45th Turbomachinery & 32nd Pump Symposium
Short Course – September 12, 2016

Short Course Description

PUMP CAVITATION – PHYSICS, PREDICTION, CONTROL, TROUBLESHOOTING

by

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This short course deals with cavitation in general and rotodynamic pump cavitation in particular. It gives an introduction to the subject matter and provides insights in particulars like cavitation inception, 3% head drop, and 40,000 hours impeller life, as well as NPSH scaling laws. It further devotes attention to the effect of dissolved gases, and thermal suppression (i.e. thermodynamic effect) when pumping hot water or hydrocarbons. For (hydrocarbon) mixtures it will also be outlined that cavitation intensity can be expected to be far less than with pure fluids. With regard to numerical prediction capabilities the use of Computational Fluid Dynamics (CFD) shall be discussed, and empirical correlations will be presented. Furthermore, some guidance for cavitation damage diagnosis shall be given, including prediction of cavitation erosion rate, and assessment of impeller life expectancy. Also addressed are suction specific speed, and how this dimensionless group tends to cause bias and give rise to misunderstanding and misinterpretation. In this context also the corrected suction specific speed will be presented, and the concept of suction energy will be discussed. Furthermore, NPSHR criteria and establishing NPSHA margins will be outlined. As special modes of operation, the effect of fluid transients will be highlighted, demonstrating that such may yield excessive cavitation. Furthermore, a qualitative "Cavitation Modes Map" will be presented, which reflects five decades of fundamental cavitation observations and experimental facts (laboratory research and field data) published in the years 1941 – 1991. In particular, the typical shape of the erosion curve versus flow – seemingly peculiar, but fully supported by cavitation physics for all types of rotodynamic pumps – is discussed by highlighting an absolutely striking departure from the shape of conventional NPSHR3% curve (universally used for decades) at part flows. This deviation, which has been fully ignored in the past and is today still often neglected at various stages (pump specifications and selection, pump design, and field root cause analysis) is a primary reason of the majority of cavitation pump problems, as will be explained in this short course. The course further includes four Field Case Studies demonstrating the practical application of "Cavitation Failure Analysis – Methodology (Diagnosis and Solution Strategy)", covering low and high energy, single- and multistage, pumps.

Short Course

Pump Cavitation – Physics, Prediction, Control, Troubleshooting

Bruno Schiavello has been Director for Fluid Dynamics at Flowserve since 2000 and previously served with Ingersoll Dresser Pump Company. Mr. Schiavello was co-winner of the H. Worthington European Technical Award in 1979. He has written several papers and lectured at seminars on pump recirculation, cavitation, and two-phase flow. He is a member of ASME and has served as Associate Editor for ASME Journal of Fluids Engineering (two terms). He has received the ASME 2006 Fluid Machinery Design Award, and has been Co-Lead Organizer of ASME Pumping Machinery Symposium in 2005, 2009, 2011, and 2015. He has served on the International Pump Users Symposium Advisory Committee since 1984. Mr. Schiavello earned a B.S. degree (Mechanical Engineering, 1974) from the University of Rome and an M.S. degree (Fluid Dynamics, 1975) from Von Karman Institute for Fluid Dynamics, Rhode St. Genese, Belgium.

Frank Visser is Principal Engineer at Flowserve, Aftermarket Services & Solutions (AMSS), in Etten-Leur, The Netherlands. He joined Flowserve in 1995 and has held several positions in research, development, and (product) engineering. His key expertise and interests relate to fluid mechanics, CFD and thermo-dynamics of (centrifugal) pumps and hydraulic turbines, on which he has authored & co-authored multiple technical papers in journals and proceedings. Dr. Visser obtained a B.S. degree (Mechanical Engineering, 1985) from Technical College Alkmaar, The Netherlands, and an M.S. degree (Mechanical Engineering, 1991) and Ph.D. degree (Technical Sciences, 1996) from the University of Twente, Enschede, The Netherlands. He is a member of the Royal Institution of Engineers in the Netherlands, a member of the Industrial Advisory Board for the J.M. Burgerscentrum, Research School for Fluid Mechanics, and former Associate Editor for ASME Journal of Fluids Engineering (two terms).

