the net deformation of the material.
1.5 References


VOITH “Science Dialog PROcess & PROgress.” *International Customer Conference*. 