# *Dynamic loads in ESP and production tubing, and how to avoid subsequent damage*

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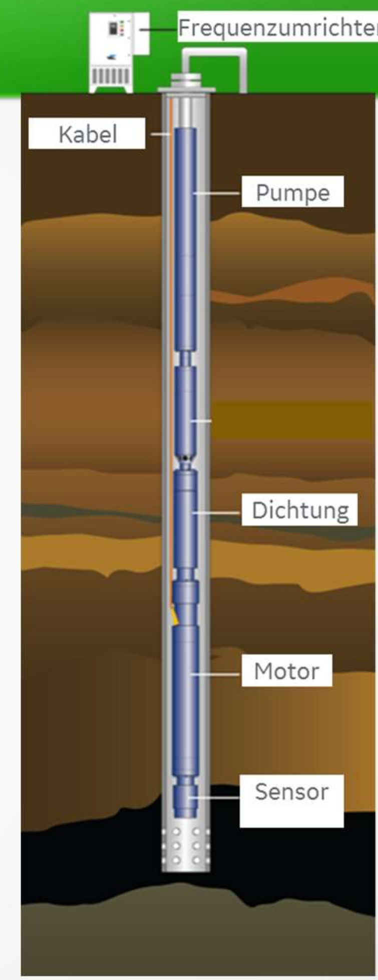
Matthias Möller, **geoTKP** Consulting

# topics

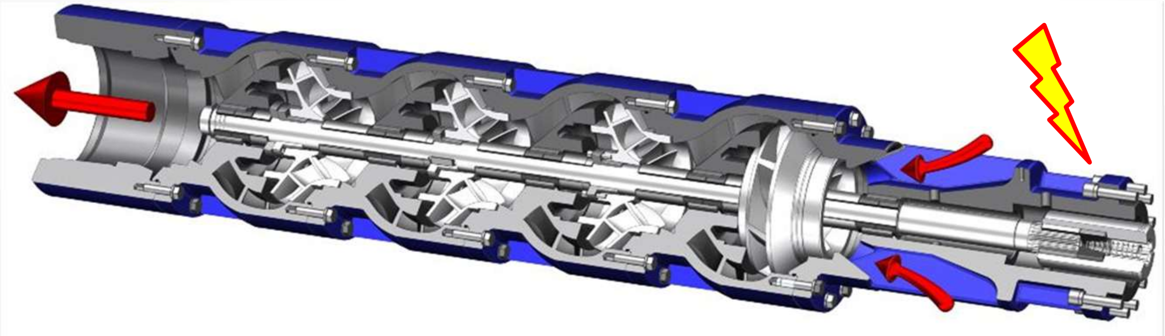
- typical production strings in hydrothermal wells
- excitation of vibration in the production string
- typical damages from vibration
- measures to prevent harmful vibration

# typical production strings in hydrothermal wells




## Installation

- heavy and stiff **production tubing** (max. 13 3/8“ = **340mm**), 500 - 800m
- **Pump** (max. 12“ = 305mm), up to 6m long
- Seal / Protektor (max. 220mm), up to 6m long
- **Motor** (max. 225mm) up to 44m long !!!
- Flange connections between components with significant diameter reduction and low stiffness



