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A study on production breaks in gynecological examination table cover paper rolls processed on a Schultz Rewinder

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ABSTRACT

This work is a case study dealing with the production of examination table covering used in gynecological offices which has been a problem for its manufacturer, Little Rapids Corporation. During production, the rolls of paper break or tear causing production to cease while the machine is reloaded, costing about $10,000 of lost production in a year. This study was done to investigate the independent variables that contribute to those breaks and to determine if breaks have a significant impact on production rate (speed). Tensile strength and stretch of the paper were chosen as the independent variables in a binary regression analysis. In addition, breaks were compared to machine speed settings to see if there was a correlation. The results showed that the independent variables did have an impact on the probability of breaks occurring and a corresponding relationship was derived using regression analysis. The study recommended that the tensile strength or stretch of the specified paper be increased by 25% to lower the probability of breaks to an acceptable level and allow operators to maintain the desired speed setting. Any greater increase in tensile strength and stretch would incur capital expense that would be prohibitive.

1. Introduction

The paper products manufacturing industry takes paper rolls as input and converts them into rolls of stronger and improved paper. The finished product rolls must be able to be processed at a profitable rate of manufacturing, and stopping a converting machine reduces the productivity. One cause for stopping the converting machine is that the paper being fed into the converting machine breaks and disrupts the feed. The operator must then stop the machine and manually rethread the paper through the machine. This is cumbersome, time consuming, and an odious chore for the operator.

There are several theories regarding what parameters affect the paper breaking during processing. If the paper is being removed from the converting machine faster than it is being fed into the machine, the resulting tension can cause the paper to rip or break. Bagnoto [4] attributes paper breaking during processing to high rates of reel acceleration and deceleration. Grenfell [11] attributes breaking of paper to the tension control of the converting machinery. Carrasco and Valenzuela [6] discuss trying to control that tension to reduce the breaking of paper. The problem of breaks is often addressed by inclusion of driven unwind. This means that the paper being fed into the converting machine is on a roll that has a motor that turns the roll at a designed speed. Hence, the speed of the unwinding and the speed of the winding can theoretically be matched. With matched speeds a roll does not leave the converting machine faster than it is going into the machine and no breaks occur [5]. Liu et al. [13] discuss controlling this tension with disturbance controllers. Raul et al. [14] discuss how to control the matching speeds using a synthesizer to prevent breaks. Chai et al. [7] recommend using a PLC to match the speeds of unwinding and rewinding rolls to prevent the tension that causes breaks. The difficulty is that not all converting machines have driven unwinding capability. In addition, retrofitting the machine could be costly and inconvenient if space is limited.

Consani America [8] proposes that the parent roll properties are a contributing cause to paper breaking when there are high rates of reel acceleration and deceleration. Paper has internal strength that resists tearing apart. This strength is called tensile strength. Yamauchi and Yamamoto [18] found that, irrespective of the processing, a strong relationship between tensile strength and Young's modulus, which corresponds to mechanical fiber bonding, was

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found for papers from both softwood and hardwood pulps. Mechanical bonding is the mechanism that dictates the internal tensile strength of the paper. The less the internal tensile strength the higher the probability of the paper ripping or breaking during final use or conversion to a finished product. This is true even if there is a tension differential between the unwinding roll and the rewinding roll.

Tensile strength is considered such a critical factor in paper production that much research has been done with the conclusion that tensile strength is improved and processing of the paper is easier when strengthening agents are added. Kröling et al. [12] studied reinforcing fiber strength using epoxy resin. Del Rosso et al. [9] studied polymeric microbraiding to reinforce fiber strength. Wang et al. [16] studied the use of polyurethane to strengthen fibers. Vishtal [15] studied agar and gelatin to modify fibers to improve strength. Each of these studies was done to improve the performance of paper and paper products in their use in finished products or in conversion to finished products.

If an organization does not have converting machines that have driven unwinds and cannot or will not install them the only alternative appears to be changing the internal tensile strength of the paper to compensate for the tension differential between unwinding and rewinding.

This work is a case study that deals with Little Rapids Corporation, a manufacturer of paper and paper-based products. One product made is a specialty examination table covering used in gynecological (OBGYN) doctors' offices. Little Rapids uses an old model Schultz Rewinder that does not have driven unwinds and experienced paper breaking frequently during processing. The problem was how to minimize the events of breaking paper without adding capital costs incurred by modifying the equipment or adding to the cost of the paper being processed.

