EXPERIMENTAL INVESTIGATIONS IN WINDING AND UNWINDING OPERATIONS

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ABSTRACT

The trend in winding in the paper industry can be simply characterized by : wider and faster with more dense webs with a lower level of accepted defects. This is valid for paper production and printing, especially in rotogravure.

Europe's rotogravure industry is investing in wider printing machines : 3.08 m - 3.18 m - 3.48 m - 3.52 m - 3.60 m. These machines are already ordered and the widest will start up end of 1997. In the unwinding process the techniques of fiber cores is running to the edge of physical limits : vibrations. Experimental natural frequency analyses and trials on a core rotational test stand demonstrate limits and potentials of cores and unwind stands.

Jumbo reels in roto are exceeding masses of 5 tons. In the unwinding situation bursts near the core occur - the more often, the wider and heavier the reels are. A systematic winding test on a production winder with a modified unwind stand demonstrate the creation of bursts and leads to a method to avoid center bursts in jumbo reels for rotogravure.

In paper production there is an idea to produce machine wide reels with high diameters for a high efficiency an a minimum of paper losses. Limits in winding of LWC base paper are observed because of center bursts. Investigations of thermal phenomena in the center of big reels show characteristic temperature structures during winding. Bursts can be detected because they produce a local temperature "hot" spot. From this ideas can be created to develop a new winding test or inspection system to detect winding structures and winding failures.

INTRODUCTION

Winding is one of the key processes in paper production. Let's have a look to a light weight coated paper line (=high quality magazine paper) for rotogravure papers: in an off coating line there are at least nine winding operations during the production , figure 1. And one additional unwinding operation takes place at the customer - the printer.

Behind the papermachine, which runs continuously, the paper is wound in a big reel. The length of the paper and the diameter are calculated so that out of this a fixed number of complete customer reels (1-2-3 or 4) can be produced. This paper machine reel, in a second step, is unwound in a rereeler, possible holes or breaks are repaired and a second time the paper is wound. The paper is unwound in the coating machine, coated , dried and wound up. For the calendering process at much lower speeds again the paper is unwound, calendered and wound. In the reelcutter the web is unwound, cut and wound up to the customers reels. If there are imperfections recognized after the coating machine or the reelcutter, reels are returned to doctor winders with additional two winding operations. Last not least the paper is unwound in the pressroom.

At all production steps the operation parameters are run close to limits. It is a challenge for research and development to improve and ensure best runnability and efficiency. In „Experimental investigations in winding operations" we want to give examples for the work of applied research. We transfer knowledge and analyses methods from our papermaking processes to „winding". "Experimental" means we run trials and follow the trials with analyses equipment to get an answer to our questions about the process. "Winding operations" characterize that the trials are run in production scale.

We would like to present three examples of experiments in winding, two customers problems in the press room and one in paper production.

STABILITY OF REST-REELS IN ROTOGRAVURE PRINTING MACHINES

The dimensions of reels for rotogravure printing have grown in the last years tremendously, figures 2 and 3. A „jumbo" reel 12 years ago had a width of 2.45 meters, a diameter of 1 meter and a weight of about 2200 kg. Roto machines have grown : widths of 2.65 m, 3.08 m and 3.18 m are standard. 3.28 m and 3.48 m are running. And end of 1997 the first 3.60 m wide machine will start up. The speed of the machines is in the range of 12- 15 m/s.

For the machines in the 3 m range vibration problems have been reported with the rest reels. When the diameters of reels become smaller and smaller before the flying splice the thin rest reels with 3 " fiber cores (76 mm inner diameter) some times show considerable vibrations.

For investigations of this problem a core rotational test stand was constructed. Cores with a length of about 3 m were speeded up to frequencies corresponding to the conditions in printing machines. Also in this test stand major vibrations occurred. At certain speeds bending deformation of the cores started, figure 4. Even disintegrations occurred (1). Breaks of the cores may happen in the middle of the core. Or cores may fail in the area of the chucks when the wall of the core breaks.

Vibration analyses show that the core instabilities are a problem of the first bending natural frequency. When the diameter of the reel in an unwind stand decreases, the rotational speed of the reel increases and moves steadily to the natural frequency. Created forces may be so high, that not only cores themselves but even cores with 25 mm (1 ") of paper on it may disintegrate.

The natural frequency is not only a property of the core or the restreel (core with small amount of paper). The value of the natural frequency is depended on the chuck construction and also on operation parameters of the chuck. Figure 5 shows that these influences are significant: they can change - reduce in this example - the values for the natural frequency by more then 30 % .
Axial tension to the cores increases, axial pressure decreases the natural frequency of the restreeel system. A recommendation for the operation of a unwind stand of a printing machine is to reduce the axial forces to the core at smaller diameters to keep the natural frequency on a higher level.

Summarizing the results of experiments in the test stand and natural frequency analyses in printing machines it can be stated, that 76 mm fiber cores are limited in the application in wide and fast rotogravure printing machines, figure 6. Cores with an inner diameter of 150 mm (6 " cores) reduce the rotational speed and additionally have a higher natural frequency. Fibre cores are the standard in Europe. And projections show, that also the latest generation of 3.60 m wide machines can be operated with this type of fiber cores at the planned speeds of 15 m/s.

CENTER BURSTS IN ROTOGRAVURE JUMBO REELS

Jumbo reels in rotogravure are troubled with center bursts. At the edges - in the area of the chucks - from time to time or sometimes very often - bursts and crepe wrinkles occur, figure 7. Many ideas have been presented about the reasons : paper properties, winding technology, paper profiles or core quality (2,3,4,5,6,7). The best way to characterize this phenomena is to look at it as a multi parameter system with a key problem : the very high force concentrations in the area of the chucks, that carry the whole roll mass (today up to 5700 kg) at a length of about 20 cm at the edges. The local structure of the reel at the edges must stand these forces. There are two ways : the center of the reel must be so hard that no paper slippage or movement occur, or all layers are able to slide without a stop point where creping is created.