# typical production string in hydrothermal wells

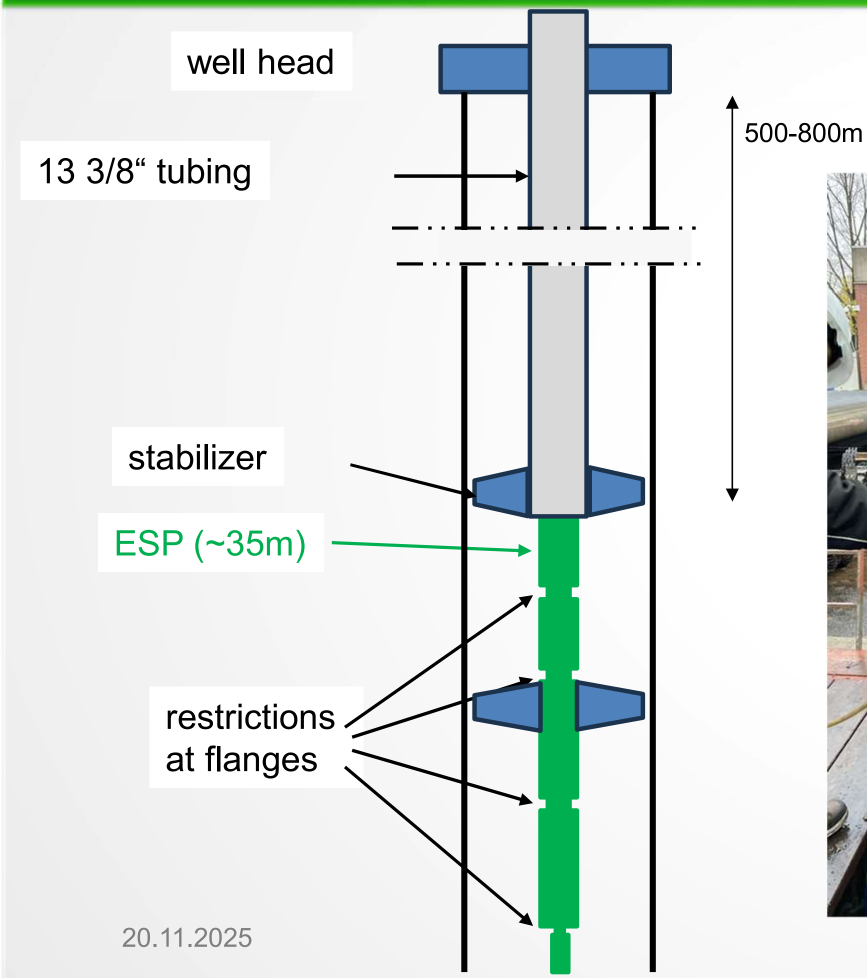
## Operating conditions:

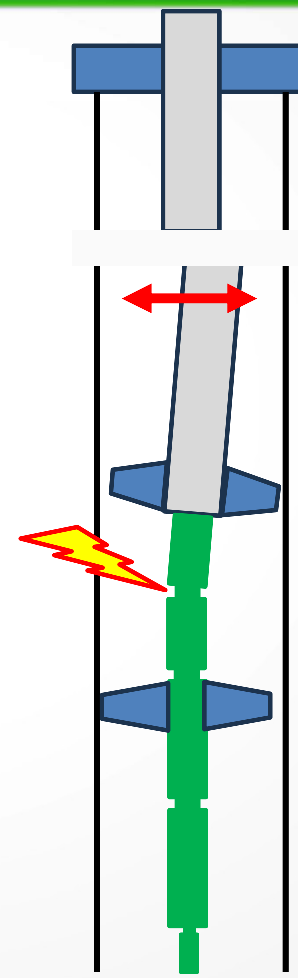
- vertical installation (no static radial bearing loads!)
- high flow with turbulence in production tubing
- stabilisation of the ESP inside the casing
- scales on all pump components
- high power demand >> big, heavy drive trains
  and medium voltage drives (>1,5MW)
- operating speeds: 2800-3500 rpm
- high operating temperatures with strong variations

# excitation of vibration in the production string

- low frequency bending vibration of the production tubing from turbulent flow.
- high frequency lateral vibration (at rotation frequency) from imbalance in the pump
- high frequency lateral vibration from imbalance in the motor
- self-excited osccilations in the radial bearing of the motor at half rotation frequency (oil-whirl) due to missing static bearing load
- high frequency pressure pulses due to equal number of vanes in impeller and diffusor
- torsional vibration due to dynamic reaction between motor, cable and drive

# vibration of the tubing



low frequency lateral vibration of the tubing due to vertical installation and high flow rates

oscillating bending loads in the most flexible section of the ESP (e.g pump intake)

# imbalance in pump and motor

**Pump**

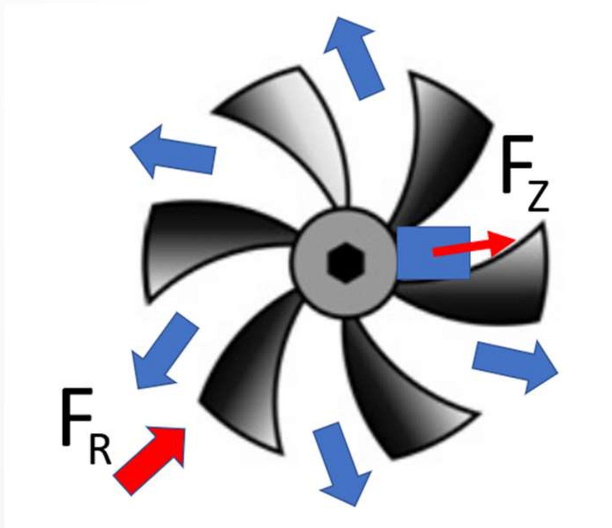
- insufficiently balanced impellers
- bent shaft (warping during operation due to released residual stresses)
- erratic distribution of scales (or lost pieces of scale)
- drawn-in debris in the lowest impeller due to missing intake screen

