CASE STUDY
APPLICATION OF HYDRAULIC COUPLING BOLTS (SLEEVE TYPE) TO HIGH CYCLE LOADED RECIPROCATING COMPRESSOR
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Motor / Compressor Flanged Coupling Application Overview

- Highly loaded reciprocating compressor type 6HG/2-1:
  - H₂ Make-up / Recycle compressor
  - ~13 MW nameplate power @ 327 rpm
  - Independent stepless regulation on the two services
- Flange coupling disassembly needed to perform corrective maintenance on motor rotor
- Connection withstands high alternating torque and rotating flexion due to flywheel and motor weight
- Coupling torque transmission predominantly by shear
- 16 fitted bolts with a tight tolerance, φ 60 mm
Issues Encountered at Motor Overhaul

Evidence of fretting wear on bolts

Some flange bolts & holes damaged during bolt removal
Potential Solutions

• Containment action: machining of flange holes, oversized bolts provided

• No room left for future contingencies in case further machining is needed in the future

• Corrective action: apply hydraulically fitted bolt concept
Pros & Cons of Conventional Solution

+ All-in-all, a proven and reliable solution, however, a flawless execution is required

− Low preload on bolts to preserve shear transmission

− On site reaming of flange holes
  • High precision needed, time-consuming
  • Lubrication needed for reaming, friction coefficient reduced

− Clearance variability within tolerance
  • Imperfect load sharing between bolts

− Non-conformal contact pattern
  • Possibility of slight fretting wear

− Once disconnected the flanges, bolts are not reusable and require replacement
Pros & Cons of Hydraulic Coupling Bolts

+ Reduction of downtime for reaming (needed just for holes alignment and cleaning)
+ Tolerant specs for in-field working, hand assembly
+ Effective fitting, zero clearance in operation
+ Eliminated risk of flange holes seizing
+ Equal load sharing between bolts
+ Fast assembly/disassembly

- Deep field experience with steam and gas turbines but no previous application on recip compressors
The hydraulic bolt consists of:

- A bolt threaded at both ends with a tapered shank
- An expansion sleeve with a corresponding tapered bore fits over the shank
- Two nuts, which complete the unit

Bolt and sleeve are clearance fit, hand assembled into bolt hole bore
Hydraulic Coupling Bolt Concept

The torque is transmitted by:

- the shear strength of the expanded sleeve in the hole and the bolt itself
- the friction effect at the flange faces created by pre-loading the bolt (increased vs. standard bolts)

The combination can theoretically provide ≥ torque of original bolt design
Decision Made and Justification

Feasibility Study to confirm design parameters:
• Verification of proposed solution and comparison w/ original design margins
• All loads considered (mean/alt. torques, flywheel and motor weight)
• Detailed FEM analysis:
  – Static calculation wrt peak torque
  – Fatigue calculation wrt mean/alt. torques
  – Contact elements analysis

➢ Decision made with End User to proceed with installation after a joint Design Review
Field Retrofit Process

- Line boring for holes alignment and clean-up (needed at each flange disconnection)
- Sleeve OD machining on a lathe to fit the final bore dimension
- ~2 working hours for each hole / bolt preparation (at first installation)
- The complete coupling re-assembly process completed in 4 shifts time
Hydraulic Coupling Bolt - Installation

Disassembly process is reverse of the installation

- Re-usable components
- Oil injection pump w/ working pressure 150 MPa (21,300 psi)
- Typically 15 minutes per bolt
After 6,000 hrs. of operation, 5 of 16 bolts were dismounted and inspected.
Visual inspection showed minor fretting wear on the sleeve OD.
NDT inspection of bolts, sleeves and flange holes showed no indications.
Returned to service seamlessly (March 2014).
Still running today on 3 units with no issues.
Additional inspection at 12K/24K hrs planned to assess long-term wear.
Q&A’s