TECHNICAL REPORT

RESULTS OF DEVIATION MEASUREMENTS AND GEOMETRY OF ROTARY KILN

August 2016
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I. **SCOPE OF WORK:**

1. Setting up the surveying bases around the kiln.
2. Measurement of kiln axis deformation in horizontal and vertical plane;
3. Measurement of rollers’ horizontal skewing and rollers’ inclination;
4. Measurement of relative movement;
5. Measurement of rollers’ operating angles;
6. Measurement of shell radial and axial deformation (shell profile);
7. Measurement of supporting rollers’ mechanical wear and radius;
8. Measurement of tires’ and girth gear axial run-out (wobbling);
9. Measurement of tires’ and shell temperatures;
10. Measurement of thrust roller position in reference to kiln axis;
11. General mechanical inspection of drive mesh, shafts condition, lubrication efficiency, inlet and outlet seal (photo report);
12. Calculation of deformations of rollers’ axis and kiln inclination;
13. Calculation of under-tire clearance;
14. Preparation of 3D model of the kiln shell and its deformation;
15. Shelltest - ovality measurement;
16. Drive train measurement;
17. Recalculation of kiln mechanical parameters;
18. Presentation and submission to the Client the complete measurement report.

II. **SURVEY OF THE ROTARY KILN**

1. All measurements were taken by Geoservex’s Hot Kiln Alignment Team from 23.08.2016 to 30.08.2016.
2. After all measurement and calculation completion, the technical documentation was presented to the Plant Representatives and the recommendation was discussed and agreed.
3. Coordinating system:
   - Piers are numbered from inlet to outlet;
   - Left and right side of kiln is orientated from inlet to outlet (material flow).
   - Starting point for all measurements is a hatch (manhole) between tire No. I and tire No. II (see page 9).
III. RESULTS OF MEASUREMENTS

1. Kiln axis

Kiln axis deviations in horizontal and vertical plane are enormous (presented in table below).

<table>
<thead>
<tr>
<th>Plane/Support</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>0.0</td>
<td>-14.0</td>
<td>-6.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.0</td>
<td>8.0</td>
<td>4.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Such significant (critical) misalignment in horizontal and vertical plane requires adjustment which is shown on pages 17 ÷ 19. This adjustment could be performed under a few condition which are mentioned in recommendation. Results of kiln axis deviations in horizontal and vertical planes are shown on pages 11 ÷ 12.

Under-tire clearances are correct and acceptable almost at all supports where values of clearance are in tolerance or close to this limit. Under-tire clearance at inlet support is out of tolerance and equals to 8 mm (recommended under-tire clearance by most of the kiln producers is 3 ÷ 6 mm in hot condition). However, it must be understood that kiln axis vertical position is directly related with under-tire clearance value and in case of sudden temperature change its position is not stable and the clearance value is also not fixed. Moreover, every change of kiln axis vertical position causes change in supports load and finally changes load on bearings. Therefore, it is strongly recommended to keep shell temperature uniform on circumference of the kiln shell. Values of under-tire clearance are shown on page 12.

Kiln inclination is 2.96% (see page 10).

2. Rollers’ parameters and thrust unit.

Most of rollers’ skewing in horizontal plane are correct (see page 13) and do not require any adjustment, except of two left rollers at first and second support. Skewing in horizontal plane at this two rollers is requires adjustment after resurfacing of running surfaces of those rollers.

Inclination of all rollers is correct (see page 14) and does not require any adjustment.

Roller operating angles have their designed values (close to 60º - see pages 10 and 12). The tolerance for operating angles given by most kiln producers is 60º +/- 1º 30’.

Mechanical wear takes place for almost rollers, it means that all rollers have a spool and conical shape (see page 22), except right roller at third support, where mechanical wear value is maximum 1.0 mm and shape is cylindrical.

Right roller at first support is classified to replacement due to enormous mechanical wear of running surface.

The running surfaces of rollers are not lubricated by dry graphite what is a bad preventive routine. All rollers running surfaces at all supports should be cleaned from oil or grease and dust.
Position of thrust rollers (upper and lower side) in reference to kiln axis is presented on pages 26 and 27. Offset of thrust unit (position of unit in reference to kiln axis) should be confirmed/verified with OEM instruction and if necessary should be adjusted.

Diameters of rollers and tires are presented in temperature present during the measurement and shown on page 21.

3. Drive station

Gear radial run-out was measured with use of laser equipment. The girth gear eccentricity is 2 mm (see page 25) and it is in tolerance.

The root clearance was measured with help of a digital camera under kiln operation and it shows that the clearance is not regular, which is why the girth gear and pinion do work with some vibration. The girth gear and pinion teeth are in poor condition. Root clearance is too small which indicate a pitch line offset 5 ÷ 7 mm in hot condition (see page 48). Backlash value is too big, because teeth of pinion are worn out (burrs) and lost their original shape. Gear wobbling equals to +/- 0.1 mm (see page 24) and is in tolerance (wobbling tolerance is +/- 2.0 mm).

Position of pinion and gear box in reference to kiln axis is correct (see pages 30 ÷ 33). Values of deviations are minor and acceptable.

4. Kiln shell

Kiln shell was measured at 43 cross sections. Cross section position diagram is shown on page 54. Shell profile diagrams are shown on pages 55 ÷ 58. In general, the kiln shell is in good shape. Shell eccentricity is rather small (not exceed 8 mm) and shouldn't cause any problems with kiln operation, except for cross sections No. 1 ÷ 2, No. 9 ÷ 11 and No. 25 ÷ 26 where the eccentricity is greater (8 to 12 mm). Shell local deformations (deformations of circular shape) are rather insignificant and perfectly acceptable, except cross section No. 10 and 27 where deformation reach 14 and rise up to 18 mm (tolerance given by most kiln producers for shell eccentricity is 12 mm and for circular deformations is 15 mm).

