Roll weight capacity of paper mill cores

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ABSTRACT: Accurate estimates of core weight capacity are necessary for safe and trouble-free winding. The author describes a method to predict core weight capacity. A laboratory tester can determine which core attributes most influence weight capacity. These findings can guide changes in the core manufacturing process that would improve core performance and lower costs.

KEYWORDS: Capacity, cores, simulation, test equipment, weight, winding, wound rolls.

Paper tubes, commonly called cores, are hollow cylinders composed of paperboard and adhesive. Their fabrication involves bonding together staggered plies of thin paperboard 0.5–1 mm thick in a spiral and continuous fashion. Cores are available in a variety of sizes that typically contain 20–40 paperboard plies. The common cores in the paper industry have inner diameters of either 76 mm or 152 mm with thicknesses between 12 mm and 18 mm. Lengths of the cores will vary and can range up to 3.1 m.

Core requirements

The minimum performance standard for cores that carry jumbo rolls is that they not fail in a manner that prohibits or unduly slows the production or the use of the paper. Selecting the proper core for a particular application is obviously more complex than this simple statement implies. Proper selection requires knowledge of both the core strength and the load applied to the core. Since this information is often not readily available in a paper mill, core users will traditionally rely on information from competing core manufacturers. In this manner, mills hope they obtain the best core for a particular application.

In actual practice, a paper mill tries various cores from the selection offered by a supplier. It then purchases the least expensive core that does not fail. This method is only partially effective because it merely identifies the least expensive, adequate core of those undergoing testing. The core selected in this way may have excessive strength, however, because there might be a more economical core not in the original offering that would have adequate but not excessive strength.

To remain competitive, core suppliers must recommend cores that are adequate for the job under consideration at a reasonable cost. This means that they should have an accurate knowledge of core failure weights and of core loads developed in winders, i.e., the information that the paper mills do not have. The core loads depend on the winder, however, and are often not available to the supplier. Core weight capacity is unique for each particular core and should be part of the knowledge bank of the supplier.

An example of development of this knowledge and its resulting benefits is the work done by our organization. In the investigation, core failure weights were determined on industrial winders, and a method for predicting weight capacity was developed. Laboratory test devices intended to simulate core loadings in winders were also evaluated. One which adequately reflected performance of cores in actual field service was used to develop an understanding of manufacturing factors which influence weight capacity. This resulted in an improved ability to design and manufacture properly the cores used in winding heavy jumbo rolls.

Core loading

Typical jumbo paper rolls have diameters of 1.0–1.2 m. There are even some very wide rolls of 2.5 m or more that have weights exceeding 4 metric tons. In all these cases, the core is the primary support for the weight. Indeed it is sometimes the only support. For example, core–

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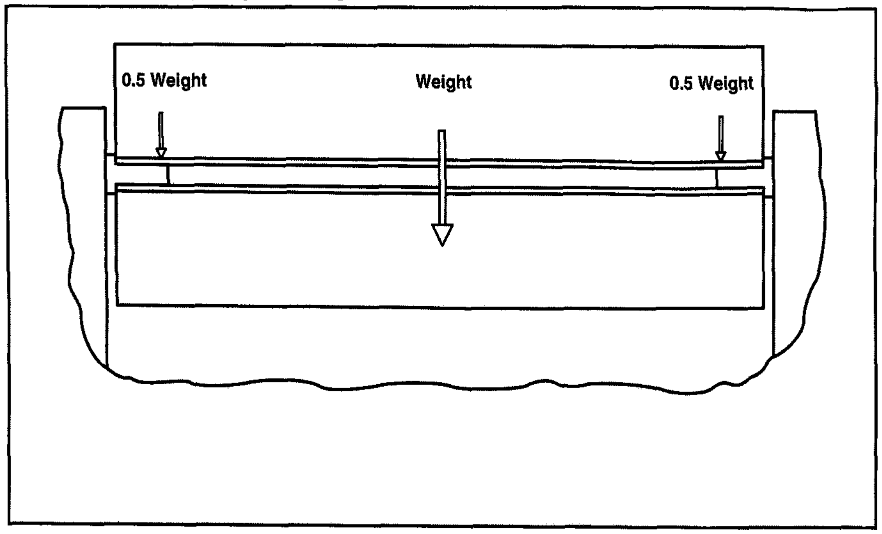
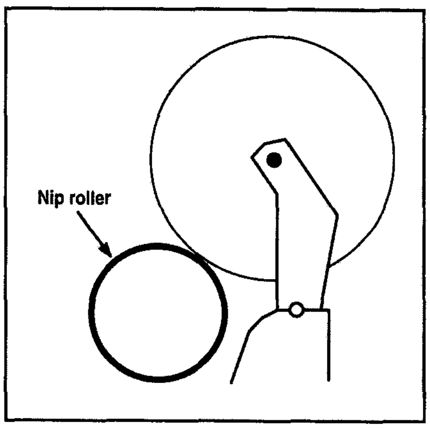
1. Diagram showing weight loading on core



