MODE SHAPES OF PACKETED BLADES

By William Sullivan

The last installment of the interference diagram series described the mode shapes possible with a single packet of six blades. This installment will describe how these mode shapes arrange themselves around a bladed disk with ten packets of six blades each. For simplicity (and visibility) we will look at axial modes only. The concepts described for axial modes apply to tangential modes as well.

In the axial blade modes of vibration, most of the blade motion is perpendicular to the plane of the disk. This makes defining the nodes (locations of no displacement) relatively easy. The nodes will be the locations where a line running from the point of maximum deflection from blade to blade crosses the center plane of the disk. These are called “0 (zero) crossings”. For a single packet of six blades there can be up to five nodes (0 crossings) within the packet. For any two adjacent packets of blades, there can be no more than one node from one packet to the next packet. Therefore, for ten packets of six blades each arranged around a disk rim, there can be a total of up to 60 nodes. These nodes represent nodal radii. For interference diagrams of bladed disks, we work in nodal diameters. Therefore, the maximum of 60 nodal radii described above represents 30 nodal diameters (1/2 the number of blades). There always will be an even number of nodes and, therefore, a whole number of nodal diameters around a bladed disk because the end of a line going from maximum deflection to maximum deflection from blade to blade must come back to the original maximum deflection. In other words, the nodes must occur in pairs.

