Development of Center Disc Design Using Finite Element Analysis

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ABSTRACT:

Center discs are avoided in large engineered pulleys used in heavy mining applications. However, many conventional pulleys used in mining have center discs. Center discs are often used with thinner rims, as they aid with manufacturing, improving the roundness of the pulley and improve the machining of rims, when required. This paper will focus on understanding the relationship between the rim and center disc and the development of Finite Element Analysis (FEA) model to properly design center discs in drum conveyor pulleys.

INTRODUCTION:

When FEA (Finite Element Analysis) was applied to the design of conveyor pulleys, its use was primarily in the design of turbine pulleys. Turbine pulleys typically have a T joint that connects the tapered disc to the rim. The rims in these pulleys are thick enough to handle the stresses without the support of center discs. Center discs are considered of little use in a turbine pulley, as they cause more stress risers than help in the support of the rim.

Since turbine pulleys do not use center discs, little thought was given to the modeling of center discs in the FEA programs as they were being developed, Laughlin (2002). However, as computers and programming have advanced, FEA is being used on more than just turbine pulleys, including pulleys with center discs. Center disc designs have traditionally been based as much on manufacturing techniques as on the design of the pulley. These designs are based on assumptions that the center disc is rigid and stresses in the center disc are not calculated. While these techniques have worked in the past, advances in belting have put more loads on the rim and the center disc causing issues with the existing design practices.

Empirical equations used for rim and center disc designs were developed approximately 50 years ago. These equations placed great emphasis on the hoop or circumferential stress in design of the rim. Axial or bending stress in the rim was considered minor and little attention was given to it. It was also reasoned that a center disc would be effective in controlling rim stress, since the hoop stress from belt contact would tend to deflect the rim into an elliptical shape and the round center disc would resist this deflection.

Figure 1 is a compilation of hundreds of FEA runs to determine the rating of the rim without center discs (CD). These runs were done with constant thickness, with the only variables being the angle of wrap and the diameter of the pulley. The different curves show what effect the pulley diameter has on the rim rating. It shows that the hoop stress is a major or controlling factor in the low angle of wrap pulleys as shown in the left hand part of the curves that form a large U shape in the plots up through about 100 degrees. Above 100 degrees the axial stress becomes the controlling factor in the design.

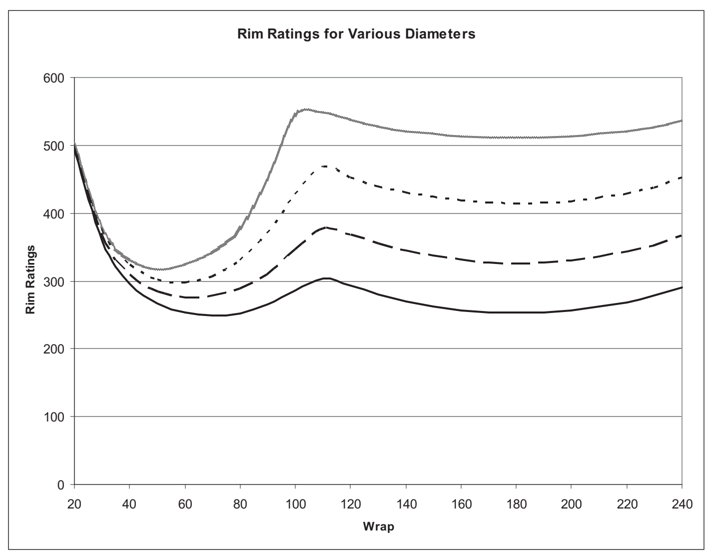

Figure 1 – Rim ratings for Various Diameters

Figure 1 shows that both the hoop stress and the axial stress are important in pulley design. The hoop stress is significant at lower wraps. The axial stress is significant at higher wraps. While both axial and hoop stress in the rim need to be included in the design, pulley geometry also plays an important part of the design process. Figure 1 also shows that changing the pulley geometry, in this case the diameter, will affect the rim design.

PROBLEM:

Issues with pulley center discs fall into 3 categories; 1) center disc cracking, 2) weld failure, 3) rim cracking above the center disc. Center disc cracking as the primary mode of failure is rare. Most often center disc cracking occurs after the center disc weld fails. The few cases of center disc cracking reveal that the center disc was too thin.

Examinations of weld failures show problems with fit up of the rim to the center disc or problems with the weld. The problem was not with the design, but the manufacturing of the pulleys. Improvements in manufacturing techniques addressed these issues.

While the first 2 issues with center discs can be addressed using existing methods, rim cracking above the center disc presents a challenge. Existing design models have performed well, but can not explain some issues with rim cracking at the center disc. FEA can provide the analysis needed to understand the interaction of the center disc with the rim. Figure 2 is a deflection plot of the FEA model used.