The kiln shell was examined for combination of thermo - mechanical hidden crank formation presence. Mechanical crank formation can be examined by measurements of roller shaft deflection changes. The measurements result is shown on page 29. No deflection change exceeds value of 0.15 mm for eccentricity, which value is normally safe. There is no indication of hidden mechanical crank formation in shell structure.

The kiln shell has been examined for thermal crank formations presence. Thermal crank formation can be detected by measuring temperatures on shell circumference at the tires. Maximum difference in temperatures measured this way is 75 degrees Celsius (see page 16) which is too low (in this case) to cause thermal crank formation.

Tires and girth gear wobbling are usually caused by shell crank formation, but as mentioned above the shell eccentricity is minor and therefore, tires and gear wobbling values are low (refer to page 23) and in tolerance (wobbling tolerance is +/- 2.0 mm), except for third tire where wobbling exceeds tolerance and reaches +/- 3.0 mm.
5. Ovality of heavy kiln shell

All measurements of shell ovality were taken during normal kiln operation. The expected maximum ovality for a kiln of this diameter (3600 mm) would be 0.46 %. Range value of ovality of all station is 0.10 % - 0.53 % (see pages 36 ÷ 39). Summary graph is presented on page 34. All measurements was taken on heavy kiln shell with distance approx. 0.8 m from center of tire. Tires’ and shell temperature was recorded during measurements. Migration for all tires during the measurement was in rage 6 ÷ 25 mm/rev.

6. Base frames

The results of measurement of base frames’ inclination are correct except for second station where base plate inclination is below 2.95% (refer to page 28).

IV. ADJUSTMENT OF THE KILN

After completing all measurements, technical documentation was presented to the Plant Representatives and the adjustment program and schedule were discussed and agreed. Adjustment could not be performed this time due to lack of time which is needed for preparation (cleaning of adjustment bolts, increase a place for shell at the wall (building/steel construction), preparation for roller replacement etc.).

V. VISUAL INSPECTION

After completing our visual inspection of the rotary kiln we have to admit that the kiln is working with some vibration on drive station and requires some seriously corrections to be made.

- Rollers’ housing condition are good. Bearings’ lubrication systems are complete and they also work correctly.
- Mechanical wear and distance between side surface of tire and stopblocks (upper/lower side) is improper at inlet support. This gap must be fixed (reduced).
- Plexiglas of inspection window is cracked at left roller at inlet support.
- Huge edge and enormous mechanical wear of roller surface at first and second station.
- Upper and lower resistance rollers are worn out. At lower and upper part of running surface are a visible edges.
- There is some oil leak from upper shafts of left rollers at first, second and third support.
- Missing stopblock - upper side of tire No. III. Missing stopblock is located under the tire on the base frame.
- Cracks on chair pad at lower side of tire No. III.
- There is some leakage of grease from pinion housing.
Rotary Kiln Inspection

August 2016 (Hot Condition)  Page 7

- Pinion and girth gear teeth are worn out, because of improper pitch line.
- Adjustment system is insufficient and could not work properly at inlet and outlet support. Adjustment bolts are covered by material, dust etc.
- Outlet support is covered by material dropping from planetary coolers. Whole support, rollers housing, inspection windows, adjustment bolts, roller running surfaces, base frame are covered by material.
- Poor condition of concrete at second and third support. Cracks in concrete parts, some part are missing, visible steel reinforcement of concrete.
- Graphite lubricating system is not working. Graphite bars are missing and rollers are covered by oil and grease.

For all mentioned above please refer to pages 22 and 40 ÷ 53.

VI. RECOMMENDATIONS

Actions to be taken in nearest future:

- Replacement of plexiglas in inspection window at left roller at inlet support will prevent oil contamination.
- In case of any problem with kiln thrust (kiln pushing uphill or downhill), please make some correction moves according page 20.
- All running surface of rollers’ and tires should be clean. It is strongly recommended to keep all running surfaces free from oil or grease.

Actions to be taken to improve the kiln operation:

- Pay attention to tire migration. Monitor under-tire clearance all the time and get ready to reduce the under-tire clearances by shimming or replacing the chair pads (supporting plates between tire and kiln shell) according to OEM instruction, when the migration reach 20 mm per kiln revolution in hot condition;
- Adjustment of kiln axis must be performed due to critical deviations of kiln axis in both planes. Before adjustment some actions must be taken:
  - replacement of right roller at first support due to huge mechanical wear (adjustment was calculated for old roller);
  - inlet sealing space to be checked;
  - gap/space between kiln shell and wall construction of the building to be increased;
  - roller adjustment system at inlet support to be checked.
- Additional adjustment of kiln to improve root clearance (change of pitch line offset) by shift in rollers at all supports to lift up the kiln.
- Condition of girth gear and pinion teeth should be checked during next stoppage/shutdown. Burrs should be grinded from side surface of teeth. Offset of pitch line must be reduced and drive system must be properly realigned. If this operation will not solve problem with vibration get ready to make a plan for future reverse of girth gear and pinion.
- Resurfacing of running surface of almost all rollers (except right roller at third support) should be taken into consideration due to mechanical wear of this surface.
- Reducing of horizontal skewing of left rollers at first and second support could be done after grinding surfaces irregularities.
- Resurfacing of running surface of resistance roller should be taken under consideration due to high edges at lower/upper part of roller.
- Offset of thrust unit (position of unit in reference to kiln axis) should be confirmed/verified with OEM instruction and if is needed should be adjusted. This operation can be done after grinding of side surface of tire and running surface of thrust unit.
- Running surface of rollers and tires must be cleaned from oil. Graphite bars should be reinstalled.
- Mechanical wear (incorrect distance) between side surface of tires and retainers (stopblocks) should be corrected at inlet support. Tire thrust can be reduced by following actions:
  - Reducing the relative movement between tire and shell as much as possible.
  - Lubricate the tire face and retainers (stopblocks) with proper lubricants.
  - Increase the height and length of retaining rings.
  - Resurface tire and rollers surface by grinding the surface irregularities especially at outlet support.
  - Adjustment of roller skewing in horizontal plane after grinding the surface irregularities at tire and rollers.
If this action can not solve the problem, a root cause analysis must be performed, as well as the total review of the kiln design.
- Oil leaks at left roller at supports No. I, No. II and No. III must be stopped.
- During next stoppage stopblock at upper side of tire No. III should be welded back
- Cracked chair pad of tire No. III must be replaced during next stoppage/shutdown.
- Inspection windows, rollers housing, bolts, frames at all stations should be cleaned especially at inlet and outlet zone. Dust can easily contaminate an oil and scratch surface of shaft.
- The kiln surroundings area to be cleaned especially at outlet zone.
- Inspection of concrete foundation should be considered due to many cracks around base frame at second and third support.