**Motor**

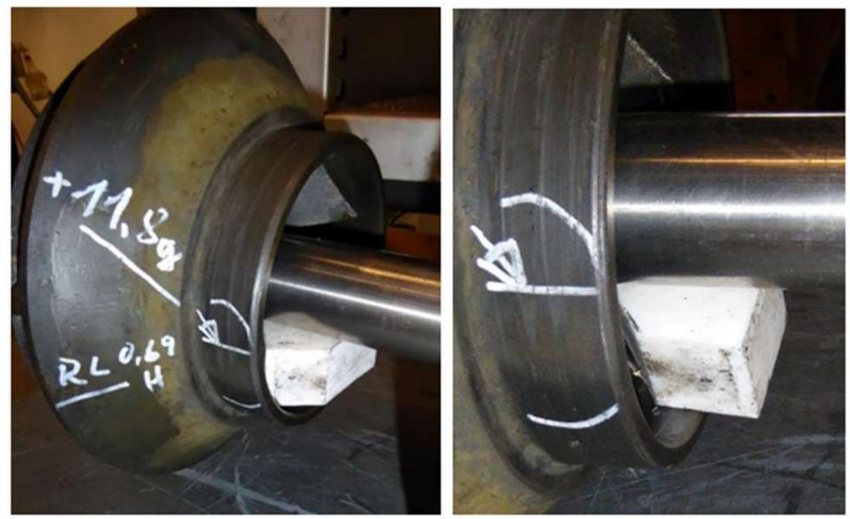
- uneven mass distribution in the rotor stack
- bent shaft (warping during operation due to released residual stresses)

# imbalance in pump

- pump sucks in a piece of stabilizer that broke off during installation
- the resulting imbalance creates extreme vibration and wears the rotors on one side




*picture 30: reproduced Teflon piece fits through intake*



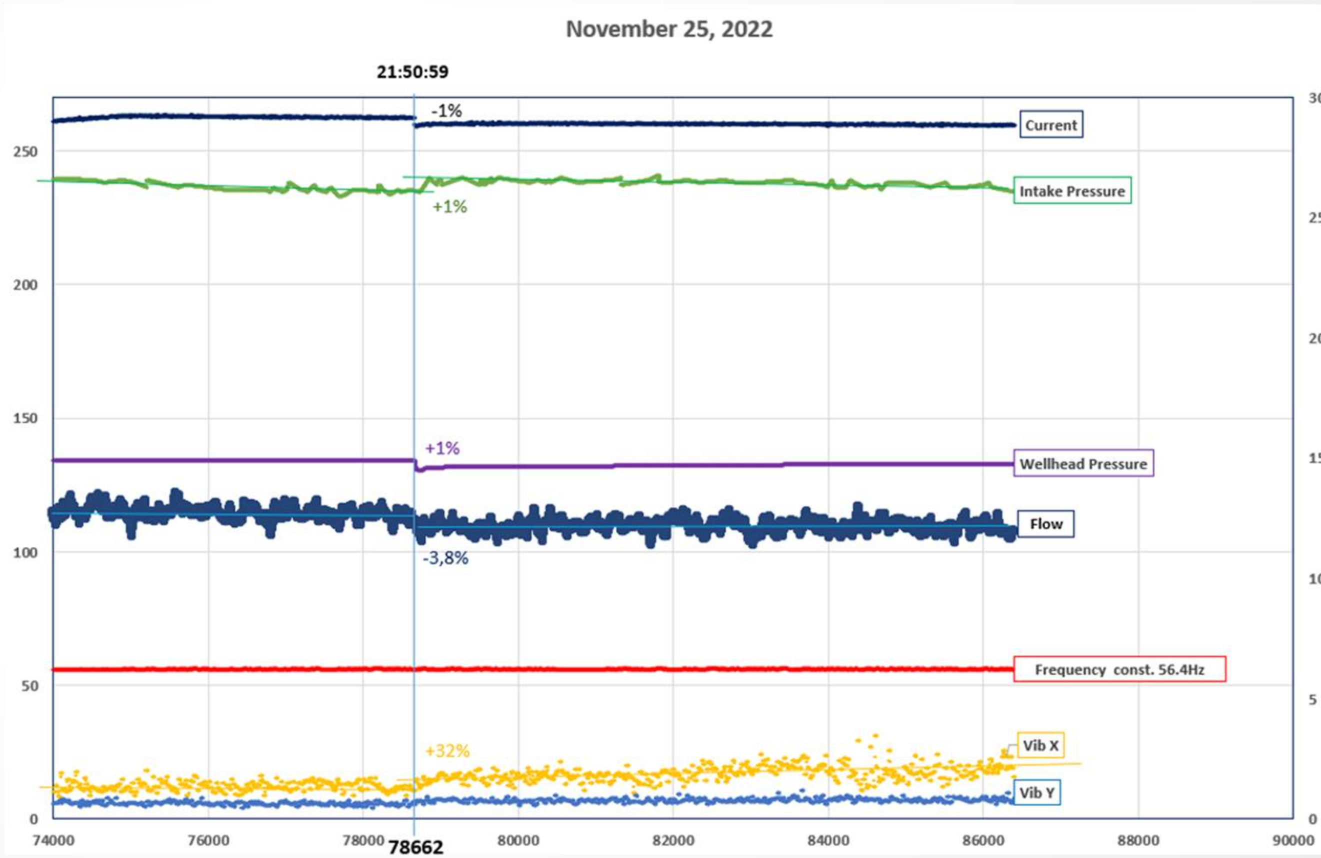
*picture 31: reproduced Teflon piece fits into impeller shroud*

