Ramsay Maunder ASSOCIATES

Finite Element Specialists and Engineering Consultants

Design/Analysis of a Pair of Pulleys

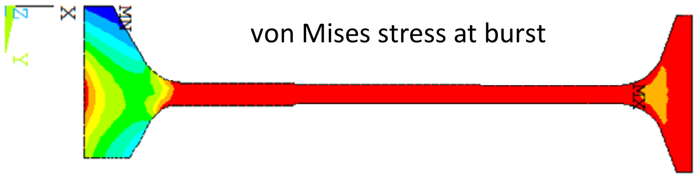
This case study describes a design-analysis project in mechanical engineering undertaken by Ramsay Maunder Associates (RMA) for the pulleys of an industrial bandsaw.

The bandsaw comprises two main pre-tensioned pulleys that drive a saw band. The stresses induced in the pulleys are primarily due to centrifugal loading but also to the interference fit between the pulley and the shaft.

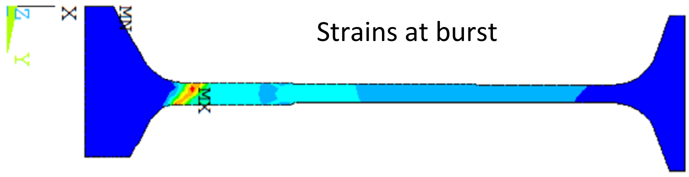
The manufacturer is designing a new machine to run at a higher speed and requested RMA's assistance in undertaking a finite element stress analysis of the pulleys in order to establish whether the existing cast iron would be acceptable to take the higher stresses.

RMA conducted a detailed finite element stress analysis and fatigue assessment of the two pulleys. Additional analyses were conducted to establish the burst speed and the natural frequencies.

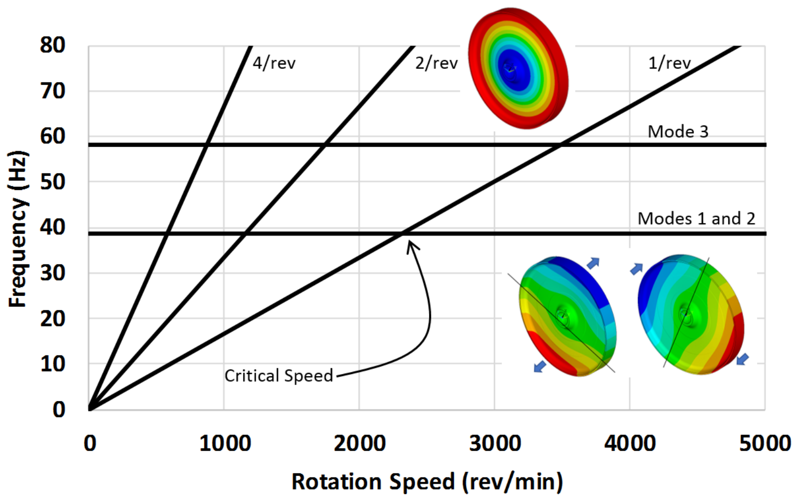
Although the pulleys, which contain holes in the web and hub, are not strictly axisymmetric, an axisymmetric finite element model provides valuable information that can then be refined using a three-dimensional model to include the influence of the holes on the stresses.



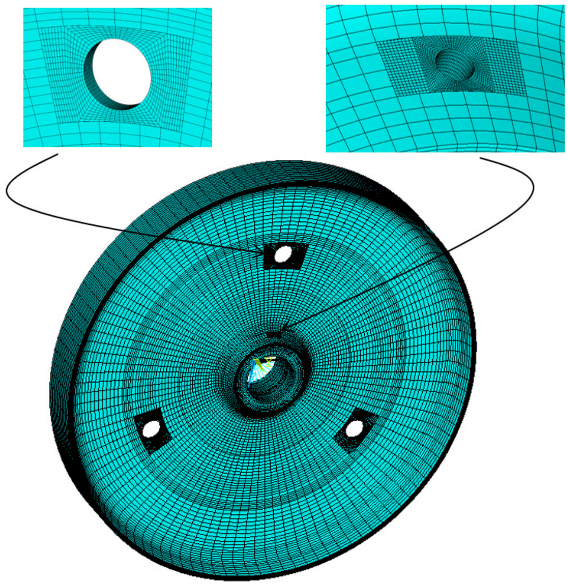
The burst speed was established through an incremental FE analysis using elastic, perfectly plastic material properties and the von Mises yield criterion. Because cast iron has limited ductility it was important to confirm that the strains at burst did not exceed those that the material can take.