VII. THE KILN MECHANICAL PARAMETERS

The kiln mechanical parameters were calculated with consideration of kiln shell data, refractory lining, material flow, as well as all dimensions of kiln components. The results are shown in an appendix.

Geoservex’s Team would like to thank the Plant Representatives for cooperation and assistance during our visit.
Coordinating System, Symbols and Terms

x  axial coordinate
y  horizontal coordinate
z  vertical coordinate
s  under-tire clearance
α  rollers’ operating angle
η  kiln inclination
dy  horizontal axis correction
dz  vertical axis correction
ds  skewing correction

---  reference axis

---  real axis

---  adjustment axis

Hatch (manhole) starting point for all measurements
## Measurement Data

### Coordinate "x"

| OUTLET [m] | \(x_4\) | 77.42 |
| OUTLET [m] | \(x_3\) | 51.45 |
| OUTLET [m] | \(x_2\) | 25.57 |
| INLET [m]   | \(x_1\) | 0.00 |

### Coordinate "y"

| OUTLET [mm] | \(y_4\) | 0.0 |
| OUTLET [mm] | \(y_3\) | -6.0 |
| OUTLET [mm] | \(y_2\) | -14.0 |
| INLET [mm]   | \(y_1\) | 0.0 |

### Coordinate "z"

| OUTLET [mm] | \(z_4\) | 0.0 |
| OUTLET [mm] | \(z_3\) | +4.0 |
| OUTLET [mm] | \(z_2\) | +8.0 |
| INLET [mm]   | \(z_1\) | 0.0 |

### Under-tire clearance "s"

| OUTLET [mm] | \(s_4\) | 2.0 |
| OUTLET [mm] | \(s_3\) | 2.5 |
| OUTLET [mm] | \(s_2\) | 5.0 |
| INLET [mm]   | \(s_1\) | 8.0 (average) |

### Rollers' operating angle "\(\alpha\)"

| OUTLET [°] | \(\alpha_4\) | 60° 30' |
| OUTLET [°] | \(\alpha_3\) | 60° 20' |
| OUTLET [°] | \(\alpha_2\) | 60° 25' |
| INLET [°]   | \(\alpha_1\) | 60° 05' |

### Kiln inclination

| \(\eta\) | 2.96 % |

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**Rotary Kiln Inspection**

August 2016 (Hot condition)
Axial Deviations in Horizontal Plane

- Tolerance zone: ±1.5 mm
- Axial Deviations in Horizontal Plane:
  - Left side: 0.0 mm
  - Right side: -14.0 mm, -6.0 mm

[Diagram showing the deviations with marked areas and directions]
Axial Deviations in Vertical Plane

\[
\begin{align*}
\alpha &= 60^\circ 05' \\
s &= 8.0 \text{ mm} & \quad \alpha &= 60^\circ 25' \\
& & s &= 5.0 \text{ mm} & \quad \alpha &= 60^\circ 20' \\
& & & s &= 2.5 \text{ mm} & \quad \alpha &= 60^\circ 30' \\
& & & & s &= 2.0 \text{ mm}
\end{align*}
\]

0.0 mm

+8.0 mm

+4.0 mm

0.0 mm
Rollers’ Skewing - Horizontal Plane

Roller skewing value is reduced for adjustment bolts’ distance
Rollers’ Inclination - Vertical Plane

---

Roller inclination value is reduced for adjustment bolts’ distance.
Mechanical Position of Support Rollers

contact gap contact gap contact gap contact gap gap

right side

left side

shaft roller shaft resistance ring bearing

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Rotary Kiln Inspection August 2016 (Hot condition)
Tires’ and Shell Temperature

Unit: [°C]
Emission factor: 0.95
Date of survey: 24.08.2016

<table>
<thead>
<tr>
<th>PIER</th>
<th>inlet side</th>
<th>outlet side</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>136</td>
<td>140</td>
</tr>
<tr>
<td>II</td>
<td>175</td>
<td>181</td>
</tr>
<tr>
<td>III</td>
<td>263</td>
<td>265</td>
</tr>
<tr>
<td>IV</td>
<td>279</td>
<td>261</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>minimum</th>
<th>maximum</th>
<th>difference</th>
</tr>
</thead>
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<tr>
<td>136</td>
<td>154</td>
<td>18</td>
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<td>175</td>
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<td>75</td>
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<td>263</td>
<td>278</td>
<td>15</td>
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<td>279</td>
<td>299</td>
<td>20</td>
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</table>

<table>
<thead>
<tr>
<th>minimum</th>
<th>maximum</th>
<th>difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td>163</td>
<td>15</td>
</tr>
<tr>
<td>181</td>
<td>204</td>
<td>23</td>
</tr>
<tr>
<td>265</td>
<td>287</td>
<td>22</td>
</tr>
<tr>
<td>261</td>
<td>284</td>
<td>23</td>
</tr>
</tbody>
</table>

PIER I

PIER II

PIER III

PIER IV

I N L E T

100 103

O U T L E T

156 158

165 155

170 175
Adjustment Program in Horizontal Plane

Note: Calculation not including roller replacement

- 21.0 mm  0.0 mm  0.0 mm  0.0 mm
Adjustment Program in Vertical Plane

Note: Calculation not including roller replacement.
Adjustment Schedule

Rollers’ operating angle on inlet support before adjustment $\alpha = 60^\circ 05'$