# operating data analysis

**averaged values: +/- 15 min.**

- constant RPM
- decrease in flow (-3,8%)
- decrease of efficiency
- drastic increase of vibration (+32%)

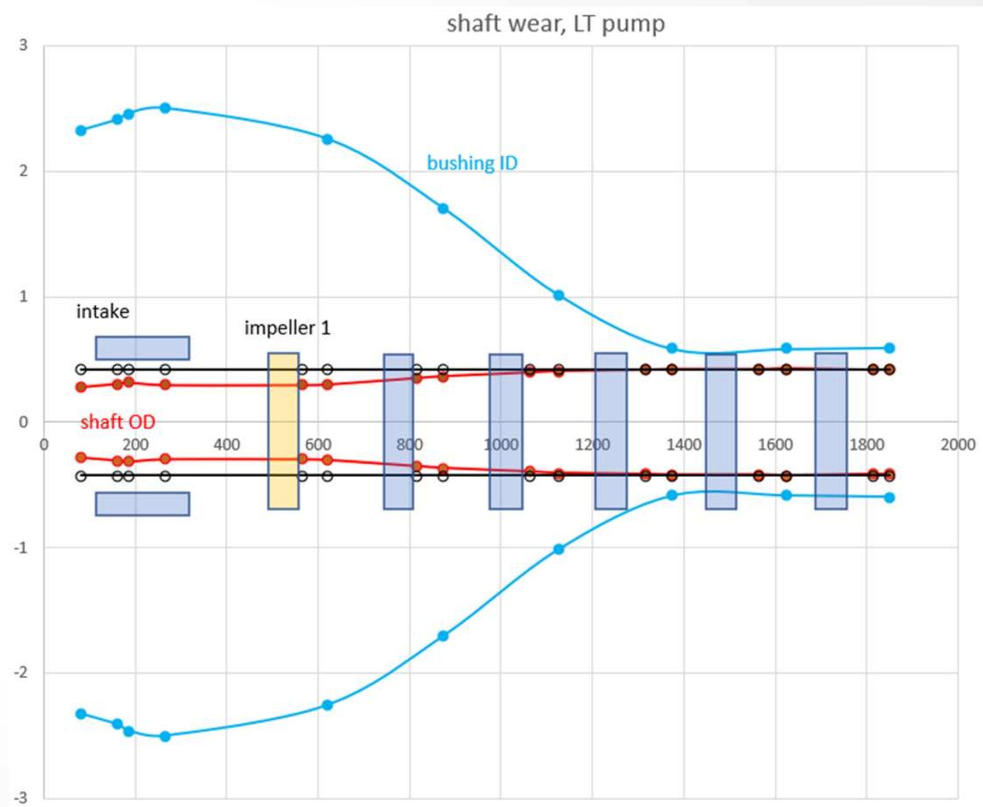
**partially plugged pump**



# failure investigation (pump)

- Concentric wear of the stationary bearings: maximum around the first impeller

- first impeller with significant eccentric wear



# oil whirl in motor bearings

- the oil film in (up to 15) motor bearings forms a wedge, which rotates around the shaft  (with half rotation frequency) due to insufficient static load in the bearing.