Most of the center burst problems occur in the unwind stand of the printing machines. And here the bursts cause web breaks. In paper production all possible actions had been made to avoid the bursts - but without sufficient success in the unwind stands.

The idea was born to support the reel in the unwind stand to reduce the force concentrations (8). Extreme large jumbo reels (width 3.58 m, diameter 1.46 m, roll weight 7.6 tons) were produced. An unwind stand of a rereeler was equipped with a belt supporting system from the bottom, see figure 8. A systematic trial program should show the effect of the support. Unwinding reels with and without support gave a clear result : all reels with support showed no bursts, all reels without support created bursts and crepe wrinkles, figure 9. The bursts were created in the first minutes of rotation and stopped growing at a diameter of about 1.20 m.

Following this result the design of unwind stands of big rotogravure printing machines was changed : these machines have a belt system from the bottom, that supports the reel and reduces the active force at the chuck system. Figure 10 shows the very first system under construction. Now after more then one year of operation, it can be stated, that center bursts for these unwinding systems are unknown.

Transferring this experience to running machines with a belt drive system from the top there can be given the recommendations :

- increase acceleration time for the new reels at flying splice
- keep the load down during unwinding to a level just high enough to control web tension

This reduces the loads and may reduce the tendency for the creation of center bursts.

THERMAL ANALYSES OF MACHINE WIDE REELS IN PAPER PRODUCTION

Machine wide reels in paper production have other dimensions than customers reels : width is up to 9.4 meters and diameters can be 3.5 meters. But here spools made of steel and covered with rubber are used. Spool diameters mostly are in the range of 70 - 80 cm, but for the latest big machines the spool diameters exceed 1 m.

Looking to the situation of a light weight coated paper production line: the coating machine is very sensitive machine : breaks must be avoided - the machine has to run.

But the reels of the base paper show a problem : center bursts. Mainly on the edges bursts occur in the range of up to about 4 centimeters, sometimes even up to 10 cm of paper. For the reels of the paper machine this means paper losses at the rereeler, but for the reels of the rereeler these bursts causes breaks in the coating machine. To avoid these stops in the coating machines a lot of paper is left on the spool to ensure runnability.

Working on this problem, the question came up : what is going on in the center and how can experimental analysis support optimization works ?

Paper in a reel is deformed by dynamic stresses during one cycle of rotation. In the top position a volume element is under high compressive stresses. These are much lower in the bottom position. Additional shear stresses occur during rotation. Because paper is not a perfect elastic body and during deformation of the layers also frictional effects occur, the fast dynamic changing stresses should create heat. And heat can be measured as a temperature rise.

Investigations with infrared thermal analyses equipment confirmed this idea (1). Figure 11 gives an example of a reel in the unwind stand of a coating machine. This is a view to the front side of a reel. During the winding process heat is generated and can be detected as a warm ring in the center of a reel - just in the range of a few centimeters above the spool. The temperature rise in the center in comparison to the not influenced sectors of the reel is not extreme high : just one or two degrees. But this temperature can be detected quite certain. The chronological development of the warm ring gives additional information. When the big reel in the unwind stand is accelerated for the flying slice the temperature begins to rise, figure 12. During further unwinding the temperature reaches a maximum. After this less heat is created due to lower masses and therefore lower stresses. Cooling effects begin to dominate.

These results demonstrate the major influence of reel diameter and reel masses to stresses in the center of a reel. Temperature analysis may be a tool in future to judge winding processes and winding quality.

What happens if a burst occurs? There is a sudden major local movement between layers. Slippage between layers under high pressure is a friction process. Friction creates heat. So thermal analysis on the edge of a reel should be able to detect bursts.

Figure 13 gives an example that this, indeed, is possible. Here - during winding at big diameters - suddenly a "hot" spot can be noticed. Later inspection confirmed the existence of a burst (9). This is the first time that hidden bursts in machine wide basepaper reels have been detected online (without a break).

CONCLUSIONS AND RECOMMENDATIONS

Paper production applies tools of trouble shooting to winding operations : high speed video analyses, vibration and modal analyses, infrared thermal techniques. This is a method to get a lot of information in a short time and to understand theories and their practical consequences. But perhaps there is also stimulation for deepening research. These experimental investigations gave clear advice for technical actions in the fields of cores of jumbo reels in rotogravure and also for the design of unwind stands of printing machines. But there are especially in winding inspection techniques open fields that cannot be answered by time limited spontaneous investigations. Here systematic research and development is needed.

Technology in winding operations needs further development. Reel dimensions are growing. We hope and are convinced that the combination of experiment in production scale and theory will cover the challenges of future demands.