Rollers’ operating angle on inlet support after adjustment $\alpha = 59^\circ 10'$

Note: Adjustment should be carried out in stages
Recommendation for Future Thrust Correction

Perform only if necessary

kiln down

1

kiln up

2

0.2 - 0.5 mm

kiln down

2

0.2 - 0.5 mm

kiln up

1

0.2 - 0.5 mm

left side

right side

INLET

OUTLET

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Rotary Kiln Inspection

August 2016 (Hot condition)
Tire and Roller Diameter during Measurement (with Influence of Temperature)

\[ \phi = 1226 \]
\[ \phi = 1288 \]
\[ \phi = 1288 \]
\[ \phi = 1288 \]
\[ \phi = 1293 \]
\[ \phi = 1296 \]
\[ \phi = 1298 \]
\[ \phi = 1294 \]
Rollers’ Mechanical Wear

OUTLET

deviation [mm]

0.0
- 2.5
- 3.0
- 3.5
- 4.0

max. radius = 649.5 mm

P - IV

deviation [mm]

0.0
- 1.0
- 2.0
- 2.5
- 1.0

max. radius = 649.0 mm

P - III

deviation [mm]

0.0
- 0.5
- 1.0
- 1.0
- 0.5

max. radius = 650.0 mm

P - II

deviation [mm]

0.0
- 1.5
- 1.5
- 1.5
- 0.5

max. radius = 645.5 mm

P - I

deviation [mm]

- 1.0
- 2.0
- 2.0
- 2.0
0.0

max. radius = 646.0 mm

INLET

max. radius = 631.0 mm

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Rotary Kiln Inspection  August 2016 (Hot condition)  Page 22
### Tire Axial Run-out (Wobbling)

**Tire No. I - example** (VIEWING FROM INLET SIDE)

![Diagram of Tire Axial Run-out]

Note: Hatch (manhole) describing kiln position - at the bottom

<table>
<thead>
<tr>
<th>Tire No.</th>
<th>Value [mm]</th>
<th>Point No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Inlet)</td>
<td>+/- 0.8</td>
<td>22/6</td>
</tr>
<tr>
<td>II</td>
<td>+/- 0.2</td>
<td>28/12</td>
</tr>
<tr>
<td>III</td>
<td>+/- 3.0</td>
<td>28/12</td>
</tr>
<tr>
<td>IV (Outlet)</td>
<td>+/- 0.3</td>
<td>16/32</td>
</tr>
</tbody>
</table>

---

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Rotary Kiln Inspection   August 2016 (Hot condition)   Page 23
Girth Gear Axial Run-out (Wobbling)

Girth Gear
(Viewing from Inlet side)

Note:
Hatch (manhole) describing kiln position - at the bottom

TIRE No. II
GIRTH GEAR
TIRE No. III

INLET

0.1 (Point No. 21)

0.1 mm (Point No. 5)

OUTLET

TIRE No. IV

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Rotary Kiln Inspection
August 2016 (Hot condition)
Girth Gear Radial Run-out

Girth Gear
(VIEW FROM INLET SIDE)

Note:
Hatch (manhole) describing klin position at the bottom

<table>
<thead>
<tr>
<th>GEOMETRIC CENTRE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Y</td>
</tr>
<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
</tr>
</tbody>
</table>
Thrust Roller Axis (Upper Side) in Reference to Kiln Axis

OUTLET

Kiln axis

Tire No. II

10 mm

Thrust roller axis

LEFT SIDE

INLET

RIGHT SIDE ATTACKING SIDE
Thrust Roller Axis (Lower Side) in Reference to Kiln Axis

OUTLET

LEFT SIDE

RIGHT SIDE ATTACKING SIDE

Tire No. II

Kiln axis

INLET

9 mm

Thrust roller axis
Rollers Shaft Deflection Value Change

Support No. III
Right Roller - example

Eccentricity: 0.07 mm
Total deflection value: 0.13 mm
Maximum deflection at point No.: 5

Measurement Method

View from inlet side

Rollers Shaft Deflection Value Change - All Supports

<table>
<thead>
<tr>
<th>Support No.</th>
<th>I (Inlet)</th>
<th>II Support</th>
<th>III Support</th>
<th>IV (Outlet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roller Side</td>
<td>Eccent. [mm]</td>
<td>Point No.</td>
<td>Eccent. [mm]</td>
<td>Point No.</td>
</tr>
<tr>
<td>Left Roller</td>
<td>0.03</td>
<td>9</td>
<td>0.04</td>
<td>25</td>
</tr>
<tr>
<td>Right Roller</td>
<td>0.04</td>
<td>11</td>
<td>0.03</td>
<td>24</td>
</tr>
</tbody>
</table>

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Rotary Kiln Inspection August 2016 (Hot condition) Page 29
Axial Deviations of Pinion and Gear Box in Horizontal Plane

- 1.0 mm

0.0 mm

0.0 mm

0.0 mm

Line Parallel to Kiln Axis

OUTLET

850 mm

Kiln Axis

800 mm

INLET

420 mm
Axial Deviations of Pinion and Gear Box in Vertical Plane

0.0 mm  - 1.0 mm  - 1.0 mm  - 2.0 mm
In Horizontal Plane

In Vertical Plane

Note:
Values of pinion axis deviation are calculated for adjustment bolts’ distance
Shell ovality measurement
Shell ovality measurement

