Rotating Machinery Services, Inc.

AXIAL COMPRESSOR ROTOR BLADE ROOT REDESIGN

By Chris Sykora, Senior Structural Analyst

RMS recently completed the machining of a brand new, upgraded axial compressor rotor for a major West Coast oil refinery. The upgrade of this rotor included a complete redesign of the rotor blade root attachments to the rotor drums. The previous configuration of this rotor used blades with conical seats that were screwed into the hollow drums and attached with nuts inside the drums. While this allows for many different aerodynamic designs since the blades can be rotated, assembly of these blades is a real hassle. Someone has to be physically inside the rotor drums to turn the nuts while the blade is held in position from the outside by another person and blade angles must be checked and rechecked during assembly.

To help the customer avoid this, RMS upgraded the blade root designs to a tangential entry dovetail that is a fixed angle and can be easily assembled, common in steam turbine blades. This was a proven concept that was used on a previously overhauled rotor that was about half the size of the current rotor.

In order to qualify this upgraded design, the new blade roots of all 10 stages had to be analyzed for stresses and vibrations, while trying to replicate the previous aerodynamic design as close as possible to maintain performance.

The first step was to analyze the stresses in the blade roots with a 3D solid ANSYS model of the entire blade, the section of rotor drum around the blade root, and the spacer pieces used in between blades. Parametric optimization routines in ANSYS were used in the preliminary design of this blade root in order to minimize the stresses by adjusting the flank angle, neck width, and fillet radii. Adjusting some of these parameters larger or smaller caused tradeoffs in blade versus disc stresses, so the proper application of the multi-objective genetic optimization algorithms in ANSYS was critical to finding the best design. RMS has both the software capabilities and engineering knowledge to implement this kind of optimization on many different projects.

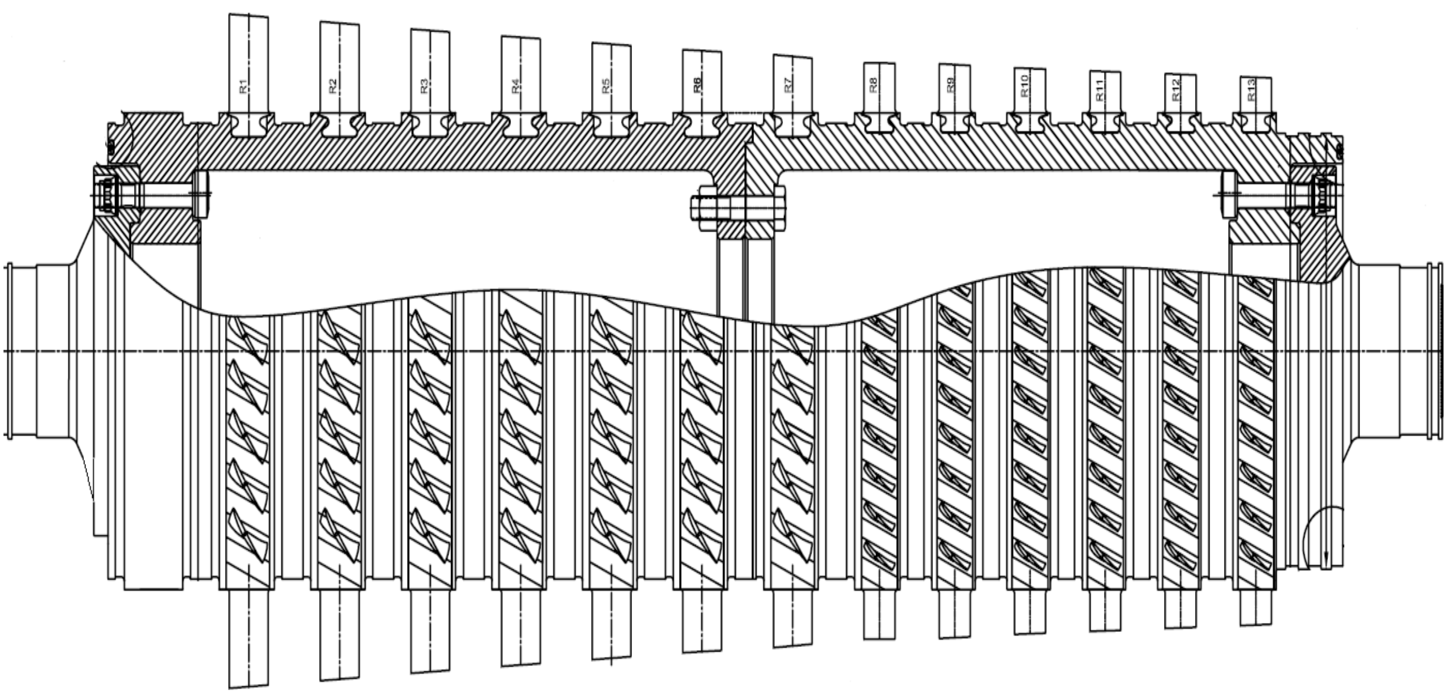

Figure 1: Tangential entry rotor concept

The next step in the redesign was to check that the vibration frequencies of each rotor blade were appropriately separated from the excitation frequency stimuli. Campbell diagrams were used to interpret the modal analysis results from ANSYS. Since the blade roots were significantly altered compared to the old screw-in design, the vibration frequencies of some mode shapes were different than the original blades. As a result, there were several preliminary blade designs that had unacceptable frequency separation margins that could have resulted in damaging resonance during operation.