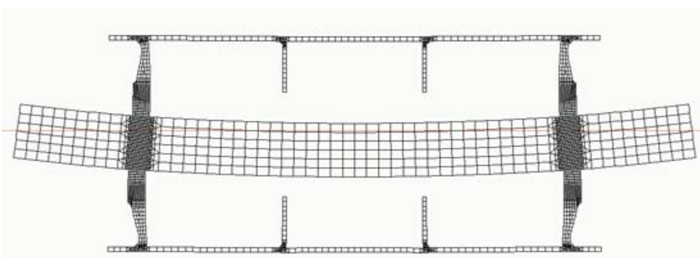

Figure 2 – FEA Deflection Plot of a Pulley with Center Discs.

ANALYSIS:

Using FEA to design center discs allows the Engineer to look at more than just the effect of rim loading on the center disc. The FEA will show what effect that the center disc has on the rim. Figure 3 is a plot of the stress in the rim with 2 center discs. The plot is the stress on the inside of the rim from a point 150 mm (6”) inside of the end disc to the center of the pulley. The 3 curves indicate 3 different center disc thicknesses. The plot is a typical example seen when comparing center disc thickness effect on the rim stress.

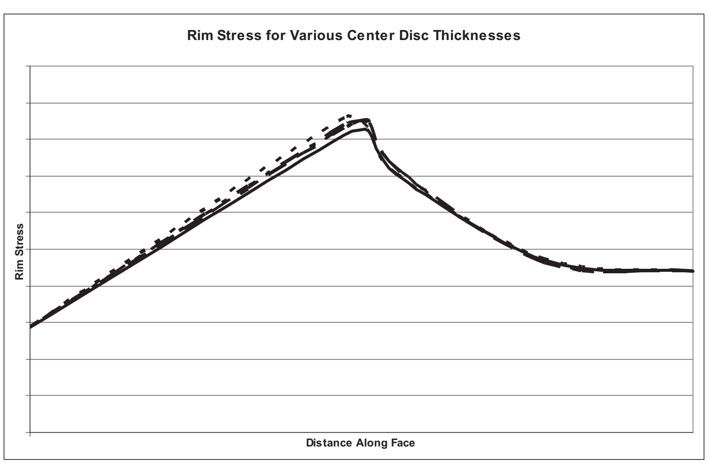

Figure 3 – Rim Stress for Various Center Disc Thickness with 2 CD

Figure 4 is a similar plot that show the effect of varying center disc thicknesses when using 3 center discs. While the center disc thickness does have an effect on the center disc stress, the effect on the rim stress is minimal.

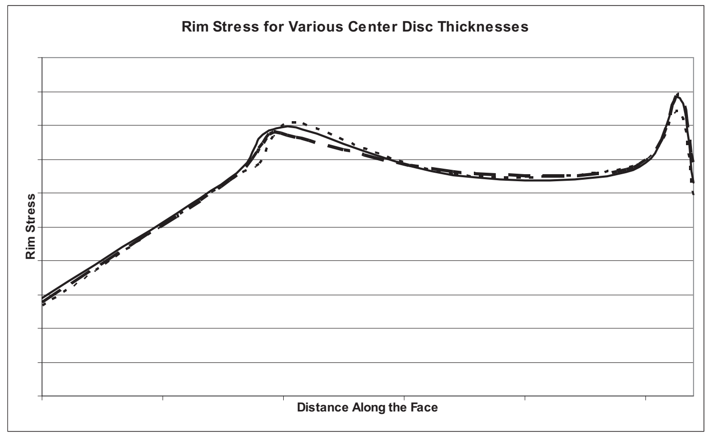

Figure 4 – Rim Stress for Various Center Disc Thickness with 3 CD

The center disc inside diameter presents another critical location. Using FEA to analyze 2 pulleys, with different center disc inside diameters (CD ID) results in Figure 5, a plot of the stresses along the inside of the rim.

Figure 5 shows a significant difference in rim stress for different center disc inside diameters. The FEA also shows that the disc stress will increase significantly for the larger diameter, which may require

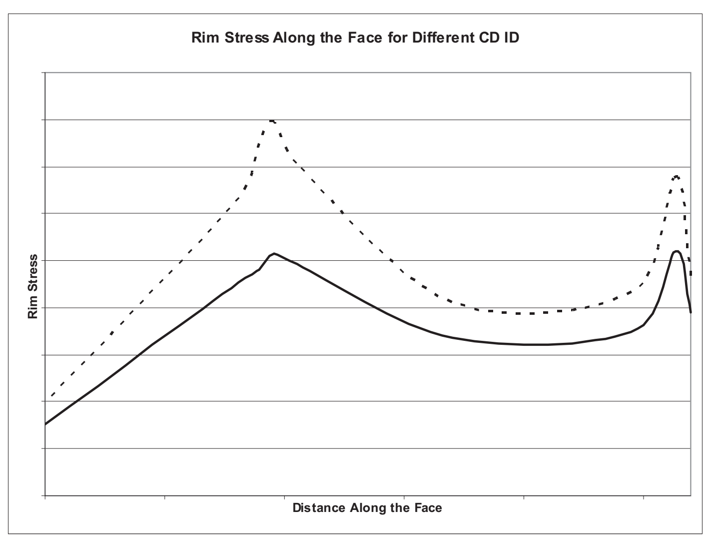

Figure 5 – Rim Stress for Different Center Disc Inside Diameters.

