

# MODE SHAPES OF PACKETED BLADES

By William Sullivan

Before proceeding further into the interference diagram, we probably should look at some packeted blade mode shapes because it is examining the likelihood of exciting (or, preferably, not exciting) these modes that the interference diagram is most useful. To do this we constructed and analyzed a simple finite element model of a packet of six shrouded blades. The first twelve mode shapes are listed to the right.

For the first mode, all six blades are moving together. The motion is roughly parallel to the rotor axis. Therefore, this is called an axial mode. The second mode is the first tangential mode. Again, all blades are moving together but this time they are moving perpendicular to the rotor axis, or tangential to the disk. The third mode is another axial mode. However, for this mode, the blades on either end of the shroud are moving in opposite directions. If one were to look down at the shroud, it would look somewhat like the letter "X". Hence, this is sometimes called the "X" mode. The plots below show this and three other "letter" axial modes: the "U", "S" and "W" modes. Note that for the "X" mode, there is a node (a location where there is no movement) at about the center of the shroud. For the "U" mode there are two nodes, for the "S" mode, there are three nodes, and so forth. (For six blades there can be no more than five nodes.)

Mode	Freq Hz	Shape	
1	1460	Axl - 1	
2	1616	Tan - 1	(Fixed-Free)
3	1692	Axl - 2	(X)
4	2310	Axl - 3	(U)
5	3351	Axl - 4	(S)
6	4138	Tan - 2	(Fixed-Fixed)
7	4661	Axl - 5	(W)
8	5782	Axl - 6	
9	5848	Tan - 3	
10	6307	Tan - 4	
11	6436	Tan - 5	
12	6471	Tan - 6	



Figure 1: First Axial Mode

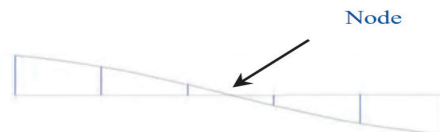


Figure 2: Second Axial Mode  
The "X" Mode



Figure 3: Third Axial Mode  
The "U" Mode

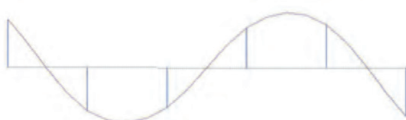


Figure 4: Fourth Axial Mode  
The "S" Mode



Figure 5: Fifth Axial Mode  
The "W" Mode

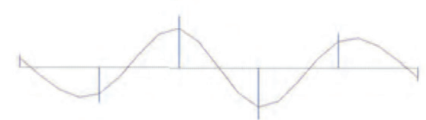


Figure 6: Sixth Axial Mode

The tangential modes also are grouped by the number of nodes in the mode shape, although the nodes aren't as obvious. The first three tangential modes are shown below. For these modes, the view is parallel to the rotor axis.



Figure 7: First Tangential Mode

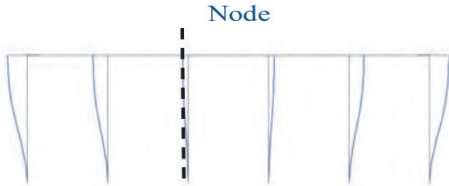


Figure 8: Second Tangential Mode



Figure 9: Third Tangential Mode

The large frequency shift from the first to second tangential mode (1,616 Hz to 4,138 Hz) is because in the first mode the shroud is moving with the blades and adds essentially no stiffness to the system. However, in the second, and all of the higher modes, the shroud is constraining blade tip movement and, therefore, is contributing a significant amount of stiffness to the system. Essentially, from the first to second tangential modes, the blades moved from a fixed-free system to a fixed-fixed system.

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