2. Single–drum winder



supported winders load the entire roll weight on the core. **Figure 1** shows that half of the weight is on each end. In the case of a single–drum winder, **Fig. 2** indicates that the nip roller provides some relief for a portion of the roll weight. Because single–drum winders have the purpose of winding very large rolls, however, core loadings will generally be just as high.

Figure 3 provides a comparison of core loading for both single–drum and core–supported winders. In this figure, a roll diameter of 1250 mm using core–support has a load of approximately 1450 kg/m. This is the same load which a single–drum unit would generate for a roll diameter of 1500 mm.

In both core–supported and single–drum winders, any load will transmit to the ends of the core with mandrels which are 120 mm or less in length.[1] This can result in localized stresses large enough to cause core failures.

During operation, note that the starter bands in an unwind stand will also place loads on the core in addition to the roll weight. These additional loads are not typically a concern, however, because the chucks in most unwind stands are longer than the chucks in most winders. The loads in the unwind stand therefore apparently distribute over this longer length in a manner that keeps the core stresses below the stresses in the winders.

Core failure

Cores loaded beyond their weight capacity exhibit a distinctive failure mode. At or near either end of the core, a crack initiates around the circumference of the tube wall. Because the core is rotating, this crack almost instantly develops into a complete circle as **Fig. 4** indicates. This phenomenon probably occurs without noticeably affecting winding, as explained later. As the core continues to rotate, this full–circle crack propagates axially into the core. At this point, the characteristic bouncing of a roll associated with this type of failure is probably first noticeable. Additional winding causes an angular displacement of the inner portion of the failed core relative to the outer portion. As the winding process continues, **Fig. 5** shows that the core eventually cleaves into 2 separate cylinders near the mandrel. Roll bounce will now be quite severe and preclude further winding. Additional core damage would occur during disposal of the now unusable roll whether unwinding took place on the winder itself or on a salvage rewinder. This further cycling of the roll would result in the loose inner cylinder being ground into the fine powder shown in **Fig. 6**.

The type of core failure described above indicates that the core does not meet minimum performance standards because the advanced stages of failure preclude the use of the paper. It also slows paper production and requires special equipment for disposing of damaged rolls. Prevention of this failure is simple—select a core which can sustain the cyclic loads involved.

Failure determination

For most on–going applications, one or more cores are usually available that will perform adequately. In the case of new and more demanding applications, trial and error is necessary to select the proper core. This is expensive and time consuming. Accurate knowledge of both core weight capacity and core loading could eliminate this expenditure of time, effort, and money.