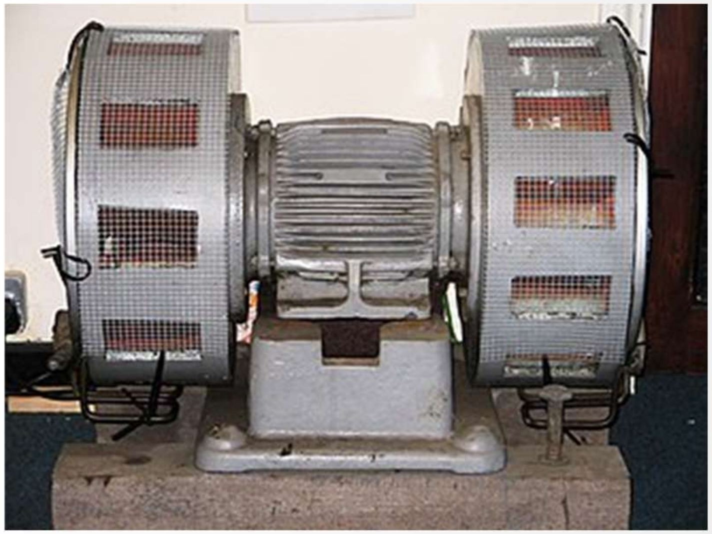
**Half-frequency whirl**

- this phenomena is depending on the temperature /oil viscosity

# pressure pulses in  the pump

- With equal numbers of vanes in the impellers and diffusors, high frequency pressure pulses can be created in the fluid (n = rpm x number of vanes, e.g. 400Hz)

- When these pressure pulses are in **resonance** with the production tubing or fluid column, extreme vibrations can be created and transmitted to the well head, where they will be clearly audible
- **Acoustic measurements** at the wellhead !!!



British air-raid siren

# torsional oscillation of the motor

Torque / current control of the variable speed drive (VSD) can excite torsional natural frequencies of the drive shaft

**Interaction of VSD, cable and motor is not yet understood**

↓

**Cooperation of motor- and VSD manufacturers with research!**

- high resolution measurements of cable and motor currents and voltages
- simulation of dynamic motor torque

↓

optimized sizing and parameter settings of the VSD for each individual application

# typical damages from vibration

**pumps:**

- losening of flange connections due to oscillating bending
- subsequent housing fractures

**seals / protectors:**

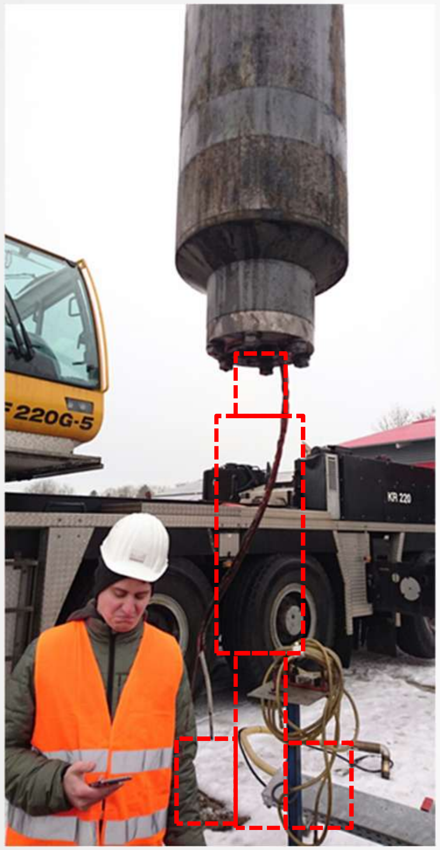
- worn radial bearings due side loads from low frequency bending at the flexible areas of the housings (e.g. pump intake)
- Shattered thrust bearing due to overload from pressure pulses

**motors:**

- Worn  radial bearings due to dynamic loads from imbalance
- Broken shafts from torsional oscillations in resonance with electric power supply

Bearing damages and fatigue fractures due to insufficient stabilisation

# „chamber of horrors“




Broken ESP gauge (sensor)

Lost flange bolts

**Cause:**
Low frequency oscillation of the production tubing


Broken fange bolts (pump intake)