The blade roots on those blades were further adjusted in order to tune the natural frequencies away from excitations on the Campbell diagrams and stresses were re-analyzed. A few of the blades also required iterating on the aerodynamic design to modify the airfoil shapes to avoid potential resonances, since blade root changes were not effective enough on their own. One of the stages of the blades was also modal impact frequency tested to validate the FEA results, since it had closer margins than could be accepted based on the analysis alone.

Ultimately, the new blades were successfully designed such that they met all RMS design criteria for compressor blades and are now being prepared for assembly into the finished rotor and reinstallation at the oil refinery.

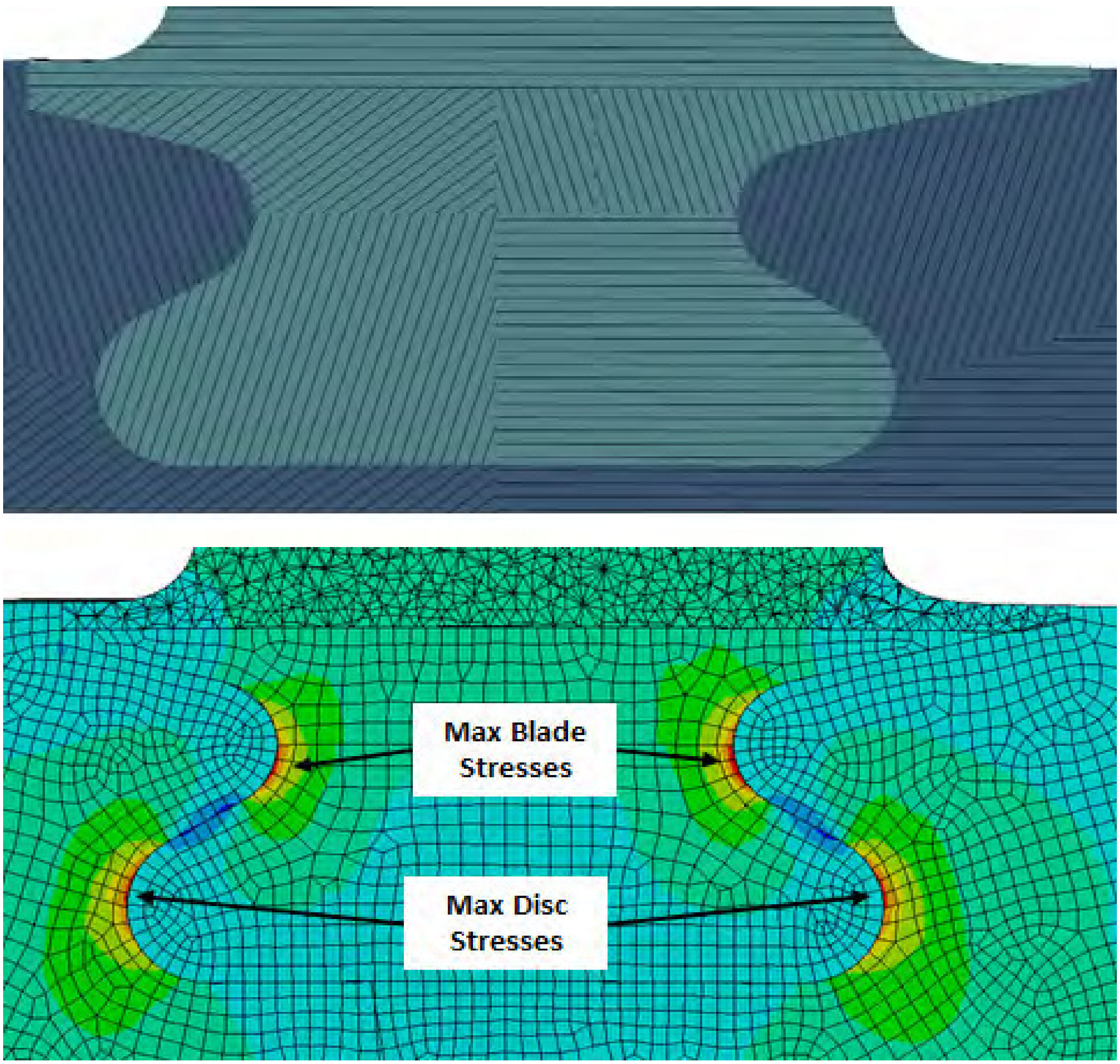

Figure 2: Tangential entry blade root design and resulting stresses

For more information:
Email: RMS@rotatingmachinery.com
Tel: 484-821-0702

Headquarters
2760 Baglyos Cir.
Bethlehem, PA 18020

Houston Office
16676 Northchase Dr., Ste 400
Houston, TX 77060

rotatingmachinery.com
Tel: 484-821-0702
Parts: rms@rotatingmachinery.com

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Rotating Machinery Services, Inc. | 2760 Baglyos Circle, Bethlehem, PA 18020 | Tel: 484-821-0702