A three-dimensional model was required to determine the modes of vibration since the first two modes were not axisymmetric in form as seen in the Campbell diagram.

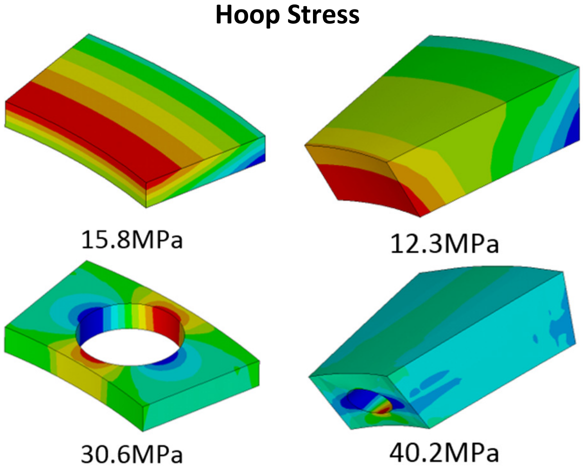


A three-dimensional FE model was constructed of the pulley to ensure high-fidelity stress predictions for the fatigue assessment, and included refined regions embedded in the mesh around the holes in both the web and the hub.

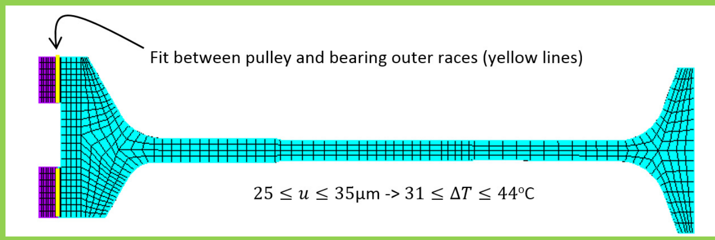


The hole in the web leads to a stress concentration factor of about 2 whereas the hole in the hub, used as a grease hole to lubricate the bearings, leads to a stress concentration of about 2.5.

Hoop Stress



With the increase in speed for the new machine it is necessary to assess the interference fit. This assessment was undertaken using axisymmetric FE analysis which now included the outer races of the bearings with contact elements between the components.



The interference was induced by applying an appropriate temperature decrease to the pulley. The radial force between bearings and pulley was established at the current speed and at the proposed increased speed and with the coefficient of friction the limiting torque for the fit was determined.

The axisymmetric model was also used to determine the nominal stress in the bore of the pulley where the grease hole penetration occurs. This stress was then scaled up with the stress concentration factor established through the three-dimensional FE model.

A fatigue assessment was conducted for the peak stress around the grease hole and was based on the start/stop cycle for the machine. As a result of the interference fit there is significant stress at this point even when the machine is stationary. The mean stress, S_m, and stress amplitude, S_a, were calculated and, using the ultimate stress, S_u, the Goodman equation was used to determine the fatigue strength, S_n, required for the pulley.

$$\frac{S_a}{S_n} = 1 - \frac{S_m}{S_u} \rightarrow S_n = \frac{S_u S_a}{S_u - S_m}$$

Thoughtful application of structural mechanics combined with careful use of the finite element analysis enabled the stresses in the pulley to simulated. With these stresses a prediction of the required fatigue strength for the pulleys could be established. RMA's long experience in the design/analysis of rotating machinery successfully assisted the customer in being able to select an appropriate cast iron for the uprated bandsaw.

RMA regularly undertakes such work for clients and can be contacted at http://www.ramsay-maunder.co.uk/