# „chamber of horrors“

Shattered thrust bearing caused by pressure pulses

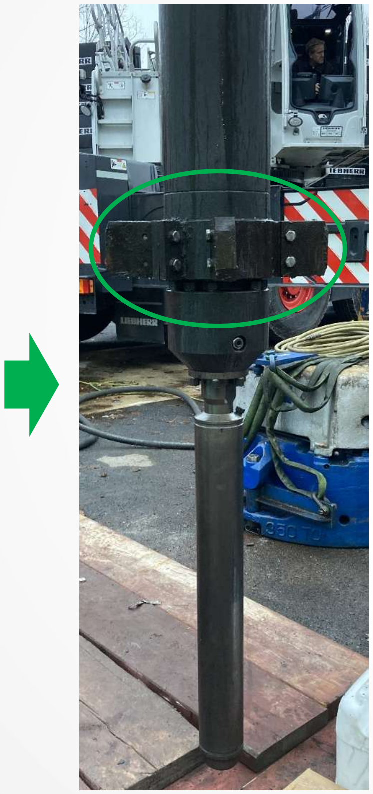
broken motor shaft (torsional oscillation in resonance with power supply)

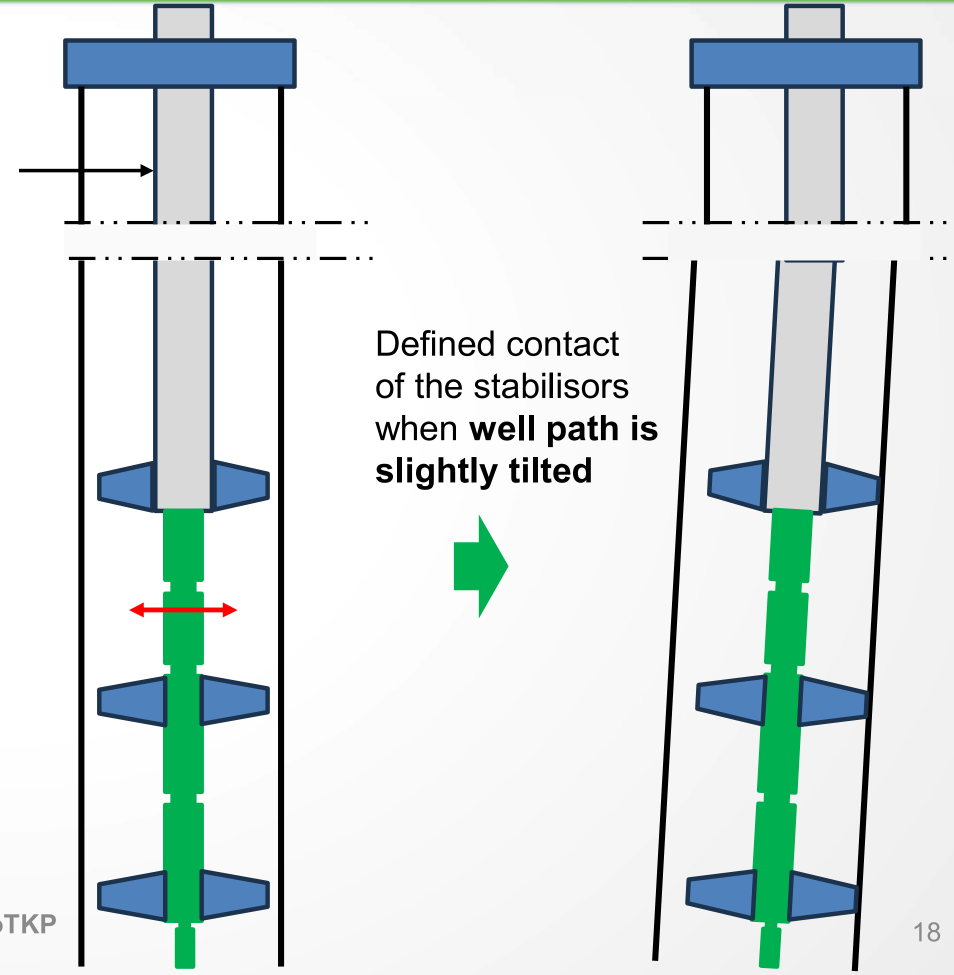
# measures to prevent harmful vibration

- diligent failure investigation and **root cause analysis**
- application specific **stabilisation of ESP AND production tubing**
- slightly **tilted well path** for a difined contact of the stabilizers
- **design optimizations** concerning bearing dynamics and imbalance
- thorough **balancing** of cast impeller (to balance quality G6,3)
- **acceptance tests with vibration measurements** (motors at elevated temperature!)
- **acoustic surveillance** during operation
- when suspecting **resonance:** change operating parameters!!!
- **Research** on natural frequencies of the production string