a thicker disc. Another interesting effect is that depending upon the actual pulley geometry the stress can be higher at the center disc closer to the end disc than the one in the middle of the pulley. While pulleys have been observed to fail at the outside center disc, it was believed that the stresses were the highest and most likely to fail at the middle center disc. This had been discounted as poor construction.

Several variations were performed and depending upon pulley geometry, including the center disc geometry would shift the curve and show higher stress above the middle center disc, while other geometries show higher stresses above the outside center disc.

Is there an optimum center disc geometry? Yes, there is, but just like the rim rating curve in Figure 1, the shape will shift with the pulley geometry. Some sample runs reveal a little insight into what happens with different center disc inside diameters. Figure 6 shows a plot of stresses for various points on the inside of the rim as a function of the center disc inside diameter. The FEA runs show that the rigidity of the center disc decreases as the inside diameter increases. This will lower the stress in the rim as it is allowed to bend with the load. However, at some point the rigidity of the center disc becomes too small, and it will not give the rim the support that it needs.

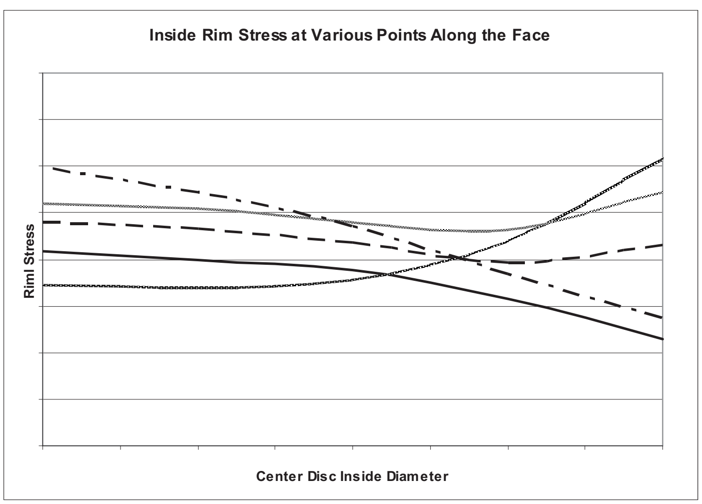

Figure 6 – Inside Rim Stress as a Function of Center Disc Inside Diameter

Figure 7 is a plot of the stresses in the outside of the rim for the same FEA runs. A similar reduction in rim stress is seen on the outside.

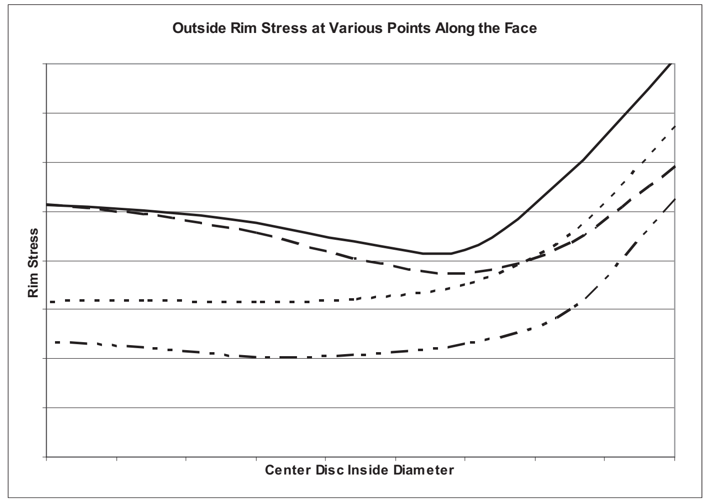

Figure 7 – Outside Rim Stress as a Function of Center Disc Inside Diameter

CONCLUSION:

Center Disc modeling in Finite Element Analysis (FEA) is an important addtion to pulley design. It can provide insight into the development of center disc usage in conveyor pulleys.

The center disc and rim must be designed together to share the load between them, similar to designing the shaft and end disc, so that they share the load and work in conjunction with each other. There is an optimal center disc design for each pulley assembly, which will require Finite Element Analysis to determine.

REFERENCES:

Laughlin, 2002, “A Comparison Of Turbine Pulley Design Philosophies With Historical Perspective”, Proceedings, Meeting of the Society of Mining Engineers, February, 2002,