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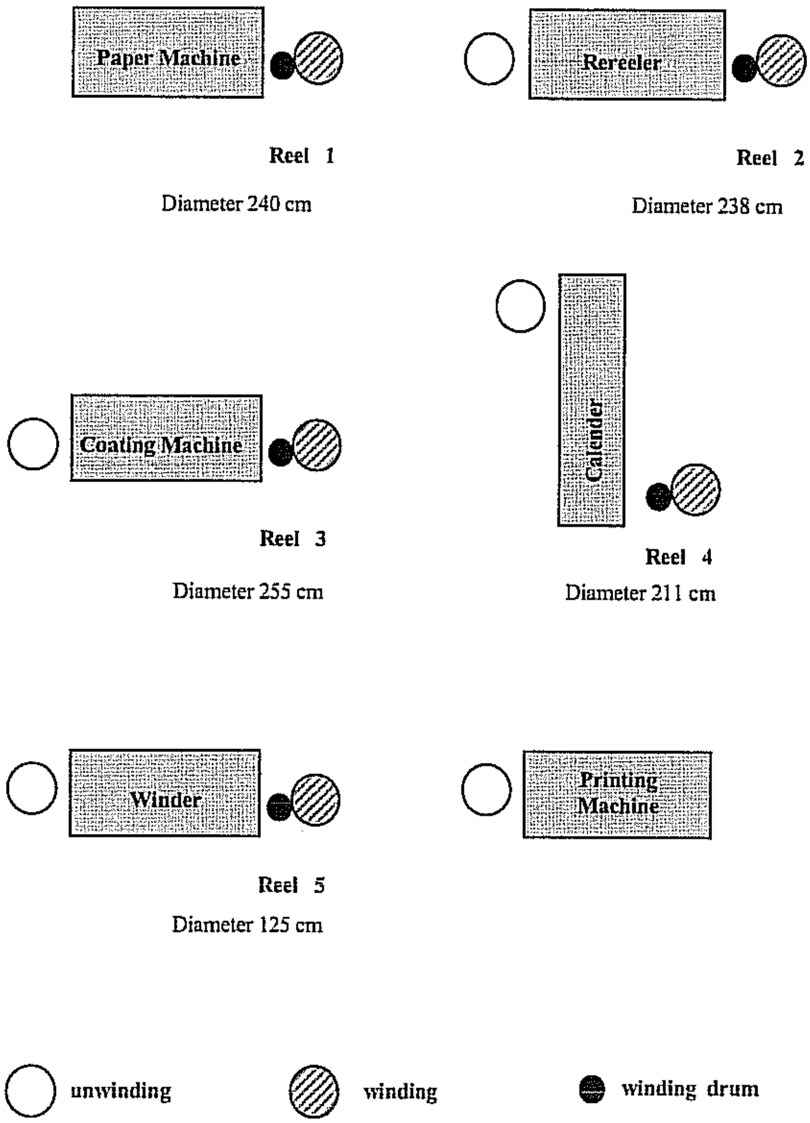

Fig. 1 Winding Operations in Paper Production (Light Weight Coated Paper LWC)