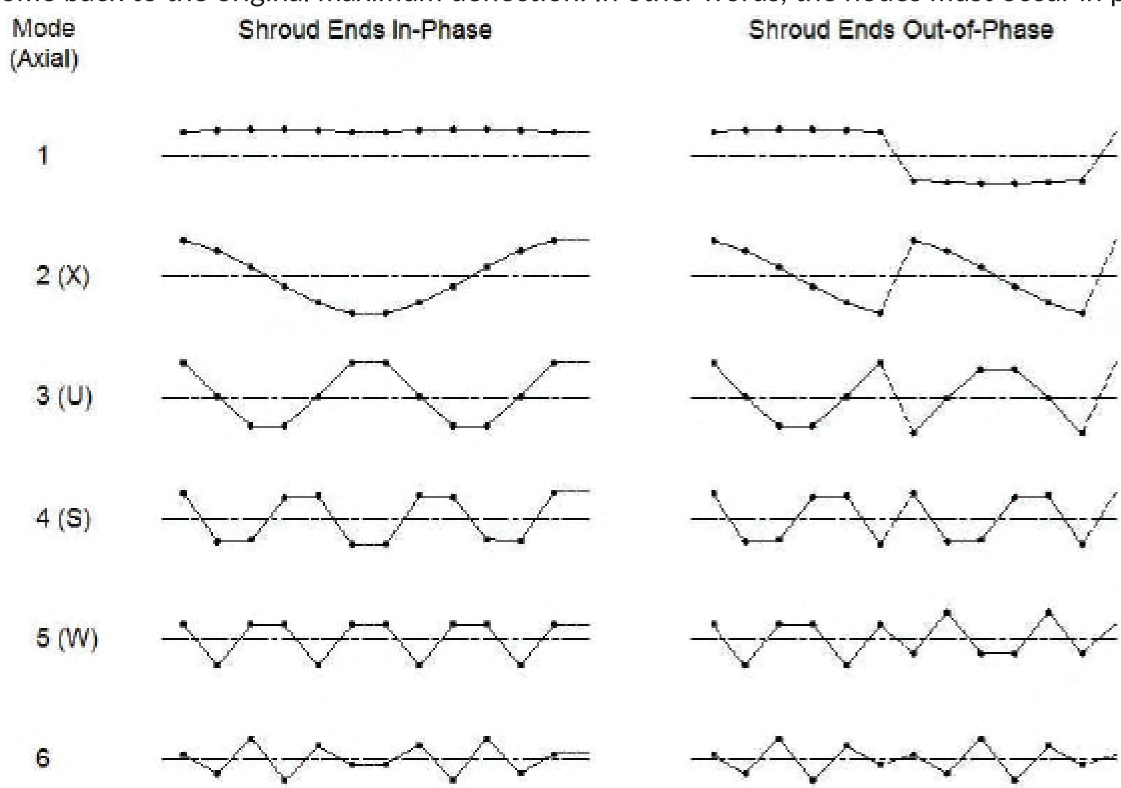

Figure 1: Packet-to-Packet Phase Relationship

The number of nodes around a disk for a given shroud mode shape will depend on the mode being excited and the phase relationships of the packets around the disk. That is, adjacent packets of the same mode shape can be in-phase or out-of-phase. The packet-to-packet phase relationship determines whether or not there is a node between the packets. The figure above shows the packet to-packet phase relationships possible with packets of six blades arranged around a disk. Although two packets are shown for each case, the nodes (0 crossings) are tabulated below the figure for one packet only. Two cases are shown for each mode: shroud ends in-phase and shroud ends out-of-phase. In any grouping of separately packeted blades around a disk, all of the shroud ends can be in-phase (exceptions occur with odd numbers of packets), all can be out-of-phase (exceptions occur with odd numbers of packets), or there can be any combination between these extremes (as long as the result is a even number of nodes).

Mode	Number of Nodes (0-Crossings) in				Number of Nodal Diameters in 10 Packets of 6 Blades Each	
	1 Packet of 6 Blades		10 Packets of 6 Blades Each			
	Ends In-Phase	Ends Out-of-Phase	Ends In-Phase	Ends Out-of-Phase	Ends In-Phase	Ends Out-of-Phase
1	0	1	0	10	0	5
2 (X)	1	2	10	20	5	10
3 (U)	2	3	20	30	10	15
4 (S)	3	4	30	40	15	20
5 (W)	4	5	40	50	20	25
6	5	6	50	60	25	30

Table 1: The Nodes (O Crossings)

The interference diagram to the right shows how the mode shapes described above are arranged for ten packets of six blades each. This diagram shows only the first order (0 nodal circle) modes of vibration on a stiff disk for clarity. (The tangential modes are shown along with the axial modes described above because they do not reduce the clarity and it is important to show that the tangential modes exhibit the same behavior as the axial modes, although the nodes are not as evident.) The numbers near each group of modes identifies the shroud (not the blade) mode shapes. Note that the modes are grouped together by frequency and possible nodal diameters.

For example, a second axial shroud mode of vibration, the "X" mode, in this arrangement will always have from 5 to 10 nodal diameters. This behavior often can be used to move vibration modes away from possible sources of vibration or to determine what nozzle count to use to avoid exciting a particular mode. This is one of the chief uses of the interference diagram and why it is such a powerful tool. It shows not only what configurations could cause a blade excitation, it shows what configurations will not cause a blade excitation.

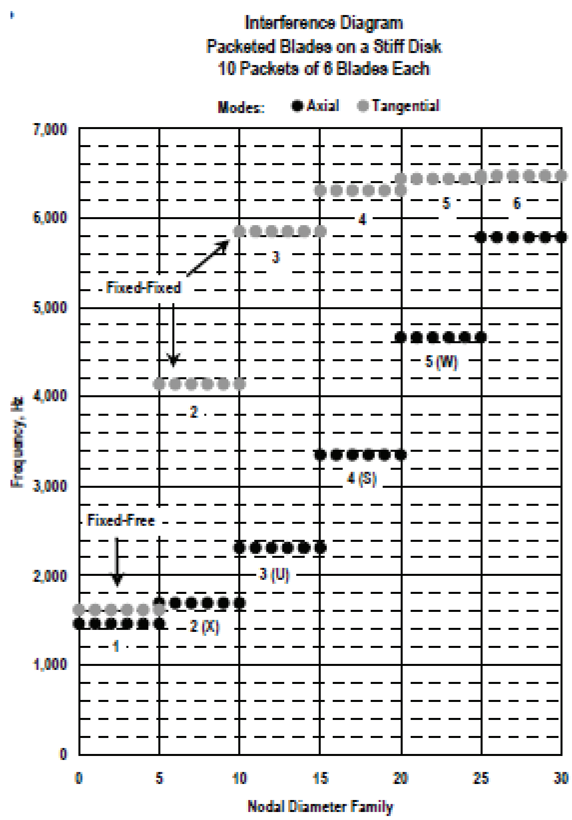

Figure 2: Interference Diagram Packeted Blades on a Stiff Disk 10 Packets of 6 Blades Each

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