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# Torsional Rotordynamics of Machinery Equipment Strings

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**Mark A. Corbo** is the President and Chief Engineer of No Bull Engineering PLLC, a high technology engineering/ consulting firm located in Schenectady, NY. He is responsible for providing rotating equipment consulting services in the forms of engineering design and analysis, troubleshooting, and third-party design audits to various clients within the turbomachinery industry. Prior to beginning his consulting career at Mechanical Technology Incorporated (MTI) in 1995, he spent 12 years in the aerospace industry designing pumps, valves, and controls for gas turbine engines. His fields of expertise include rotordynamics, torsional vibration, fluid-film journal and thrust bearings, hydraulic and pneumatic flow analysis, computational fluid dynamics, finite element analysis, and mechanical design. Mr. Corbo has B.S. and M.S. degrees (Mechanical Engineering) from Rensselaer Polytechnic Institute. He is a registered Professional Engineer in the State of New York and is a member of ASME, STLE, and The Vibration Institute. Over the course of his 30 year career, he has authored more than a dozen technical publications, including one that won the "Best Case Study" award at Bently Nevada's ISCORMA rotordynamics conference in 2001. He is currently serving as the Chair of the Torsional Vibration Section on the Task Force for the API 684 Rotordynamics Tutorial.

**Brian Pettinato** is Manager of Product Development at Elliott Group in Jeannette, Pennsylvania. He has been with Elliott Group since 1995. His areas of expertise include lateral and torsional rotordynamics, vibration analysis, and the testing and evaluation of fluid film journal bearings. He currently manages a group responsible for compressor and expander technology development. Prior to joining Elliott Group, Mr. Pettinato worked as a project engineer for an aftermarket bearing manufacturer. Mr. Pettinato received his B.S. (Mechanical Engineering, 1989) and M.S. (Mechanical Engineering, 1992) degrees from the University of Virginia. He has coauthored over ten technical papers, and holds one U.S. patent. He is a registered Professional Engineer in the State of Pennsylvania, and is a member of ASME, STLE, and the API 684 rotordynamics task force. He joined the TAC in September, 2012.

**Malcolm Leader** is the owner of Applied Machinery Dynamics Company. After working for Monsanto Company in Texas City for 9 years, Mr. Leader has run his own turbomachinery consulting business for 24 years. With a focus on providing practical solutions, he specializes in lateral rotordynamics including bearing and seal optimizations as well as steady state and transient torsional analyses. He has analyzed and improved the stability and reliability of over 176 rotating equipment trains. He also offers field diag- nostics of machinery problems and advanced vibration testing and analysis. Specialized training courses are also offered. Mr. Leader received his BSME in 1977 and his MSME in 1978 from the University of Virginia.

**Chris D. Kulhanek** is a Research Engineer in the Fluids & Machinery Engineering Department at Southwest Research Institute. He is responsible for investigating problems with fluid-process machinery and associated plant systems. His interests include lateral and torsional rotordynamics, bearings and seals, finite element analysis, and mechanical design. Mr. Kulhanek performs third-party design audits, troubleshooting, and root cause failure analysis of turbomachinery and fluid systems. He has authored technical papers in the area of fluid film bearings and torsional vibration. Mr. Kulhanek received his B.S. and M.S. degrees (Mechanical Engineering) from Texas A&M University.

44th TURBOMACHINERY SYMPOSIUM
SHORT COURSE

# TORSIONAL ROTORDYNAMICS OF MACHINERY EQUIPMENT STRINGS

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One of the foremost concerns facing rotating equipment users today is that of torsional vibration. In contrast to lateral vibration, torsional vibration is rarely monitored. As a result, torsional failures can be especially heinous since the first symptom of a problem is often a broken shaft, gear tooth, or coupling. In the past, torsional vibration problems were considered to be rare; however the number of torsional field problems has markedly increased recently with the advent of higher power, higher complexity variable frequency drives (VFD's). The increased risk plus the difficulty of detecting incipient failures in the field makes the performance of a thorough torsional vibration analysis an essential component of the turbomachinery design process.

There are three objectives to this Short Course. First, it will provide users with a basic understanding of steady-state torsional vibrations, their potential for generating problems, and methodologies that are commonly used to analyze and avoid these problems. This portion of the course is aimed at younger, less experienced users, although veteran users will probably also benefit from the review. Second, it will provide users with some understanding of the more complex issues related to transient torsional vibration and acceptance based on stress analysis. Third, it will educate users on VFD's and the unique torsional vibration problems that are associated with them. This portion will be beneficial to all users since modern VFD's are not well understood, especially by mechanical engineers.

The course will be based on practical examples starting from the simple to the complex. Among the topics that will be discussed include description of torsional vibration, modeling, undamped analysis, Campbell diagrams, excitations generated by various mechanical and electrical components, steady-state and transient analyses, synchronous motor startups, fatigue life analysis, and torsional testing. At the conclusion of this portion, the user should have a good grasp of the fundamentals of this topic.

A significant portion of time will then be spent on VFD's. Topics covered will include VFD types, excitation frequencies generated by various VFD's, typical excitation amplitudes, control loop instabilities that can lead to problems, coupled electro-mechanical analyses, and design procedures for preventing VFD-related torsional issues up-front.

At the conclusion of this course, all users should have sufficient understanding of the relevant concepts so that they should be able to take the proper steps to prevent torsional vibration problems from occurring in their equipment, even when their system contains a VFD.