Material flow

<table>
<thead>
<tr>
<th>Pier No. I</th>
<th>Diameter: 3.60 m</th>
<th>T Kiln Uphill: 152 °C</th>
<th>T Kiln Downh.: 144 °C</th>
<th>T Tire: 98 °C</th>
<th>Rel. Mov.: 25 mm/rev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier No. II</td>
<td>Diameter: 3.60 m</td>
<td>T Kiln Uphill: 176 °C</td>
<td>T Kiln Downh.: 178 °C</td>
<td>T Tire: 154 °C</td>
<td>Rel. Mov.: 19 mm/rev</td>
</tr>
<tr>
<td>Pier No. III</td>
<td>Diameter: 3.60 m</td>
<td>T Kiln Uphill: 248 °C</td>
<td>T Kiln Downh.: 251 °C</td>
<td>T Tire: 117 °C</td>
<td>Rel. Mov.: 9 mm/rev</td>
</tr>
<tr>
<td>Pier No. IV</td>
<td>Diameter: 3.60 m</td>
<td>T Kiln Uphill: 291 °C</td>
<td>T Kiln Downh.: 279 °C</td>
<td>T Tire: 177 °C</td>
<td>Rel. Mov.: 6 mm/rev</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection

August 2016 (Hot condition)
# Shell ovality measurement

<table>
<thead>
<tr>
<th>No. of the Tire and side of measurement</th>
<th>Mean ovality from three measurements</th>
<th>Distance from the tire center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire IV Inlet side</td>
<td>0.13 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire IV Outlet side</td>
<td>0.10 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire III Inlet side</td>
<td>0.25 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire III Outlet side</td>
<td>0.26 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire II Inlet side</td>
<td>0.27 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire II Outlet side</td>
<td>0.25 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire I Inlet side</td>
<td>0.50 %</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Tire I Outlet side</td>
<td>0.53 %</td>
<td>0.8 m</td>
</tr>
</tbody>
</table>

# Ovality limits as a function of the kiln diameter

![Graph showing ovality limits as a function of the kiln diameter]
Pier No. I Uphill

A: 0.37%
B: 0.44%
C: 0.68%
Avg.: 0.50%

Pier No. I Downhill

A: 0.43%
B: 0.51%
C: 0.64%
Avg.: 0.53%
Pier No. II Uphill

- A: 0.29%
- B: 0.27%
- C: 0.26%
- Avg.: 0.27%

Pier No. II Downhill

- A: 0.26%
- B: 0.24%
- C: 0.24%
- Avg.: 0.25%
Pier No. III Uphill

![Graph showing data for Pier No. III Uphill]

- A: 0.36%
- B: 0.21%
- C: 0.20%
- Avg.: 0.26%

Pier No. III Downhill

![Graph showing data for Pier No. III Downhill]

- A: 0.34%
- B: 0.21%
- C: 0.19%
- Avg.: 0.25%
Pier No. IV Uphill

<table>
<thead>
<tr>
<th>A</th>
<th>0.14%</th>
</tr>
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<tbody>
<tr>
<td>B</td>
<td>0.13%</td>
</tr>
<tr>
<td>C</td>
<td>0.12%</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.13%</td>
</tr>
</tbody>
</table>

Pier No. IV Downhill

<table>
<thead>
<tr>
<th>A</th>
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<tbody>
<tr>
<td>B</td>
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</tr>
<tr>
<td>C</td>
<td>0.10%</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.10%</td>
</tr>
</tbody>
</table>
Visual Inspection

Inlet

Inlet seal in good condition

Support No. I
Right Roller

Roller running surface badly worn out
Visual Inspection

Support No. I

Tire

Damaged and worn out stopblocks (upper side)
Support No. I

Tire

Distance between lower side surface of tire and stopbloks incorrect - approx. 32 mm
Visual Inspection

Support No. I

Rollers

Adjustment system in poor condition
Visual Inspection

Support No. I

Left Roller

Plexiglass of inspection window with cracks (upper housing)
Visual Inspection

All Supports
Right Roller

Graphite system does not work
Graphite bars are missing at all stations
Visual Inspection

Supports No. I, No. II and No. III

Left Roller

Oil leak from upper shaft
Oil present on running surface of roller and tire
Visual Inspection

Support No. II
Thrust units

Upper side

Lower side

Running surface of thrust roller worn out.
Visual Inspection

Girth Gear and Pinion

Left Pinion

Girth gear and pinion teeth are worn out

Root clearance and backlash incorrect
Pitch line indicates offset 5 -7 mm during revolution
Visual Inspection

Drive Train

Leakage of oil/grease from pinion housing and counter shaft
Visual Inspection

Support No. III

Tire

Missing stopblocks
Visual Inspection

Support No. III

Tire

Cracked chair pad
Visual Inspection

Support No. IV

Whole support covered by lime material
Visual Inspection

Support No. II and No. III

Concrete foundation

Cracks in concrete around pier base
Visible steel reinforcement
Cross Sections’ Diagram
for Kiln Shell Deviation Survey

Hatch describing kiln position

| Section No. | 1 | 2  | 3  | 4  | 5  | 6  | P-I | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | P-II | 18 | 19 | DRIVE | 20 | 21 | Unit |
|-------------|---|----|----|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|------|----|----|--------|----|----|------|
| Y geom.centre | -8 | -9 | -5 | -1 | 0  | -1 | -  | 0  | +6 | +8 | +7 | +5 | +5 | +3 | +2 | 0  | -1 | 0  | -  | 0    | -1 | -5 | mm    |
| Z geom.centre | -5 | -5 | -5 | -5 | -5 | -3 | -  | 0  | +1 | +7 | +9 | +9 | +6 | +4 | +3 | 0  | 0  | 0  | -  | 0    | -2 | -3 | -4 mm |
| Eccentricity  | 10 | 10 | 7  | 5  | 3  | 1  | -  | 0  | 6  | 11 | 12 | 10 | 7  | 5  | 4  | 0  | 1  | 0  | -  | 2    | 3  | 6  | mm    |