2. Material and method

The Schultz Rewinder takes large rolls of paper and rewinds them into smaller rolls with a special plastic backing for additional strength and protection of the OBGYN exam table where this is used. The process is continuous with the large roll of paper, which is located on a shaft, being unwound and processed into smaller rolls.

The large rolls of paper are produced in batches at the paper mill at the rate of one batch per month. Paper is made by dissolving pulp in a water mixture and pouring it onto a porous belt which is about ten feet wide. Water is removed from the pulp-water slurry on the belt and super-large rolls of paper come off at the end of the line. A super-large roll is about 9 feet wide. Rate of water removal can affect the strength and stretch properties of the paper. The super-large rolls of paper go through one final process step at the paper mill where some stretch is removed. The paper is inspected for internal strength that resists tearing or breaking (tensile strength). The paper is also tested for the inherent amount of stretch or elasticity; this is called stretch. There are specification limits for both tensile strength and stretch.

2.1. Research questions

The following was the first question to be answered by this research, "Do recorded tensile strength and/or stretch of the paper affect or predict if breaks will or will not occur while making OBGYN product out of the specified paper?" This research was designed to answer the research question inferentially to the extent that a formula was developed to determine the minimum tensile and stretch required to insure 50/50 odds of no breaks while running a roll of paper through the Schultz Rewinder.

If the first question was answered in the affirmative, then a second question was asked, "Does the presence of breaks significantly affect the speed setting the operator uses for the Schultz Rewinder?" Speed is then the dependent variable and breaks are the independent variable. If this is shown to be true, then a practical application can be made that tensile and stretch will indirectly affect the speed and, hence, the production rate of OBGYN product off the Schultz Rewinder. The effect can be quantified so that a decision can be made regarding the appropriateness of the current specifications for strength and stretch.

2.2. Statistical techniques

The first research question was a quantitative, causal-comparative method using random data provided from non-experimentally designed operating conditions. A Binary Logistic Regression was used because the results of a previous preliminary Discriminate Analysis proved that the two, interval, independent variables under consideration have an effect on breaks. The dependent variable is mutually exclusive categorical (breaks or non-breaks). Even though the researchers cannot change the independent variables at will, the research design is inferential to the extent that it provides a good approximate model for predicting the odds of breaks occurring. For this research interaction was not considered. Although interaction may be taking place, the correlation of tensile strength and stretch was strong enough (See Fig. 1) that it can be assumed that raising one will increase the other. There is very little possibility of achieving a very high tensile strength and very low stretch in everyday production. Thus, the study of interaction was excluded from this study.

For the second research question a "T-test" was used to compare the speed settings of two different conditions. The first condition was runs that did not experience breaks and the second was runs that did experience breaks. In this analysis, the dependent variable was speed settings of the converting equipment and the independent variables were the two categories of breaks or non-breaks. Fig. 2 shows how speed setting relates to breaks. It is clear from Fig. 2 that the break and speed settings are correlated. High speed setting yields no breaks and low speed results in breaks.

Equipment used was limited to the Schultz Rewinder but the employees involved were not limited. Any trained operator could have participated in the research. This was considered "noise" to the research. Because the research did not adversely affect the finished product, there were no extra budgeting requirements for this study. No additional supplies or costs were incurred for the production or testing that was included in this research.

A combination of Mini-tab and SPSS software was chosen because each gives a little different perspective on the analysis.

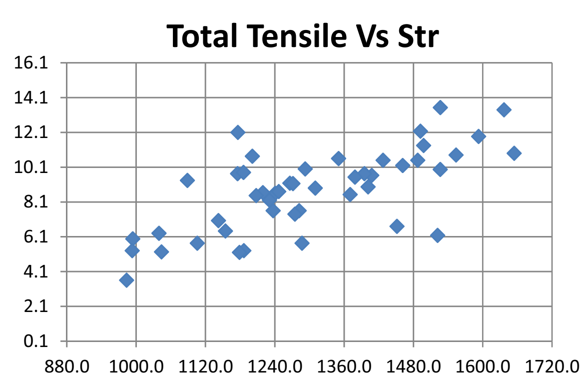

Fig. 1. Stretch on the *y*-axis vs. tensile strength on the *x*-axis.