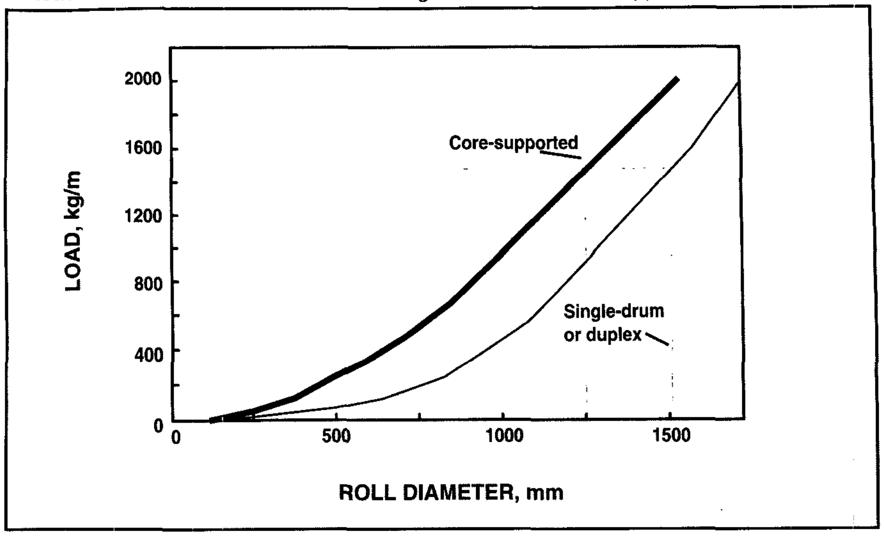
An obvious way to determine core failure weight is simply to wind a core to failure. Core manufacturers can use this technique to determine accurately the failure weights for their products. One problem, how-

[1]Welp, E. G., *Proceedings of the First International Conference on Web Handling*, Oklahoma State Univ., Stillwater, 1991, pp. 154–166.

ever, is that even cores made with extreme care will be somewhat variable. It is therefore necessary to test several of any given class of core. Another problem is that accurate failure weight determination requires a quick halt to winding when a core fails. This requires special instrumentation to detect core failures immediately. Without this instrumentation, failure weight determination would be imprecise, since a core failure might be unnoticeable for some time.

It should be obvious now that immediate failure detection and progressive windings beyond the initial failure were the probable cause of the previously described hypothesis of failure sequence discussed in the example cited for Fig. 4.

3. Load as a function of roll diameter for single–drum and core–supported winders



Core testing

The number of experiments required to test every paper mill core available in a supplier's product line would be very high. The availability of personnel, equipment, and funds could limit such testing. It is therefore important to be able to extend experimentally determined failure weights of certain cores to other core designs. This would require a method for reliably predicting maximum core roll weight capacity. It would also be necessary to ascertain the accuracy of predicted failure weights by comparing them with the results of tests where cores were wound to failure.

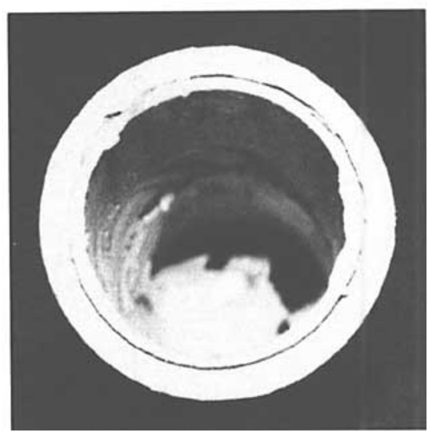
The actual method of determining failure weights was to wind just enough paper on the cores so that they failed. The first step in preparing the specimens was cutting to the proper length. A length of 3 m was used so that the rolls would weigh enough to fail most cores. This relatively long length was necessary because the winder used in these tests had a maximum roll diameter limit of 1.5 m. Shorter rolls of this diameter would not have been heavy enough to fail the majority of cores tested. Next, the cores were instrumented with the electronics needed to detect immediately core failures. Winding of the cores was then initiated as normal. The state of the cores was monitored throughout the run. Roll diameter, as indicated by winder readout, was recorded immediately when failure was detected. In most of the tests, winding was immediately halted. After the rolls were removed from the winder, physical measurements of roll diameter and roll weight were made.

This method provided very good agreement between predicted failure rates and actual performance. **Figure 7** shows a comparison of predicted failure weights with actual values for a number of different cores. Note in this figure the excellent agreement of the actual values with the predicted values. The r^2 value for the data in this figure is 0.963. The average error between predicted capacity and actual strength was 3.2%. The method therefore provides a highly accurate guide for core selection for new applications.

Improving core performance

Improving core weight capacity requires an understanding of the manufacture of a core. There are numerous factors involved in the manufacturing process. Each of these may have an impact on performance to one degree or another. Determining the relative importance of so many factors by conducting actual winding tests is economically unfeasible. An alternate approach is to use some sort of laboratory core tester that would simulate winding conditions. Such a tester would allow determination of the impact of manufacturing factors on test performance relatively inexpensively.