<table>
<thead>
<tr>
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<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>P-III</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
<th>36</th>
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<th>39</th>
<th>40</th>
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<th>41</th>
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<th>Unit</th>
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<td>+2</td>
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<td>-3</td>
<td>mm</td>
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<td>8</td>
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<td>6</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Shell Profile
Starting point at the bottom - 0°

| Section No. | 1  | 2  | 3  | 4  | 5  | 6  | P-I | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | P-II | 18 | 19 | DRIVE | 20 | 21 | Unit |
|-------------|----|----|----|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|-----|----|----|-------|----|----|-------|
| Y geom.centre | -8 | -9 | -5 | -1 | 0  | -1 | -   | 0  | +6 | +8 | +7 | +5 | +5 | +3 | +2 | 0  | -1 | 0   | -   | 0   | -   | 1   | 0   | -   | -   | -1  | -5  | mm   |
| Z geom.centre | -5 | -5 | -5 | -3 | -1 | -  | 0   | +1 | +7 | +9 | +9 | +6 | +6 | +4 | +3 | 0  | 0  | 0   | -   | 0   | -2  | -   | -3  | -4  | mm   |
| Eccentricity  | 10 | 10 | 7  | 5  | 3  | 1  | 0   | 6  | 11 | 12 | 10 | 7  | 5  | 4  | 0  | 1  | 0   | -   | 0   | 2   | -   | 3   | 6   | mm   |

| Section No. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | P-III | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | P-IV | 41 | 42 | 43 | Unit |
|-------------|----|----|----|----|----|----|----|----|-------|----|----|----|----|----|----|----|----|----|----|-----|----|----|----|-------|
| Y geom.centre | -3 | -3 | -1 | -1 | 0  | -1 | -2 | -2 | +1    | +1 | -   | 0  | +3 | +3 | +3 | 0  | -2 | -1 | -4 | -4 | -6 | -6 | -1 | -2 | -5 | +4 | mm   |
| Z geom.centre | -6 | -7 | -7 | -8 | -9 | -7 | -7 | -3 | -1    | -1 | -1 | -1 | -4 | -4 | -3 | 0  | +3 | +4 | +4 | +3 | +2 | -1 | -1 | +1 | 0  | -3 | 4 | mm   |
| Eccentricity  | 7  | 7  | 7  | 8  | 9  | 7  | 3  | 1  | -     | 1  | 5  | 5  | 4  | 0  | 4  | 4  | 5  | 7  | 6  | 1  | -2 | 5  | 5  | 5  | mm   |
Shell Profile
Starting point at 90°

| Section No. | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | P-II | 18 | 19 | DRIVE | 20 | 21 | Unit |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|----|----|--------|----|----|-------|
| Y geom. centre | -8 | -9 | -5 | -1 | 0  | -1 | -  | 0  | +6 | +8 | +7 | +5 | +6 | +4 | +3 | +2 | 0  | -1 | 0    | -  | 0  | -1    | -3 | -5 | mm    |
| Z geom. centre | - 5 | -5 | -8 | -3 | -1 | -  | 0  | +1 | +7 | +9 | +9 | +6 | +4 | +3 | 0  | 0  | 0  | 0   | -2 | -3 | -4    | mm |
| Eccentricity  | 10 | 10 | 7  | 5  | 3  | 1  | -  | 0  | 6  | 11 | 12 | 10 | 7  | 5  | 4  | 0  | 1  | 0   | -  | 0  | 2    | -3 | 3  | 6     | mm |

| Section No. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | P-III | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | P-IV | 41 | 42 | 43 | Unit |
|-------------|----|----|----|----|----|----|----|----|--------|----|----|----|----|----|----|----|----|----|----|-----|----|----|-----|-------|
| Y geom. centre | -3 | 0  | -1 | 0  | -2 | -2 | +1 | +1 | +1     | -  | 0  | +3 | +3 | +3 | 0  | -2 | -1 | -4 | -6 | -6 | -1 | +2  | +5  | +4 | mm |
| Z geom. centre | -6 | -7 | -7 | -8 | -9 | -7 | -3 | -1 | -1     | -4 | -4 | -4 | -4 | -3 | 0  | +3 | +4 | +4 | +3 | +2 | -1 | +1  | 0   | -3 | mm |
| Eccentricity  | 7  | 7  | 7  | 8  | 9  | 7  | 3  | 1  | -      | 1  | 5  | 5  | 4  | 4  | 5  | 7  | 6  | 1  | -  | 2   | 5   | 5  | mm |

GeoCement

Rotary Kiln Inspection
August 2016  (Hot condition)
Shell Profile
Starting point at 180°

| Section No. | 1   | 2   | 3   | 4   | 5   | 6   | P-I | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | P-II | 18  | 19  | DRIVE | 20  | 21  | Unit |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-------|-----|-----|-------|
| Y geom. centre | -8  | -9  | -5  | -1  | 0   | -1  | -   | 0   | +6  | +8  | +7  | +5  | +5  | +3  | +2  | 0   | -1  | 0   | -    | 0   | 0   | -1   | -1  | -5  | mm    |
| Z geom. centre | -5  | -5  | -5  | -3  | -1  | -   | 0   | +1  | +7  | +9  | +9  | +6  | +4  | +3  | 0   | 0   | 0   | -    | 0   | 0   | -2   | -3  | -4  | mm    |
| Eccentricity  | 10  | 10  | 7   | 5   | 3   | 1   | -   | 0   | 6   | 11  | 12  | 10  | 7   | 5   | 4   | 0   | 1   | 0   | -    | 0   | 2   | 3    | 6   | 6   | mm    |

| Section No. | 22  | 23  | 24  | 25  | 26  | 27  | 28  | 29  | P-III | 30  | 31  | 32  | 33  | 34  | 35  | 36  | 37  | 38  | 39  | 40  | P-IV | 41  | 42  | 43  | Unit |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-------|
| Y geom. centre | -3  | 0   | -1  | 0   | -2  | +2  | +1  | +1  | -     | 0   | +3  | +3  | +3  | 0   | -2  | -1  | -4  | -6  | -6  | -1  | -   | +2  | +5  | +4  | mm    |
| Z geom. centre | -6  | -7  | -7  | -8  | -9  | -1  | -3  | -1  | -     | -1  | -4  | -4  | -3  | 0   | +3  | +4  | +4  | +3  | +2  | -1  | -   | +1  | 0   | -3  | mm    |
| Eccentricity  | 7   | 7   | 7   | 8   | 9   | 7   | 3   | 1   | -     | 1   | 5   | 5   | 4   | 0   | 4   | 4   | 5   | 7   | 6   | 1   | -   | 2   | 5   | 5   | mm    |
### Shell Profile
Starting point at 270°