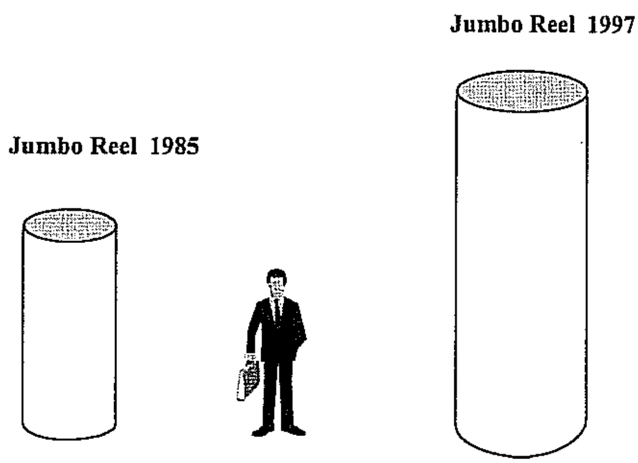

Fig. 2 Dimensions of Reels for Rotogravure Printing

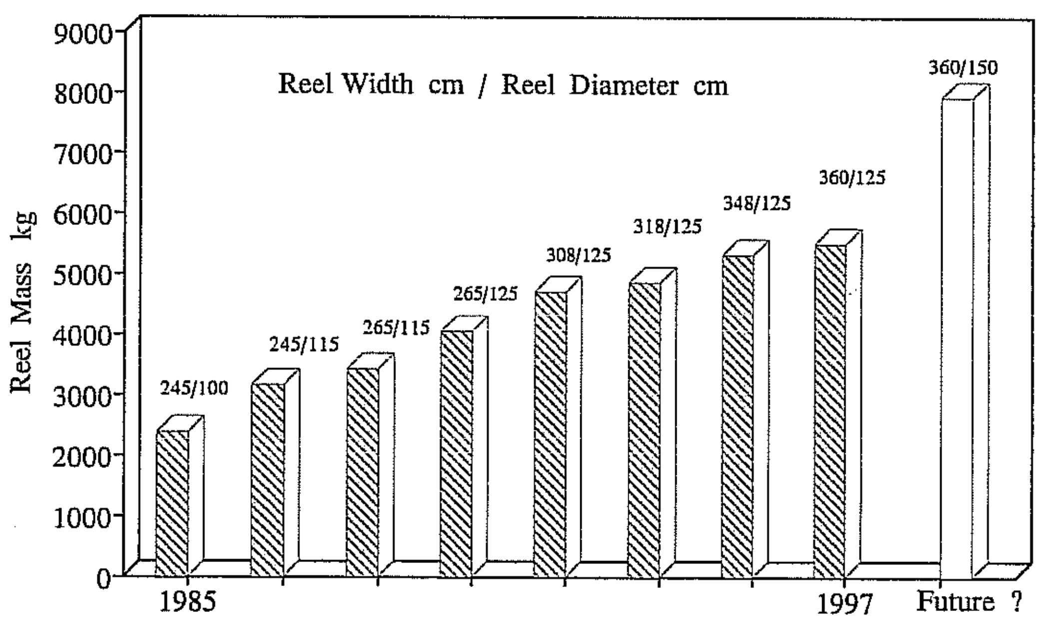

Fig. 3 Jumbo Reels for Rotogravure

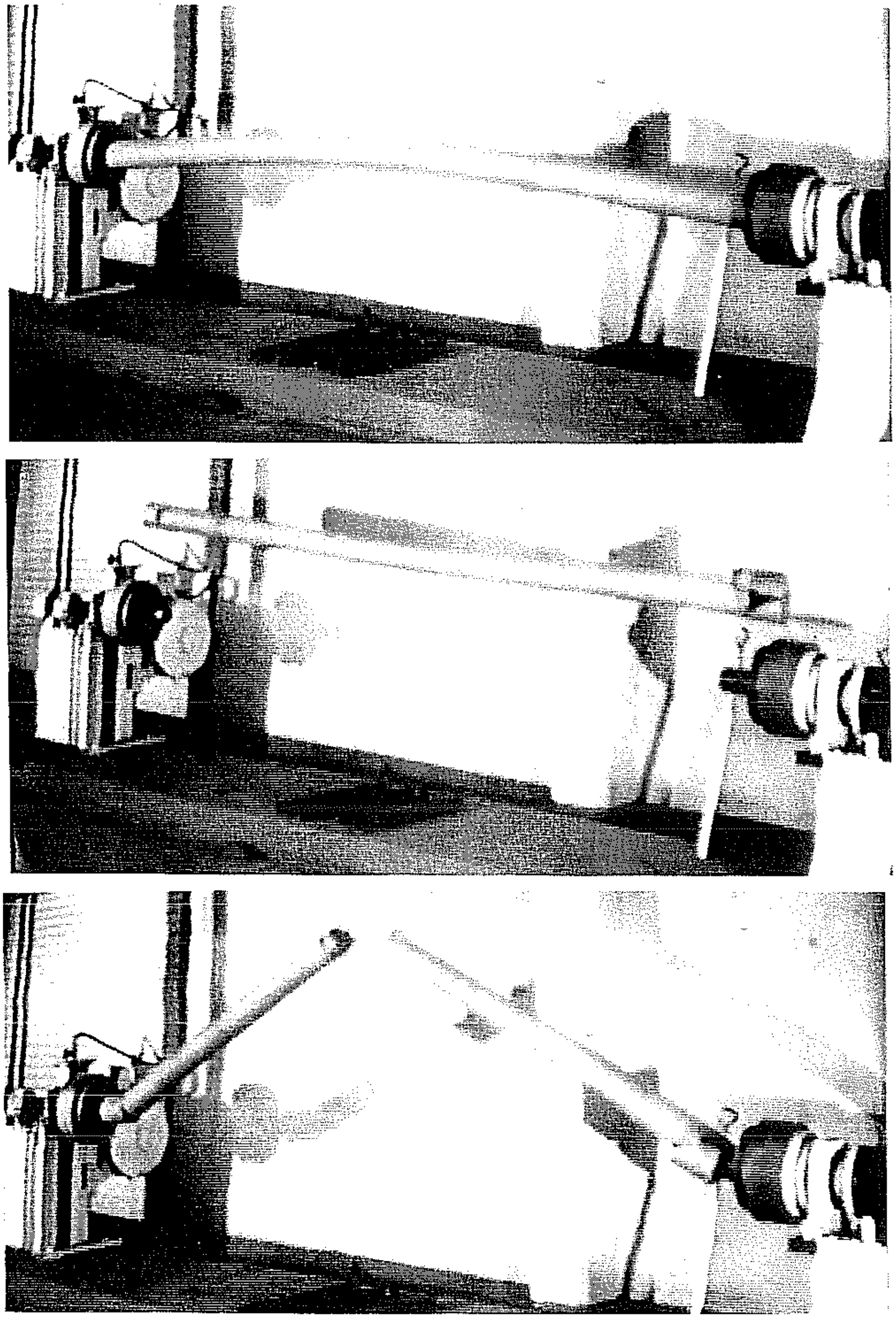

Fig. 4 Vibration and Disintegration at a Core Rotation Teststand : Bending, Break at Chucks and Break at Core Centre