4. Initial failure of a core

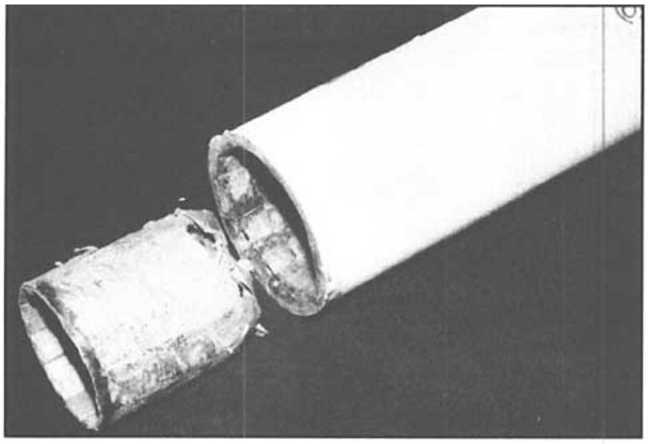


A search of the patent literature reveals that two laboratory test devices are available.[2,3] Both units use

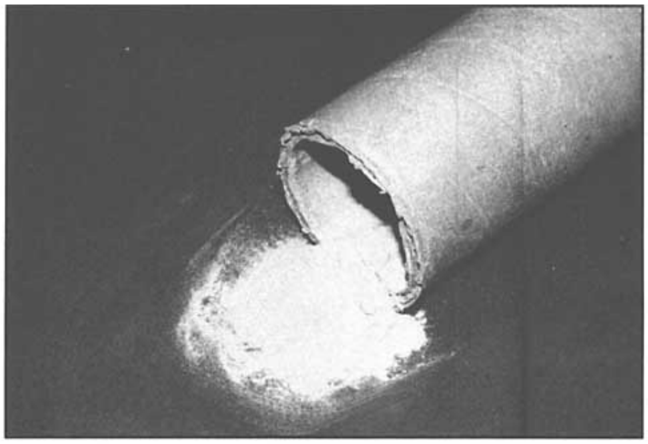
[2]Morel, J., *U.S. pat. 4,819,488* (April 11, 1989).

[3]Järvinen, M., Novaky, M., and Romml, H., *European pat. appl. 0 309 123 A2* (Sept. 9, 1988).

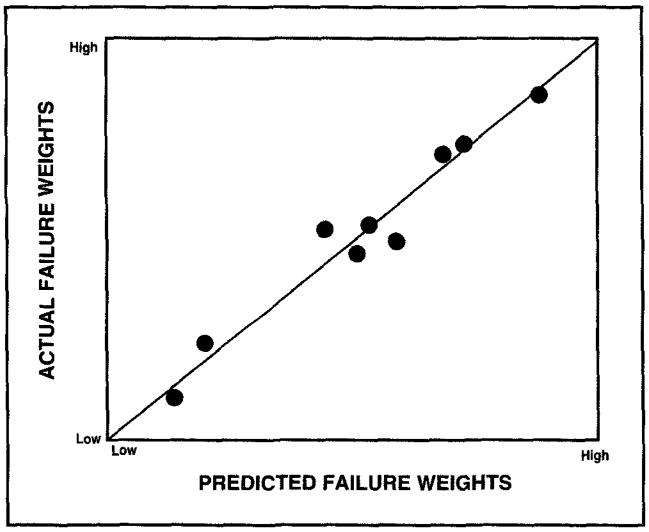
5. Failed core which has separated into two cylinders



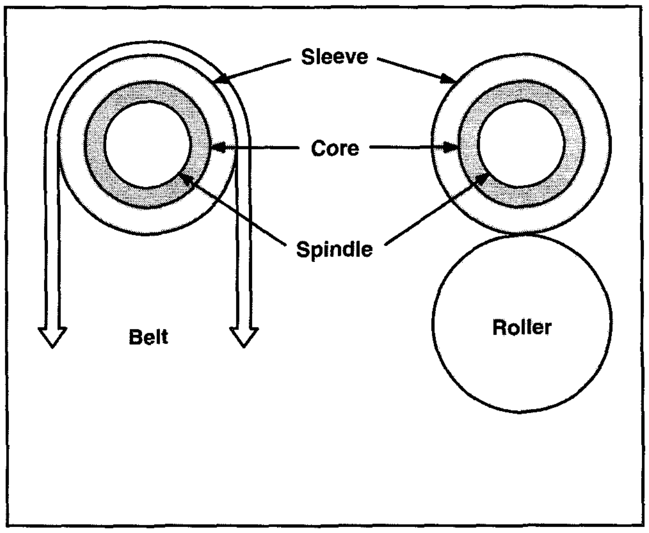
6. Failed core showing inner cylinder ground to a fine powder