| Section No. | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | P-I | 18 | 19 | DRIV | 20 | 21 | Unit |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|------|
| Y geom. centre | -8 | -9 | -5 | -1 | 0  | -1 | 0  | +6 | +8 | +7 | +5 | +5 | +3 | +2 | 0  | -1 | 0  | -  | 0   | 0   | -1  | -5  | mm   |
| Z geom. centre | -5 | -5 | -5 | -3 | -1 | -1 | -1 | +1 | +7 | +9 | +9 | +6 | +4 | +3 | 0  | 0  | 0  | -  | 0   | -2  | -3  | -4  | mm   |
| Eccentricity  | 10 | 10 | 7  | 5  | 3  | 1  | 0  | 0  | 6  | 11 | 12 | 10 | 7  | 5  | 4  | 0  | 1  | 0  | -   | 0   | 2   | 3   | 6   | mm   |

| Section No. | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | P-III | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | P-IV | 41 | 42 | 43 | Unit |
|-------------|----|----|----|----|----|----|----|----|--------|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|------|
| Y geom. centre | -3 | 0  | -1 | 0  | -2 | -2 | +1 | +1 | -      | 0  | +3 | +3 | +3 | 0  | -2 | -1 | -4 | -6 | -6 | -1   | -2   | +2  | +5  | +6  | mm   |
| Z geom. centre | -6 | -7 | -7 | -8 | -9 | -7 | -3 | -1 | -      | -1 | -4 | -4 | -4 | 0  | +3 | +4 | +4 | +3 | +2 | -1   | -1   | +1  | 0   | -3  | mm   |
| Eccentricity  | 7  | 7  | 7  | 8  | 9  | 7  | 3  | 1  | -      | 1  | 5  | 5  | 4  | 0  | 4  | 4  | 5  | 7  | 6   | 1   | -2  | 5   | 5   | mm   |
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 1
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 2
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
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<tr>
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<th>-9 mm</th>
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<tbody>
<tr>
<td>Coordinate Z</td>
<td>+5 mm</td>
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<tr>
<td>ECCENTRICITY</td>
<td>10 mm</td>
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</table>

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 3
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
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<tbody>
<tr>
<td>Coordinate Z</td>
<td>-5 mm</td>
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<tr>
<td>ECCENTRICITY</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 5
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

Geometric Centre

GEOMETRIC CENTRE COORDINATES

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
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<tr>
<td>ECCENTRICITY</td>
<td>3 mm</td>
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Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 6
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>Coordinate Z</th>
<th>ECCENTRICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 1 mm</td>
<td>- 1 mm</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 7
Deformation Scale - 1 : 1

_geometric centre_

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

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<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
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</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 8
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

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<td>ECCENTRICITY</td>
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</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection
August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 9
Deformation Scale - 1 : 1

Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GeoCement

Rotary Kiln Inspection
August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 10
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

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<td>ECCENTRICITY</td>
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Rotary Kiln Inspection  August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 11
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>Coordinate Z</th>
<th>ECCENTRICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5 mm</td>
<td>+9 mm</td>
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</tr>
</tbody>
</table>

GeoCement
Rotary Kiln Inspection
August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 12
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+6 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>7 mm</td>
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</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 13
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position
at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE
COORDINATES

<table>
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<th>Coordinate Y</th>
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</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+ 4 mm</td>
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<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  
August 2016  (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 14
Deformation Scale - 1 : 1

Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 2 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+ 3 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>4 mm</td>
</tr>
</tbody>
</table>

Note:

GeoCement

Geometric centre

Axis of rotation

z

y

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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24
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26
27
28
29
30
31
32

GeoCement

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 15
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>0 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 16
Deformation Scale - 1 : 1

Note: Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>0 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 17
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

<table>
<thead>
<tr>
<th>GEOMETRIC CENTRE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Y</td>
</tr>
<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 18
Deformation Scale - 1 : 1

GEOMETRIC CENTRE COORDINATES

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>0 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 19
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>-2 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>2 mm</td>
</tr>
</tbody>
</table>
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 20
Deformation Scale - 1 : 1

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 3 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>3 mm</td>
</tr>
</tbody>
</table>

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 21
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

<table>
<thead>
<tr>
<th>GEOMETRIC CENTRE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Y</td>
</tr>
<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  
August 2016 (Hot condition)
Geometric centre

axis of rotation

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 6 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

CROSS SECTION No. 22
Deformation Scale - 1 : 1

Radial Diagram of Shell Deformation
(Circular Deviations)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 23
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

| Coordinate Y | 0 mm |
| Coordinate Z | -7 mm |
| ECCENTRICITY | 7 mm |

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 24
Deformation Scale - 1 : 1

<table>
<thead>
<tr>
<th>Note:</th>
<th>Hatch describing kiln position at the bottom</th>
</tr>
</thead>
</table>

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 7 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 26
Deformation Scale - 1 : 1

Geometric centre

axis of rotation

Coordinate Y  - 2 mm
Coordinate Z  - 9 mm
Eccentricity  9 mm

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

Rotary Kiln Inspection  August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 27
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>Coordinate Z</th>
<th>ECCENTRICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 2 mm</td>
<td>- 7 mm</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 28
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

| Coordinate Y | + 1 mm |
| Coordinate Z | - 3 mm |
| ECCENTRICITY | 3 mm |

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 29
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 1 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 30
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>-1 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection
August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 31
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 4 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection  August 2016 (Hot condition)
CROSS SECTION No. 32
Deformation Scale - 1 : 1

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>-4 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 33
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 3 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>4 mm</td>
</tr>
</tbody>
</table>

R达到了y

 Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 34
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

<table>
<thead>
<tr>
<th>GEOMETRIC CENTRE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Y</td>
</tr>
<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
</tr>
</tbody>
</table>