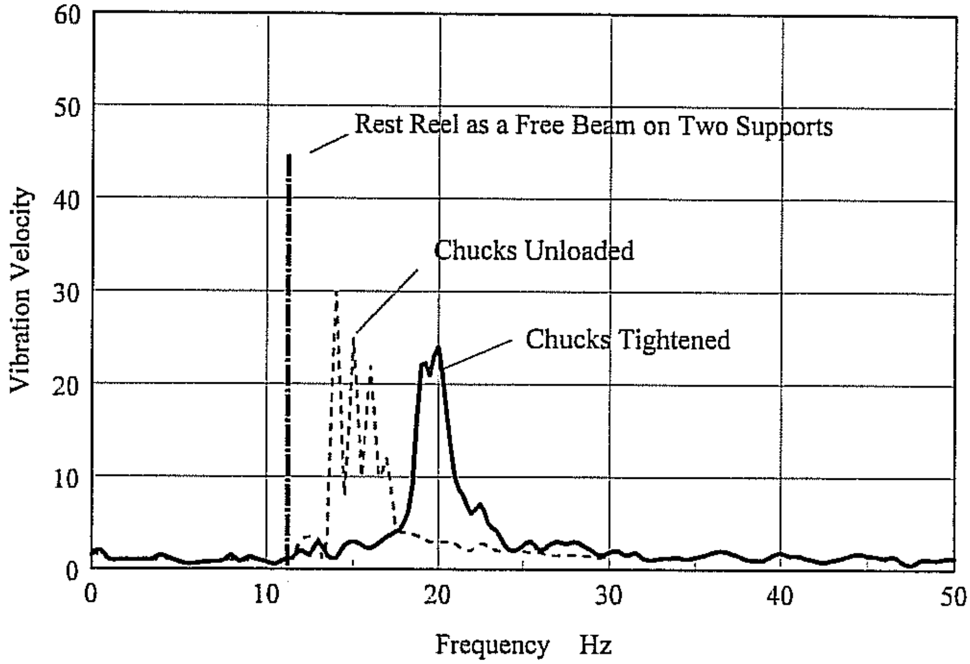

Fig. 5 Influence of Chuck Conditions to Natural Frequency

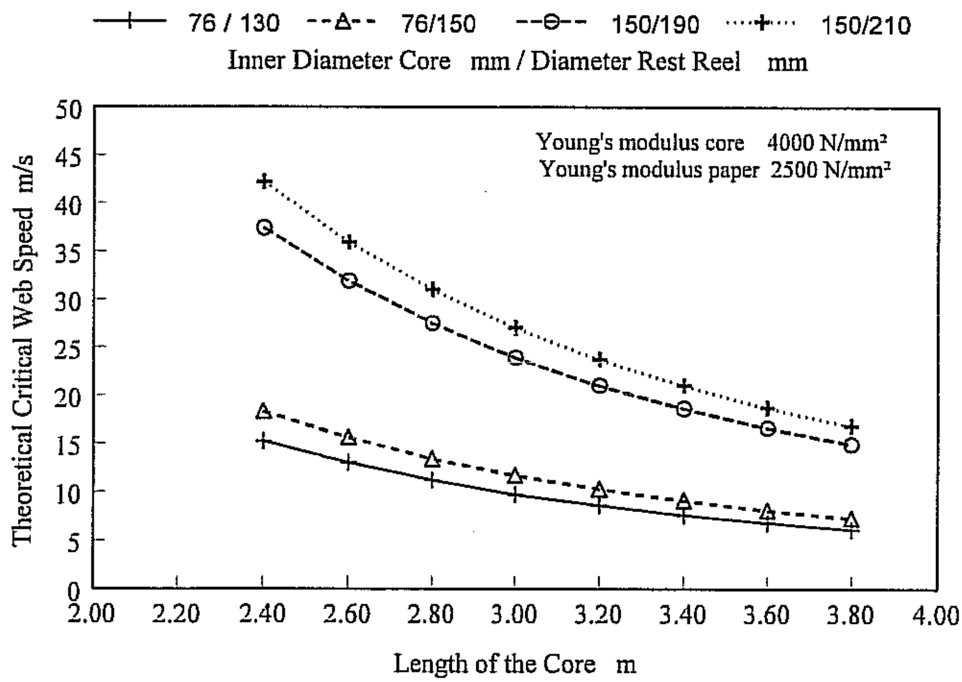

Fig. 6 Speed Limits for 76 mm / 150 mm Cores and Diameter of Rest Reels

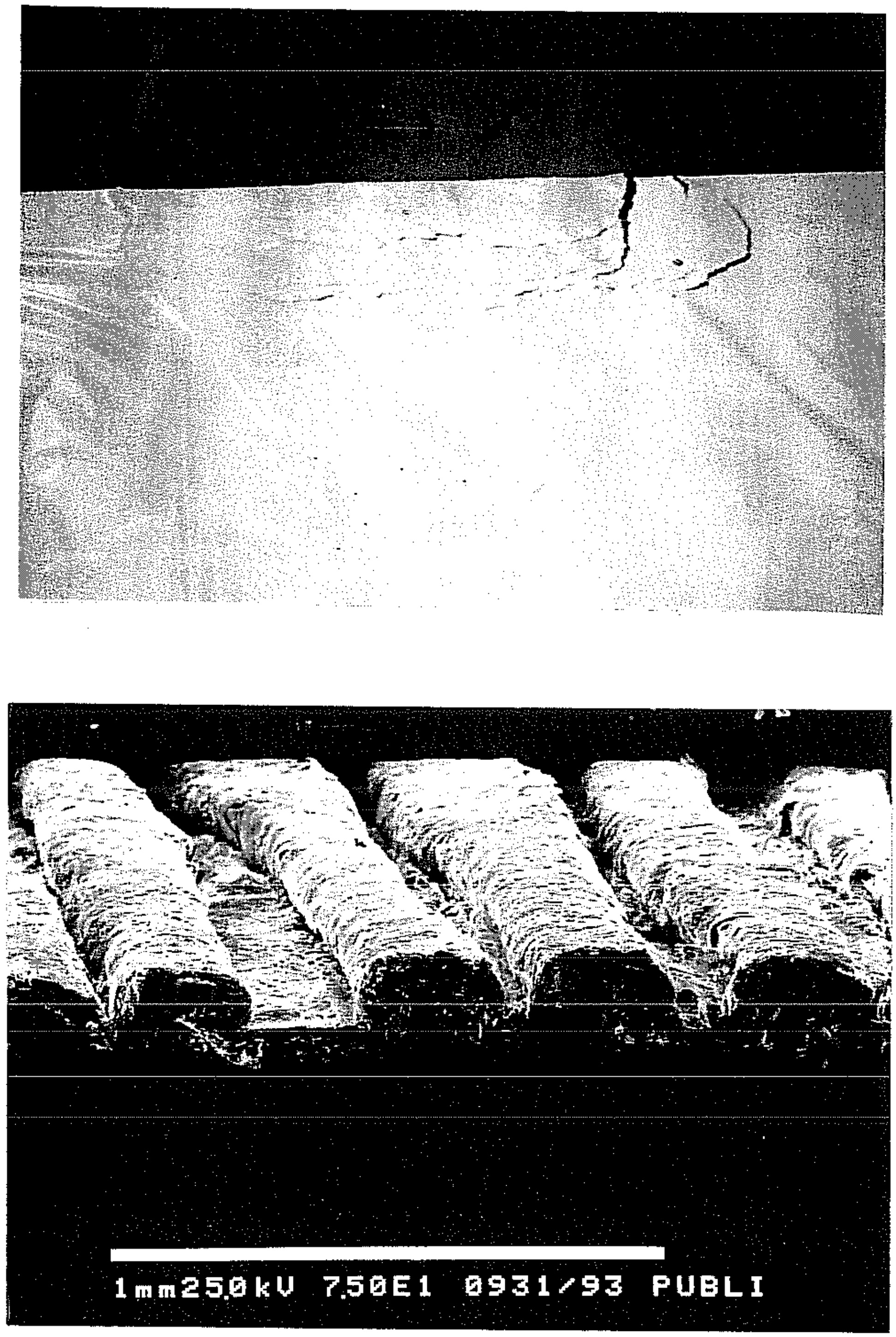

Fig. 7 Center Bursts and Crepe Wrinkles in Jumbo Rotogravure Reels