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Short Course Outline

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SESSION 1 – CAVITATION BASICS

Part A: Introduction to Cavitation
- **-- Cavitation Mechanism**
- **-- Common Stages or Modes of Cavitation**
- **-- Effects (Performance loss, Material damage, Noise & vibration)**
- **-- Detection Methods (Visual, Acoustic, Indirect)**

Part B: Net Positive Suction Head
- **-- NPSHA, NPSHR, NPSH margins**
- **-- NPSH Testing (throttling, vacuum tank)**
- **-- Predicting NPSHR (empirical correlations, NPSH 40,000 hours)**
- **-- NPSH and Submergence**

Videos, animations, and quantitative figures with examples will be provided for all above aspects. The discussion will be focused on user understanding.

SESSION 2 – ADVANCED UNDERSTANDIG

Part A: Further Insights & Particulars
- **-- Suction Specific Speed**
- **-- Suction Energy**
- **-- Dissolved and Entrained Gases (effective vapor pressure, void fraction, example**
- **-- Hot Water & Hydrocarbons (thermodynamic suppression, ANSI/HI, B-parameter, example)**
- **-- Transient Effects (acceleration head, water hammer, example)**
- **-- Scaling NPSH with Pump Size and Speed**

Part B: CFD of Cavitating Flows
- **-- Cavitation Models**
- **-- Simulation with cavitation fully suppressed**
- **-- Simulation with developed cavitation**

Emphasis will be on most influencing parameters with practical applications of formulas for education of both engineers and pump users .Moreover the value and potential effective use of CFD will be highlighted.

SESSION 3 – CAVITATION CONTROL (NPSHR3%, NPSHA, Life Expectancy)

3.1. Various NPSHR Criteria – Experimental Facts

-- Loss based on the impeller eye peripheral velocity head (Gongwer 1941)
-- Loss based on pump stage head (NPSHR0%, NPSHR1%, NPSHR3%, NPSHRbd)
-- Cavitation Inception, NPSHi: visual, acoustic, indirect

Highlights on various NPSHR curve shape (centrifugal-, mixed -, axial-flow pumps and inducers).

3.2. NPSHA Margins - Key Factors

-- Damage Curve versus Flow (Sheet Cavitation, Vortex Cavitation- Suction Recirculation)
-- Suction Components (pump suction chamber, piping),
-- Scale Effects (suppression pressure, speed, fluid temperature)
-- Suction Specific Speed
-- Impeller Design

Highlights on: Cavitation Modes, Shockless Capacity vs. BEP Capacity, Flow Unbalance, Flow Distortion, Background literature, Generic criteria for NPSHA/NPSR3% (rules of thumb) and implications about pump selection and application.

3.3. Impeller Life Expectancy - Modern Approach

-- Criteria (NPSHR40,000 hours, ER – Lcav, IL, probability)
-- Experimental background (ER- Lcav correlation: description and validation)
-- Application example
-- Cavitation Control (impeller design optimization. material)

Highlights on the modern approach of "Impeller Life Expectancy" for special pump services . One example will be presented with focus on the role (input) of: Designer – Engineer – User.

SESSION 4 - CAVITATION FAILURE ANALYSIS (METHODOLOGY)

4.1. Cavitation Modes Recognition (reference map)

-- Typical Pump Cavitation Modes Map (most common bodes)
-- Peculiar cavitation damage aspects

Highlights with "typical" field data and photos corresponding to various cavitation modes

4.2. Diagnosis Approach (Root Cause Analysis, RCA) – Solution Strategy

-- Actual Field Cases
-- Step by Step Methodology

Detailed systematic presentation of four field case to train the user in the process of: a) gathering all pertinent data, b) making first judgment about root cause (potential factors: pump design, suction piping, actual operation mode), c) effectively communicating with the designer for additional insights, d) contributing to solution strategy, and e) ensuring field implementation – monitoring.

4.4. Cases submitted by attendees

Cases submitted by attendees can be discussed for RCA and potential solutions. Some background data (photos, performance curves, field operating modes) can be proposed by the attendees with electronic anonymous format in advance (preferably) via email or directly at Short Course start.