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ADDRESSING HIGH SUB-SYNCHRONOUS VIBRATIONS IN A TURBOEXPANDER EQUIPPED WITH ACTIVE MAGNETIC BEARINGS

Tadeh Avetian, P.E.
Director of Engineering
L.A. Turbine
Valencia, CA, USA

Junyoung Park, Ph.D
Machinery Engineer
Samsung Engineering CO. Ltd.
Seoul, South Korea

Luis E. Rodríguez.
Design Engineer
L.A. Turbine
Valencia, CA, USA

Tadeh Avetian is currently Director of Engineering at L.A. Turbine in Valencia, California, where he is responsible for identifying and defining research and development projects and directing turboexpander design for new and aftermarket equipment. Mr. Avetian first joined L.A. Turbine in 2011 as Core Design Manager. His responsibilities included designing all new and custom turboexpanders and supporting the design of auxiliary systems. Mr. Avetian previously held the position of Rotating Machinery Engineer at Technip USA, Inc. (now TechnipFMC). In this role, he specified, sourced and evaluated equipment for the construction of hydrocarbon processing plants, refineries and petrochemical facilities. Mr. Avetian is a California-registered Professional Engineer (P.E.) with a Bachelor and Master of Science in Mechanical Engineering from California State Polytechnic University, Pomona, California.

Luis E. Rodríguez is a Design Engineer with L.A. Turbine in Valencia, California, where he is responsible for the mechanical design of turboexpanders. Previously, he served for 10 years in the engineering department of Sulzer Turbo Services (now Sulzer Rotating Equipment Services) in La Porte, Texas. He has co-authored papers published in the ASME Journal of Tribology and the STLE transactions. He holds a B.S. degree from Universidad Simón Bolívar in Venezuela (2001), and a M.S. from Texas A&M University in College Station, Texas (2004). He is a licensed Professional Engineer in the State of Texas since 2007 (currently inactive).

Junyoung Park, Ph.D is the Rotating Machinery Leader Engineer at SAMSUNG ENGINEERING Co. Ltd. Since joining the company in 2008, his responsibilities include detail engineering of rotating machinery and trouble shooting of mechanical vibration issues, mainly in Oil & Gas and Petrochemical Plants. He is involved in several on-going projects working with rotating machinery, such as pumps, compressors, turbines and expander-compressors. Dr. Park received his M.S degree (Mechanical Engineering, 2002) from University of Southern California and Ph.D degree (Mechanical Engineering, 2008) from Texas A&M University.
During his Ph.D period, he worked with several research projects sponsored by NASA. He is a member of KCIMD (Korea Certification Institute for Machine Diagnostics)

ABSTRACT

It is well known that cross-coupled forces can be induced by aerodynamic interactions between rotating and stationary components in a turbomachine. There is an abundance of well-documented case studies addressing unstable sub-synchronous vibration on process compressors in the technical literature. The API-617 standard addresses this topic in its rotordynamics section, requiring OEM designers perform Level 1/2 stability analyses to ensure stable designs. Potential destabilizing impeller aerodynamic forces must be considered in these analyses, utilizing equations such as the API-Wachel equation. Other analytical tools are also necessary to predict cross-coupled forces from components such as labyrinth seals. Broadly speaking, such approaches have proven to be sufficient for the design of centrifugal and axial compressors. However, the experience of the authors exposes the fact that rotordynamic instabilities induced by cross-coupling in radial inflow turbine applications are less well understood.

Accounts of such problems in turboexpanders are scant in the technical literature. In the past, various explanations have been offered to explain excessive sub-synchronous vibrations in turboexpanders. In one instance that involved a turboexpander equipped with a magnetic bearing, it was suggested that liquids in the expander inlet was the root cause (Shokraneh, 2016). In another published case study, a similar sub-synchronous vibration was induced by rotordynamic instabilities likely due to aerodynamic cross-coupling, on a machine operated with oil bearings and dry process gas throughout the flow path (Lillard, 2017). While operational problems with turboexpanders with oil bearings or magnetic bearings are rare, further understanding of the cross-coupled characteristics is necessary.

This paper presents the experience of the authors with a turboexpander (TEX) equipped with active magnetic bearings (AMBs) in a natural gas processing facility. The TEX was unable to achieve design performance due to high sub-synchronous vibration since its commissioning. Rotordynamic simulations revealed that the most likely root-cause of the high vibration was the excitation of an unstable rigid body mode of the rotor-bearing system due to high cross-coupled stiffness effects. This paper also contains a summary of the redesign features incorporated in the TEX that resolved the sub-synchronous vibration.