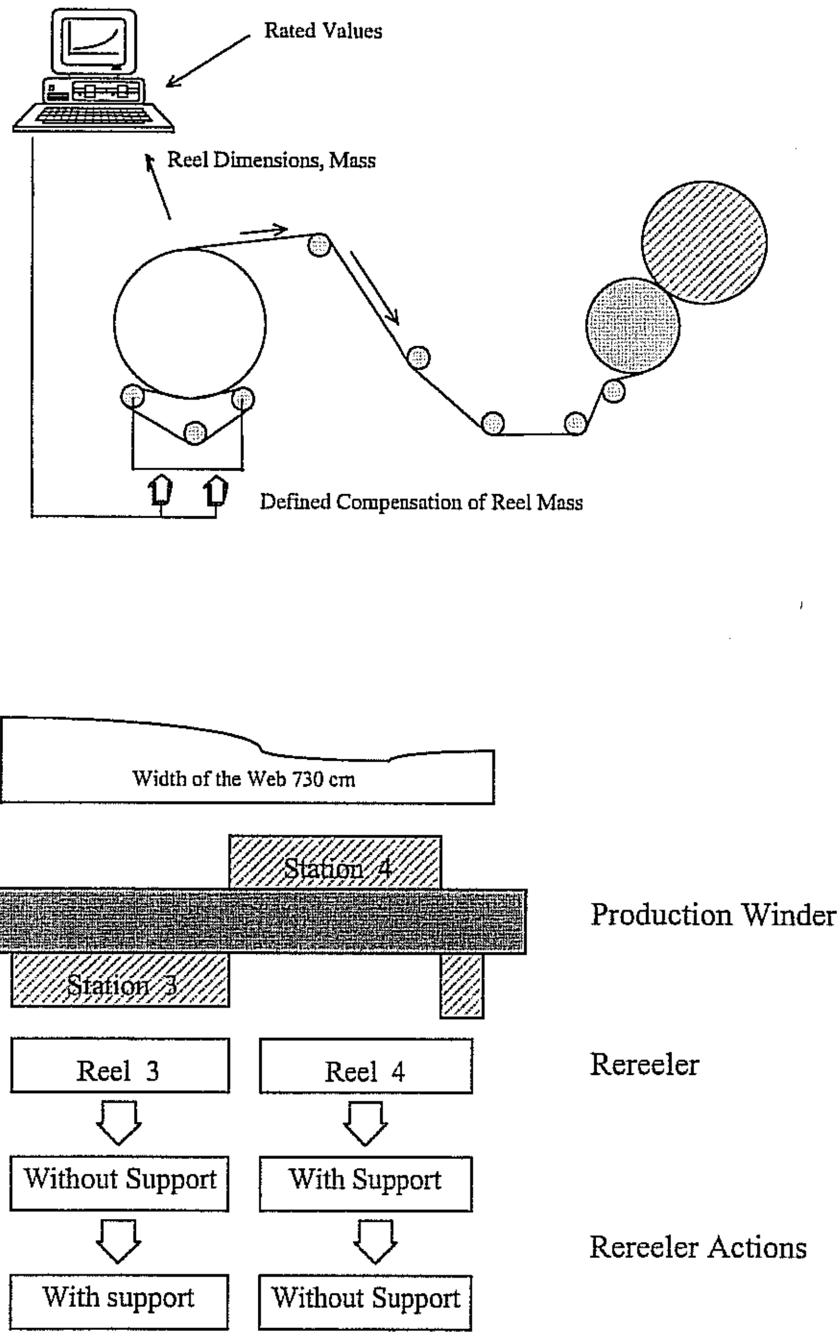

Fig. 8 Design and Experimental Procedure for Testing the Support System

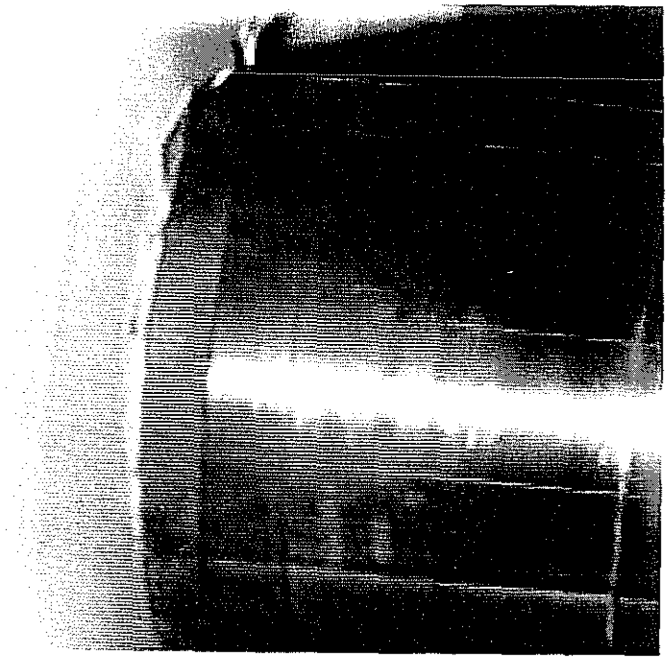

Fig. 9 Paper Shreds at the Edge of the Reel Characterize Center Bursts during Unwinding without Support