GeoCement
Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 35
Deformation Scale - 1 : 1

Geometric centre
axis of rotation

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

<table>
<thead>
<tr>
<th>GEOMETRIC CENTRE COORDINATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Y</td>
</tr>
<tr>
<td>Coordinate Z</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 36
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 1 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+ 4 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>4 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 37
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE
COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>-4 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+4 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 38
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position
at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE
COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>- 6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+ 3 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

 GeoCement

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 39
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

Geometric Centre

Coordinate Y  - 6 mm
Coordinate Z  + 2 mm
Eccentricity  6 mm

Rotary Kiln Inspection  August 2016  (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 40
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>Coordinate Z</th>
<th>ECCENTRICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 1 mm</td>
<td>- 1 mm</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection
August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 41
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE
COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 2 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>+ 1 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation (Circular Deviations)

CROSS SECTION No. 42
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom

VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>0 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection August 2016 (Hot condition)
Radial Diagram of Shell Deformation
(Circular Deviations)

CROSS SECTION No. 43
Deformation Scale - 1 : 1

Note:
Hatch describing kiln position at the bottom
VIEWING FROM INLET SIDE

GEOMETRIC CENTRE COORDINATES

<table>
<thead>
<tr>
<th>Coordinate Y</th>
<th>+ 4 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinate Z</td>
<td>- 3 mm</td>
</tr>
<tr>
<td>ECCENTRICITY</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

GeoCement

Rotary Kiln Inspection  August 2016  (Hot condition)
APPENDIX

MECHANICAL PARAMETERS

ROTARY KILN

August 2016
The kiln mechanical parameters were calculated with consideration of actual thickness of kiln shell, refractory lining, material flow, as well as all dimensions of kiln components and its current temperature. All results represent the case of straight kiln axis. To illustrate consequences for the kiln we calculate load capacity utilization of particular parameter referring to its design limit.

### LOAD DISTRIBUTION FOR ROLLERS AND TIRES

<table>
<thead>
<tr>
<th>BEARINGS</th>
<th>TIRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific load</td>
<td>Utilization</td>
</tr>
<tr>
<td>(design limit 4.4 MPa)</td>
<td>[ % ]</td>
</tr>
<tr>
<td>Support No. 1</td>
<td>-</td>
</tr>
<tr>
<td>Support No. 2</td>
<td>-</td>
</tr>
<tr>
<td>Support No. 3</td>
<td>-</td>
</tr>
<tr>
<td>Support No. 4</td>
<td>-</td>
</tr>
</tbody>
</table>

Results above show that Hertz pressure between rollers and tires as well as bending stress of tires are within design limits for all supports. Specific load values for bearings are not shown due to missing (not provided) dimensions of roller bearings.

### STIFFNESS MATRIX

<table>
<thead>
<tr>
<th>Change of reaction in [%] by lowering particular support by 10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change at</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Support No. 1</td>
</tr>
<tr>
<td>Support No. 2</td>
</tr>
<tr>
<td>Support No. 3</td>
</tr>
<tr>
<td>Support No. 4</td>
</tr>
</tbody>
</table>

The stiffness matrix illustrates kiln shell characteristics. The results illustrate change of reaction of all supports when particular support is lowered by 10 mm. Considering maximum reaction value of 27.1 % this kiln is classified as medium flexible. It means the kiln is not very sensitive for change of kiln axis position and reactions at supports do not change drastically. Anyway, it is still recommended to pay attention to the kiln alignment and under-tire clearance changes to avoid overload in the future.
Kiln shell bending stress reaches 17 MPa and it is within designed limits (25 MPa). It looks there is some spare limit for shell bending stress. However, it has to be considered that the results above represent straight kiln in static condition and without any shell deformation or crank formation. The kiln (as designed) is not overloaded at any support and theoretically shall not be a subject to cracks due to bending stress.

<table>
<thead>
<tr>
<th>SHELL</th>
<th>TIRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rel. ovality</td>
<td>Utilization</td>
</tr>
<tr>
<td>(design limit 0.30%)</td>
<td>[ % ]</td>
</tr>
<tr>
<td>Support No. 1</td>
<td>0.285</td>
</tr>
<tr>
<td>Support No. 2</td>
<td>0.241</td>
</tr>
<tr>
<td>Support No. 3</td>
<td>0.145</td>
</tr>
<tr>
<td>Support No. 4</td>
<td>0.096</td>
</tr>
</tbody>
</table>

Tire migration is in tolerance (10 – 20mm) for supports No. 2 and No. 3. For supports No. 1 and No. 2 tire migration slightly exceeds tolerance. Nies ovality is within tolerance for all tires. Relative ovality for support No. 1 is almost on design limit (consequence of tire migration).

In general, the kiln mechanical parameters are within design limits. The kiln is definitely not overloaded in terms of support loads, tire stress and Hertz pressure between tires and rollers. Also the kiln shell bending stress is within designed limit. However, it should be considered that all the design limits correspond to static condition and in fact all parameters are frequently much higher due to cyclical load change during kiln operation (crank effect). It is recommended to monitor the bearings condition and temperature frequently.

Technical drawings of calculation results are attached at the end of this report.
Load Components and Kiln 3D Model

Starting point

FEED

Rotary Kiln Inspection
August 2016 (Hot condition)
Load Components and Kiln 3D Model

Tires & gear

Shell

Lining

Coolers zone

Zone 1000°C
Weight distribution [t/m]
Longitudinal Bending Stress of the Kiln Shell [MPa]
Vertical Displacement of the Kiln Shell [mm]

Vertical displacement for $F = 197$
Hot kiln

Kiln length $x$ [mm]

Vertical displacement $y$ [mm]
Von Mises Stress of the Kiln Shell [MPa]
Bending Stress of Tires [MPa]

Bending moment in case with shim on bottom [Nm]

Support 3
Support 4

Bending moment in case with shim on bottom [Nm]

Support 1
Support 2
Bending Stress of Tires [MPa]