# measures to prevent harmful vibration

Neue Stabilisierung oberhalb des Sensors



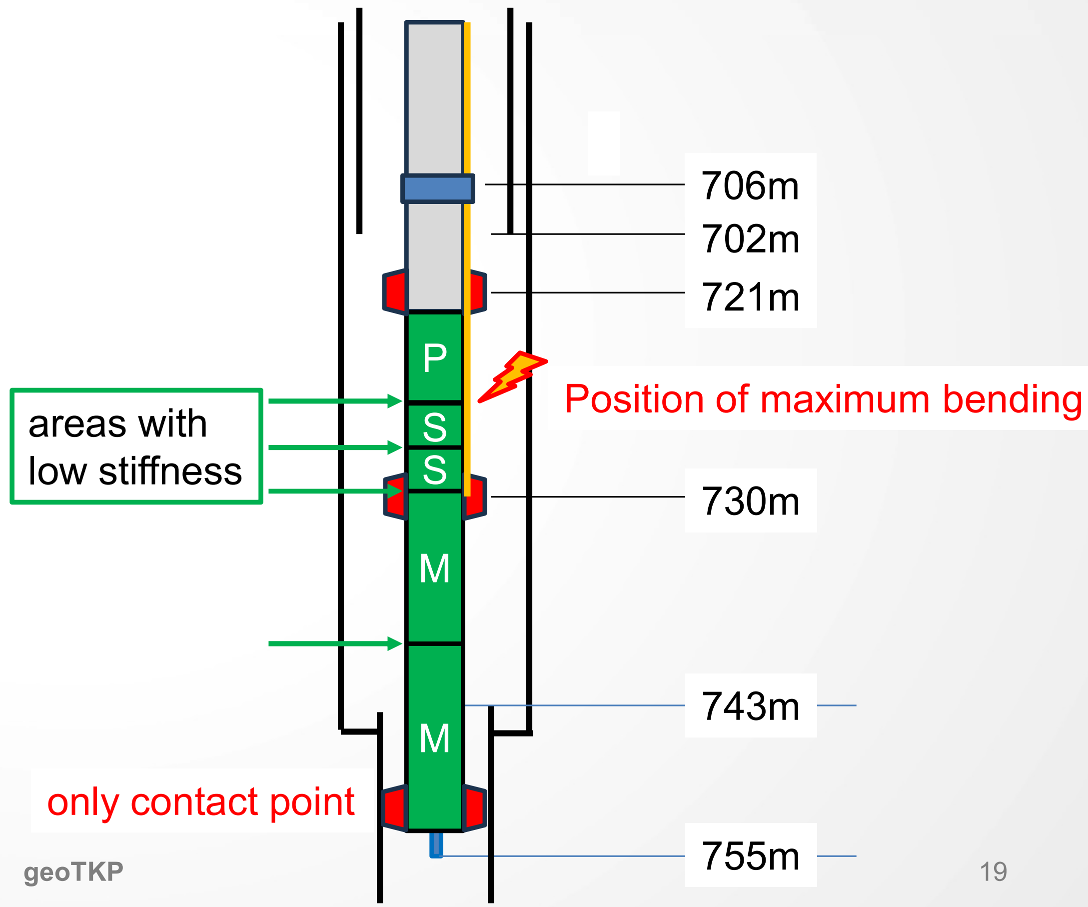


# insufficient stabilization of production tubing

ESP installation in

- 16“ tie –back (ID:14,82“ / 377mm, to 702m),
- 18 5/8“ casing (ID: 17,375“ / 441mm)
- 13 3/8“ production liner (ID: 12,259“ / **311mm,** from 743m)

- No stabilisation of ESP against lateral movement of the heavy and stiff production tubing
- Excessive (dynamic) bending in the areas with bearings will lead to excessive bearing loads