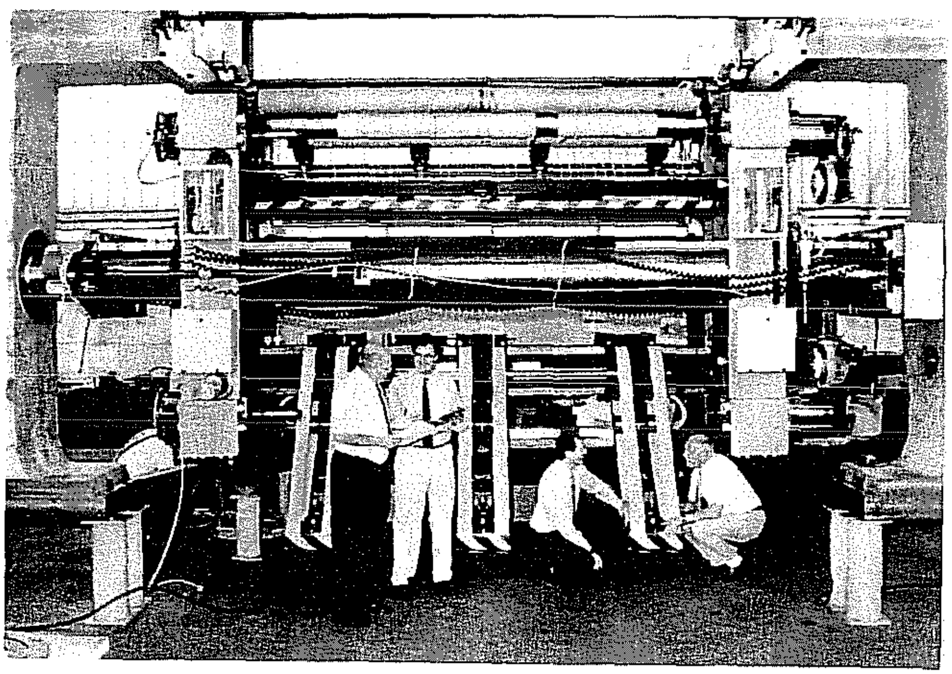

Fig. 10 Design of a Supporting Unwind Stand for Printing Machines

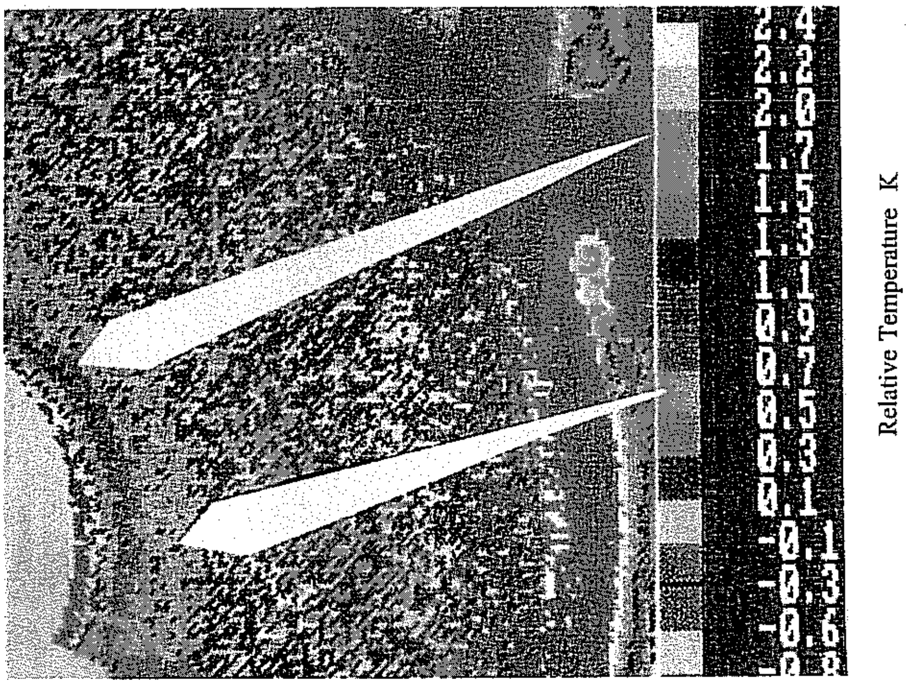

Fig. 11 Warm Ring Generated in the Center of a Machine Wide Reel (Base Paper, Unwind stand of a coating machine)

