

Failure Risk Evaluation of a Turbine Rotor's Control Stage

BACKGROUND

Partial arc admission, where some inlet control valves operate while the rest are closed, is very desirable since it increases turbine performance and efficiency during low load operation. However, the blade-fit areas of certain high and intermediate pressure steam turbines operating in partial arc, can experience shock stresses and are susceptible to failure (Fig. 1).

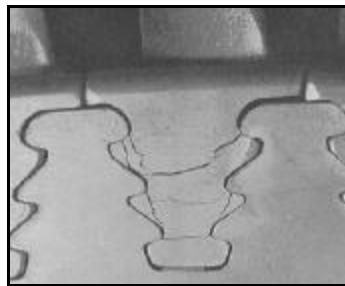


Figure 1. High cycle fatigue cracking in the blade-fit area (courtesy of EPRI)

DISCUSSION

During partial arc operation, steam loads, which appear as a step function, cause shock stresses in the blade-root and the rotor-steeple. This causes high cycle, low-amplitude fatigue loading which can lead to cracking and eventual failure of certain blade-fit areas.

To evaluate the failure risk associated with partial arc operation, MIS developed methodology and software to estimate shock stress levels during all operating conditions. The stresses for a specific rotor design are calculated based on the change in steam momentum (impulse) through the rotating stage (Fig. 2).

Information from the rotor, the condition of its control

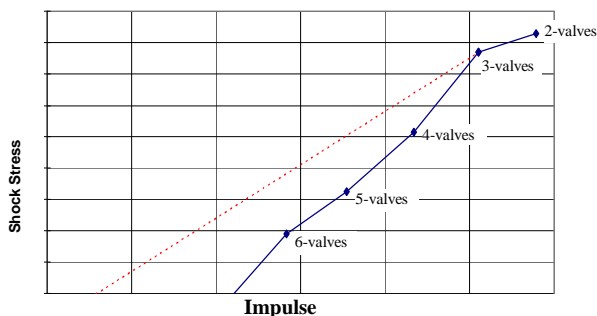


Figure 2. Shock stress vs. impulse for a control stage rotor-steeple

stage, and operating parameters at actual or simulated operating conditions are input into the MIS software to evaluate the risk of operation at any valve mode for the following three categories:

- Failure of rotor-steeple without launching blades (no forced shutdown).
- Failure of blade-root without launching blades (no forced shutdown).
- Failure of rotor-steeples or blade-root with launching blades (forced shutdown).

Table 1 shows the results of such an analysis for a specific plant.

Load	Valve Mode / Failure Risk																			
	2-Valve Mode			3-Valve Mode			4-Valve Mode			5-Valve Mode			6-Valve Mode							
	Stress	a	b	c	Stress	a	b	c	Stress	a	b	c	Stress	a	b	c				
0-X1	σ_{12}	0	0	0	σ_{13}	0	0	0	σ_{14}	0	0	0	σ_{15}	0	0	0	σ_{16}	0	0	0
X1-X2	σ_{23}	0	VL	0	σ_{23}	0	0	0	σ_{24}	0	0	0	σ_{25}	0	0	0	σ_{26}	0	0	0
X2-X3	σ_{32}	0	VL	0	σ_{33}	0	0	0	σ_{34}	0	0	0	σ_{35}	0	0	0	σ_{36}	0	0	0
X3-X4	σ_{42}	0	M	0	σ_{43}	0	0	0	σ_{44}	0	0	0	σ_{45}	0	0	0	σ_{46}	0	0	0
X4-X5	σ_{52}	0	H	0	σ_{53}	0	VL	0	σ_{54}	0	0	0	σ_{55}	0	0	0	σ_{56}	0	0	0
X5-X6					σ_{63}	0	VL	0	σ_{64}	0	0	0	σ_{65}	0	0	0	σ_{66}	0	0	0
X6-X7					σ_{73}	0	VL	0	σ_{74}	0	0	0	σ_{75}	0	0	0	σ_{76}	0	0	0
X7-X8					σ_{83}	0	L	0	σ_{84}	0	0	0	σ_{85}	0	0	0	σ_{86}	0	0	0
X8-X9									σ_{94}	0	0	0	σ_{95}	0	0	0	σ_{96}	0	0	0
X9-X10									σ_{104}	0	0	0	σ_{105}	0	0	0	σ_{106}	0	0	0
X10-X11									σ_{114}	0	VL	0	σ_{115}	0	0	0	σ_{116}	0	0	0
X11-X12													σ_{125}	0	0	0	σ_{126}	0	0	0
X12-X13													σ_{135}	0	0	0	σ_{136}	0	0	0
X13-X14																	σ_{146}	0	0	0
X14-X15																				

Table 1. Shock stresses and associated failure risk

CONCLUSION

MIS has developed methods and tools that provide engineers with a reasonable and reliable measure of the failure risk for a rotor's control stage under all operating conditions. Based on this risk, engineers can examine cost-saving alternatives to the replacement or modification of the control stage, such as new operating procedures. The program may also be implemented in the plant's control algorithms to avoid high risk operations and optimize operation at all valve modes.