# centralized tubing

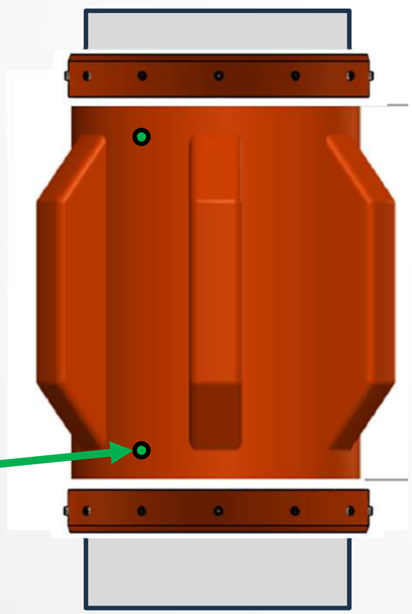
ESP installation in

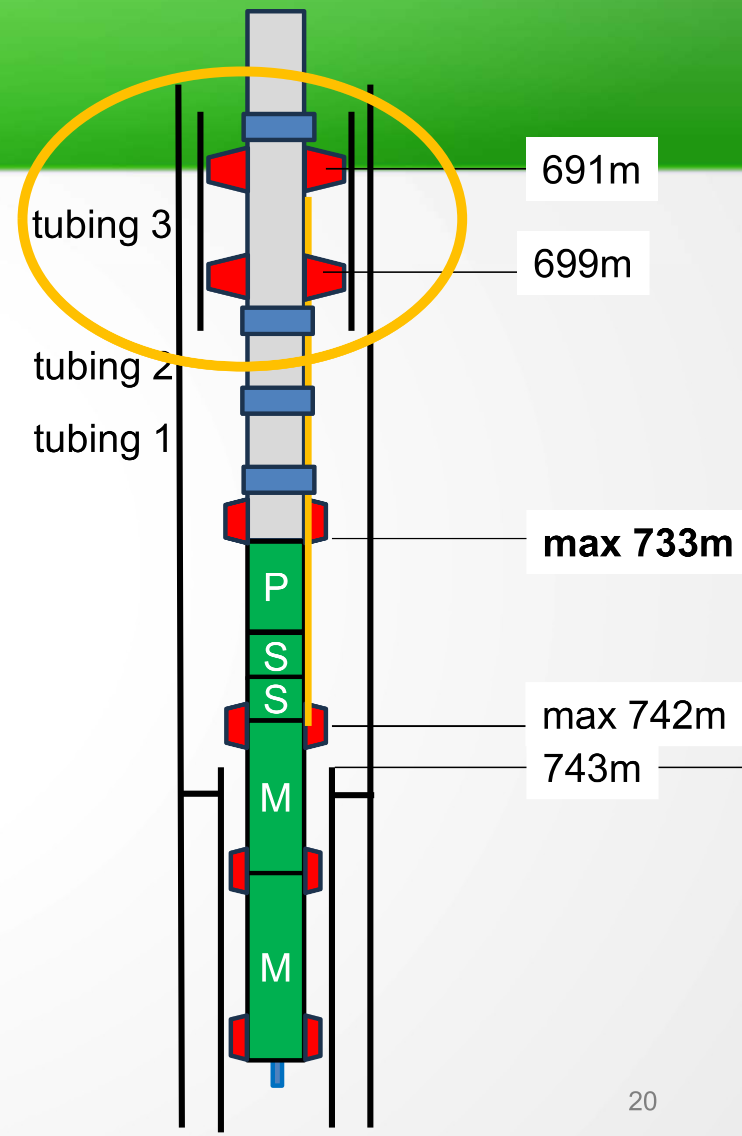
- 16“ tie –back (ID:14,82“ / 377mm, to 702m),
- 18 5/8“ casing (ID: 17,375“ / 441mm)
- 13 3/8“ production liner (ID: 12,259“ / **311mm,** from 743m)

- stabilisation against lateral movement of the procuction tubing in the 16“ tie-back
- 2 slip-on centralizers on tubing 3

OD 14,5“
368mm

Set screws
between the ribs





# measures to prevent harmful vibration

**pumps:**

- thorough balancing of cast impellers
- acceptance tests with **vibration measurements**
- flow-efficient, anti-scale intake screens
- scale prevention

**motors:**

- optimized bearing geometry to prevent oil whirl
- acceptance tests with **vibration measurements** at elevated temperature

Coated pump stages

# Many thanks!

# geoTKP Consulting

## Consulting for Deep Geothermal ESP Systems

– Failure Analysis – Development of ESP Components –
– Sizing of ESP Systems – Stabilisation of ESP Systems –
– ESP Tender Offers – Evaluation of ESP Sizing and Quotes –

matthias.moeller@geotkp.de
+49 151 700 43253