7. Comparison of actual and predicted performance



8. Typical laboratory tester



the same principle of transmitting roller- or belt-induced loads to a core encased in a hard sleeve and mounted on a rotating spindle as **Fig. 8** depicts. The sleeve protects the outer surface of the core. The spindle is expandable. The specimen length is relatively short—usually only 40–100 mm in length. A specimen undergoing testing experiences application of a constant or steadily increasing loading until failure occurs. **Figure 9** shows that failures induced in these tests appear similar to those in actual winders.

While similar in the respects noted above, the two testers operate at different load levels, load rates, and rotation rates. There are also other proprietary differences that make each tester unique. Differences in cores will impact test results in varying degrees. Guidance obtained from these testers may be different and even disparate.

Figure 10 shows that the results from the preferred tester provide a correlation between laboratory test performance and actual service with an r^2 value of 0.91. As the figure illustrates, cores that do well in the test device are able to sustain the highest roll weights and vice versa. It is therefore possible to use this tester to determine which core attributes most influence weight capacity. This information can guide manufacturers in process changes aimed at improving core performance and lowering costs.

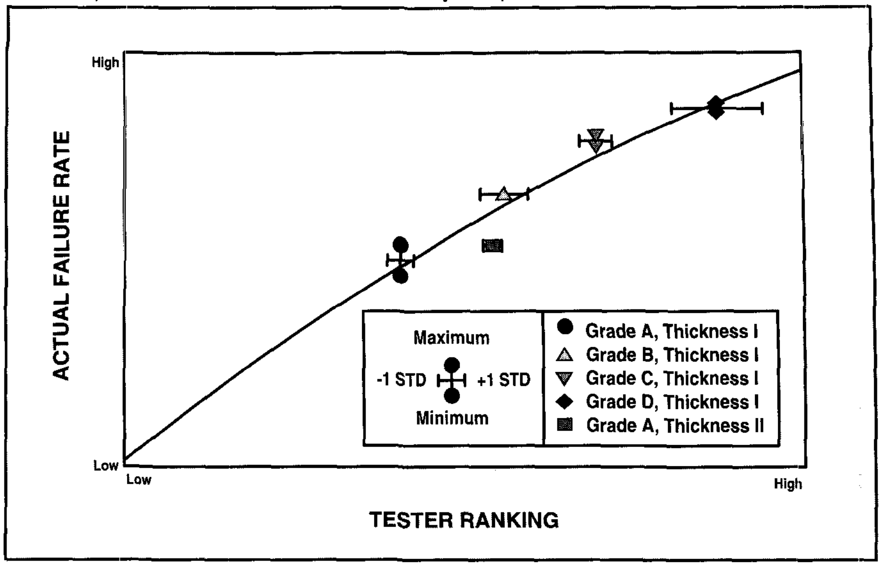
Conclusions

Cores used to carry large paper rolls must sustain high stresses and endure many winding and unwinding cycles. Although cores are available that perform adequately for most applications, the traditional trial-and-error method for selecting cores is inaccurate, time consuming, and expensive. Reducing this waste requires that core manufacturers be capable of accurately estimating maximum weight limits for safe operation.

Failure weights of paper mill

9. Failure of laboratory test specimen

10. Comparison of actual service to laboratory test performance



cores can be determined experimentally. This requires special instrumentation to detect immediately the onset of core failure. Benefits of this type of testing include very precise failure weight determinations and increased understanding of the failure itself.

Increasing core weight capacity requires an understanding of how each factor in core manufacture affects performance. A laboratory test device to simulate winding conditions can provide this information.

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