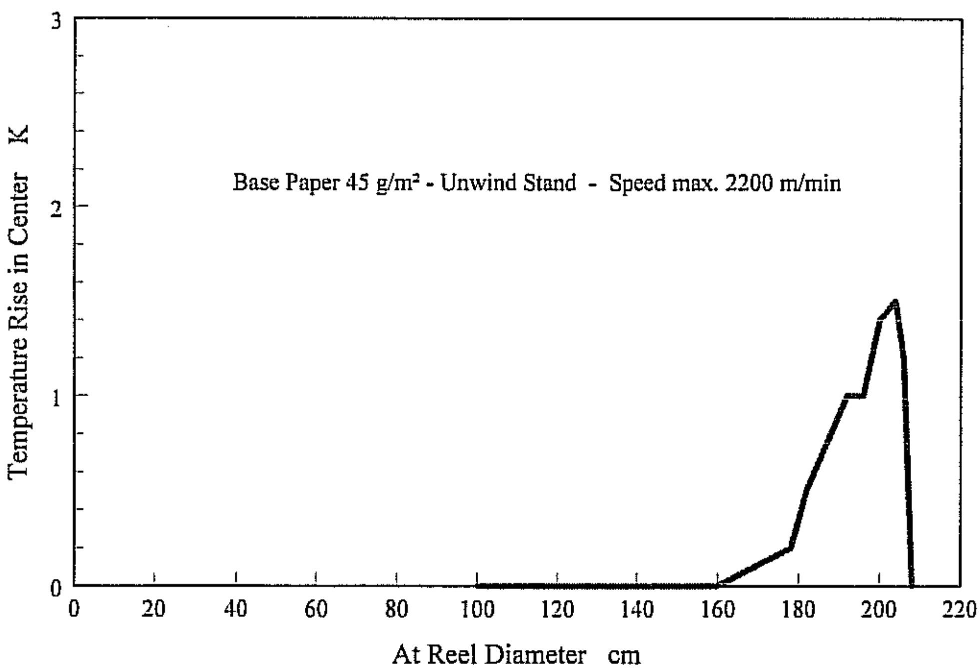

Fig. 12 Heat Development during Unwinding (Base Paper, Unwind Stand)

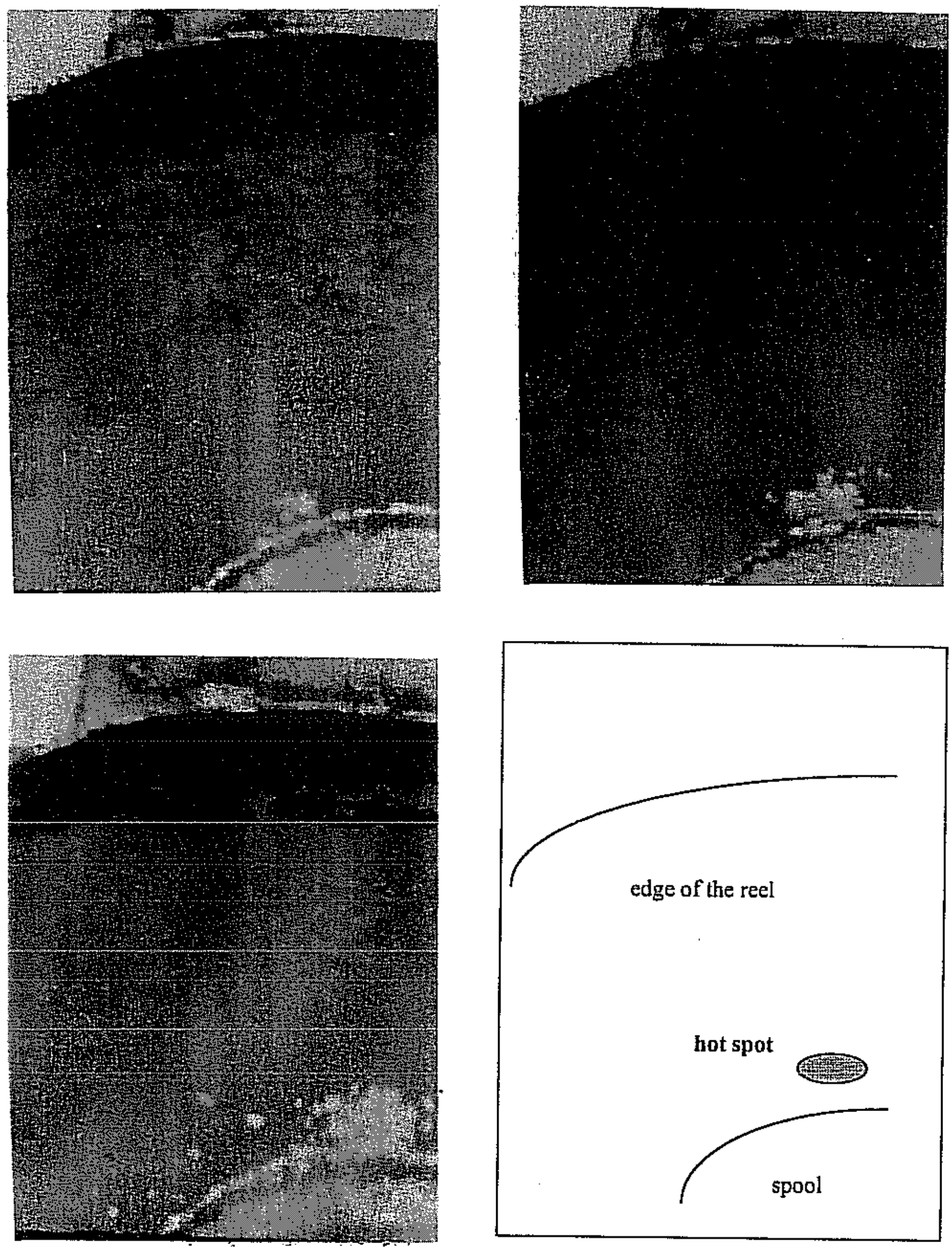

Fig. 13 Hot Spot in the Center of a Machine Wide Reel – Marking the Event of a Center Burst

Question - I want to know about the design, why do you use three supports with altogether six belts; did you investigate if one support would be sufficient or if a higher number of supports would give better results?

Answer - We did not work in this area The goal of this investigation was to see the basic mechanism of what was going on. The design of belts and number of arms was selected by the machine engineers. This is not the goal of our investigation. But, you are right this is an important point because also a belt system means that there is a nip and this nip must be very soft. It is not allowed to create any movement of layers in this contact. The only function is to support the reel, reducing the forces in the chuck area.