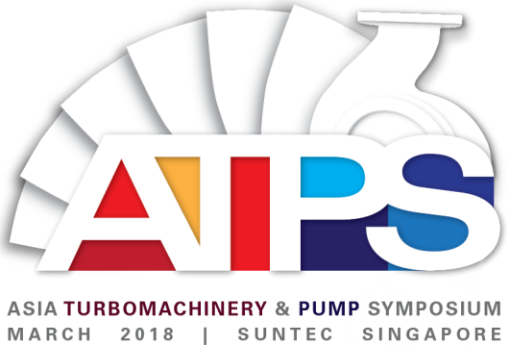


Molten Urea Transfer Pump Seal Failures – Case Study

TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION
TEXAS A&M UNIVERSITY

Author bio

Danish Moin

Danish is currently a Mechanical Maintenance Engineer at Engro Fertilizers' Urea Plant. His responsibilities include planning and execution of maintenance activities on centrifugal and PD machines of Urea plant along with investigation of reliability issues in rotary and static equipment of the aging plant. Previously he was working as Inspection Engineer at Engro Fertilizers and amassed valuable experience of FMEA studies pertaining to material failures.

Danish received B.E degree in Mechanical Engineering from National University of Sciences and Technology Pakistan, in 2013.

Danish Moin
Maintenance Engineer
Engro Fertilizers Ltd. Pakistan
dmoin@engro.com

Abstract

Urea melt pumps had been a reliability concern since commissioning (1992). Majority of the concerns were related to the failure of mechanical seal.

Unexpected failures of seal were encountered during plant startups or during pump changeover. It resulted in a major reliability concern as the continuity of operation of plant had been at stake. Also huge expenses were incurred as damaged seal caused other parts to fail. A typical overhaul costs around USD 10,000.

This Case Study highlights the identification of Failure Modes and steps taken to resolve the issues pertaining to seal reliability on this service.

Contents

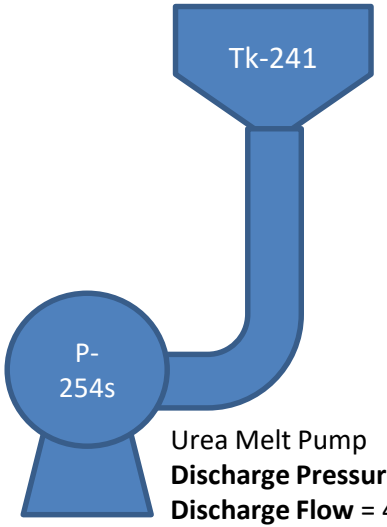
- Synopsis of the issue
- Teardown observations
- Benchmarking study
- FMEA Summary
- Post Improvement Results
- Lessons Learnt

Synopsis

- Single Stage OH1 type centrifugal pump conforming to API-610, operating with the following conditions:

Parameter	Value
Operating temperature	138 ^{o}C
Suction pressure	0.89 kg/cm^2
Discharge pressure	13 kg/cm^2
Discharge Flow	40 m^3/hr
RPM	2950
Steam Jacketing	145 – 150 ^{o}C

- Pump casing and mechanical seal housing are provided with Steam Jacketing



Synopsis

- The mechanical seal being used is Single Mechanical Seal with the following details
    - **Type:** Balanced Mechanical Seal, multi-spring design
    - **Face Material Combination:** SiC + WC
    - **Flushing Plan:** API 01 + 62 (Internal circulation through Pump Body + Steam Quenched)
- All seal failures related to this pump were reported during **Plant Startup or Changeovers** with standby pump. Such transient conditions provided a narrow window of opportunity and made it difficult to gather evidence of failure
- The multiple failure schemes made it necessary to conduct an FMEA study to finalize the potential causes failure mechanisms

Teardown Observations

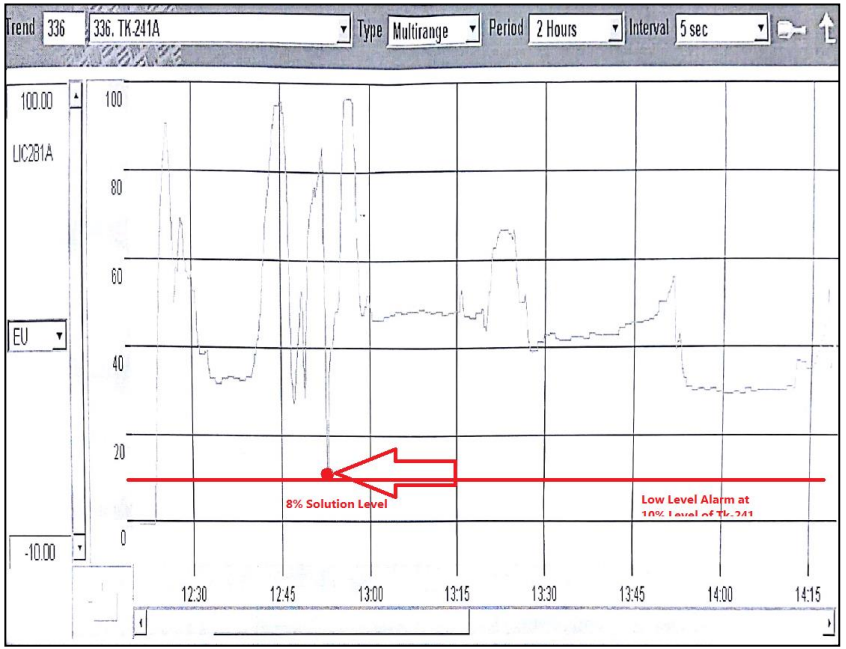
- Inspection of failed seal components was conducted of a recent failure to help in narrowing down the cause of failure. Mentioned below are the salient findings:

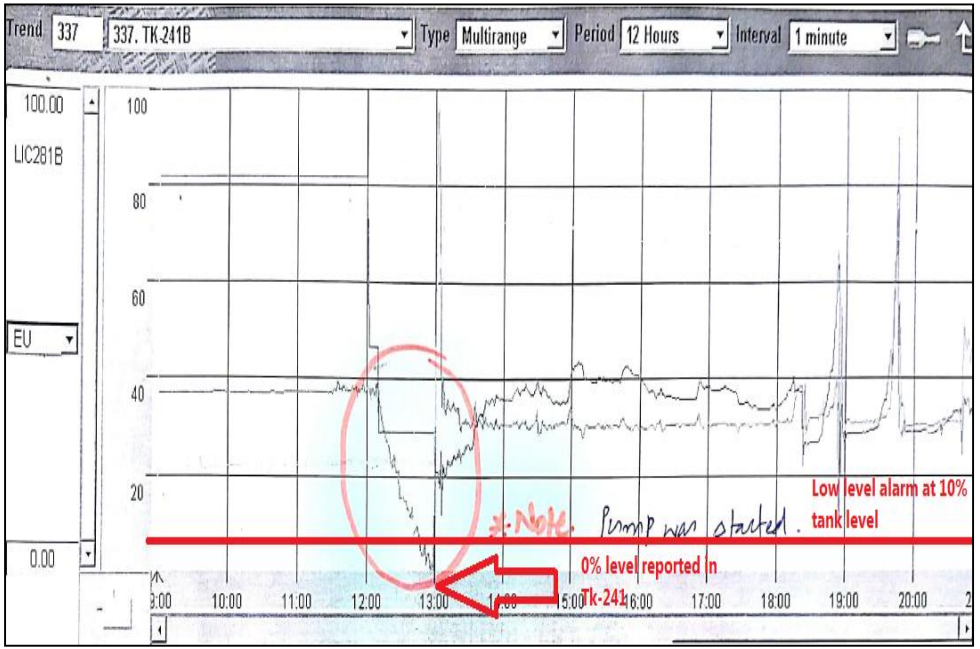
  - Pump **bearings** found in okay condition, **excessive axial or radial movement not observed**
  - All **secondary sealing** elements found okay
  - **Runout** on Seal area of shaft found within acceptable limits
  - **Even wear marks** observed on the seal faces **without deep scratches**
  - **Both seal faces found shattered**
  - **Hold tank level drops observed in Level monitoring record**

Shattered Rotary Seal Face

Shattered Stationary Seal Face

Teardown Observations





Hold up vessel level monitoring during 02 separate startups with reported seal failure

Benchmarking Study

- A benchmarking study was carried out with 03 neighboring Urea Manufacturing industries. Following are the main learnings of the study:

  - Urea Melt service is a challenging service to handle irrespective of the Plant Process designer
  - All neighboring industries face similar issues with mechanical seal reliability, irrespective of **seal manufacturer, model**
  - Hardware modifications (**changing seal make and model**) provided little relief
  - All benchmarked industries showed similar failure mechanism; **shattering of seal faces**
  - All benchmarked industries were using the **same hard-hard faces material** combination

FMEA Summary

			Criticality Analysis			Remarks
Function requirement	**Failure Mode**	**Failure Cause**	**Probability**	**Consequence**	**Detectability**	
Mechanical Seal/Sealing	Secondary sealing elements failing	1. Aging of elastomer 2. Improper Installation	Low	Med	Low	Ruled out due to no history of secondary elements failing
	Inadequacy of seal face materials	Wrong Face material combination for the service	Low	High	Med	Literature[1] suggests for abrasive services, Hard-Hard face combination is preferred
	Urea solution crystallization b/w seal faces	1. Failure of Quenching steam	Med	High	Low	There were steam leakages in the steam circuit but were addressed alongside as well
	Seal faces cocking	1. Clogging of multi-spring seal	Med	High	Low	Ruled out as even monospring seals did not prove effective
	Cavitation	1. Low NPSH 2. Chocking in suction line 3. Urea sol. Flashing	High	High	Med.	All collected Evidence suggested strong possibility of cavitation
	Poor Lubrication between Seal Faces	1.Dry/ Poor lubrication due to pump cavitation	High	High	Low	Root cause of shattered seal faces is heat shock by pump cavitation. (2)

Post Improvement Results

- The biggest contributor of Mechanical Seal failure was finalized as **Cavitation and variation in Concentration of Urea solution** as:
    - Neighboring industries also confirmed failure mode to be **shattering of seal faces**
    - Failure instances corresponded with **Low liquid levels in hold up tanks**
- Following is the breakup of the improvements made so far:

Mode of Failure	Measure	Combined Effect
Cavitation	Alarm Level increased from 10% to 20% level of Holdup Tank	Zero seal failures in the last 6 startups and changeovers
Variation in Conc. Of Urea solution	Urea melt pumps are now lined up post confirmation of high concentration	

Lessons Learnt

- Urea melt is a challenging service to deal with. High number of seal failures are common in Urea Fertilizer Manufacturing sites
- A different face material combination (other than hard-hard) is not recommended for use on abrasive services like molten urea
- A multispring seal ideally should not be used for services that can crystallize. However, with adequate steam quenching and heating of seal chamber prior to startup, the need of a monospring seal can be avoided
- Prior heating of pumps on similar applications is **mandatory** before taking in service. For the equipment discussed in this case study, a heating time of ~3 hours is necessary before the pump temperature reaches the product temperature

References

- **(1) Michael Huebner, 2005, “Material Selection for Mechanical Seals”, Texas A&M Turbolab Symposium**
- **(2) The Japan Society of Industrial Machinery Manufacturers, 2008, “Mechanical Seal Hand Book Trouble shooting” P.80**