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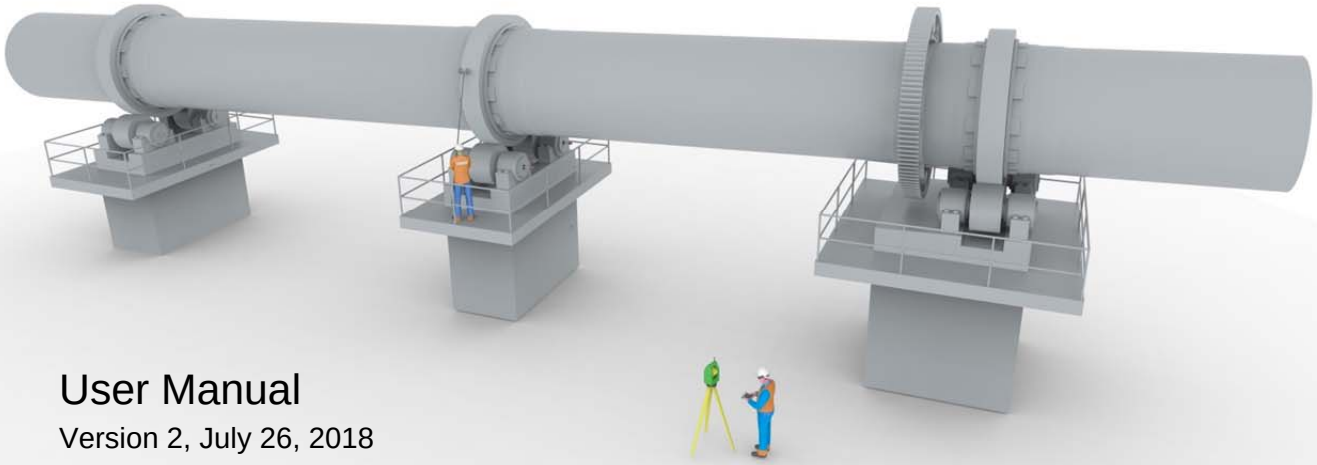

User Manual
Version 2, July 26, 2018

Kiln Axis Alignment System

1 Introduction

The Kiln Axis Alignment system is an easy and fast way to verify the straightness of rotary kilns or dryers. The combination of a modern Robotic Theodolite, the powerful software and the unique Accessory Kit facilitate the measurement in a way that no longer special surveying knowledge is needed; without compromise on accuracy.
The alignment check of the kiln axis is one of the most important measurements on rotary kilns or dryers with more than two piers. The straightness of the kiln axis needs to be within tight tolerances to minimize the stress in the kiln shell and to distribute the support loads correctly among the different piers. Typical symptoms for misalignment are circumferential cracks in the kiln shell (near middle tire) and issues with the bearings of the support rollers.

1.1 Safety

Rotary kilns and dryers, where this tool is typically used, are huge rotating equipment with many pinch points and hot surfaces which can cause serious injuries. Therefore only specialized and trained personnel shall work close to these machines. To use the tool, follow strictly the local safety rules given by the respective plant / factory / local authorities and discuss the application with the safety engineer in charge.
The tools provided by TomTom-Tools GmbH have proven their functionality in various applications; nevertheless TomTom-Tools GmbH does not take any responsibility for the application on site regarding safety. The plant is responsible for the safety, according to the local law, in a way that nobody can be hurt or injured. The application and safety instructions below are guidelines and not exhausted which include the experience from previous measurement campaigns and might need to be adapted to the local safety requirements.

Caution:

Laser Beam:
Laser radiation, do not stare into beam
Please consult the safety instruction in the manual of the Laser Theodolite.

Magnet Fields:
Be aware of the strong fields of the magnets
Keep the tool away from people with pace makers or any other sensitive item as credit cards or magnetic data carrier.

Gloves:
Wear proper gloves to protect your hands from hot and rough surfaces and sharp edges.

Hot Surface:
The kiln shell might be very hot. Do not touch it and keep sufficient distance.

Radio Waves:
Be aware of the radio waves (Bluetooth) which are emitted from the tool, as well from the Bluetooth adapter on the computer.
Do not keep the tool unnecessary in operation; switch it off, after usage.

Pinch Points:
Do not put your hands nor any items close or into pinch points (e.g.kiln tires / support rollers, girth gear / pinion,…)
Keep safe distance to avoid getting caught by moving parts.

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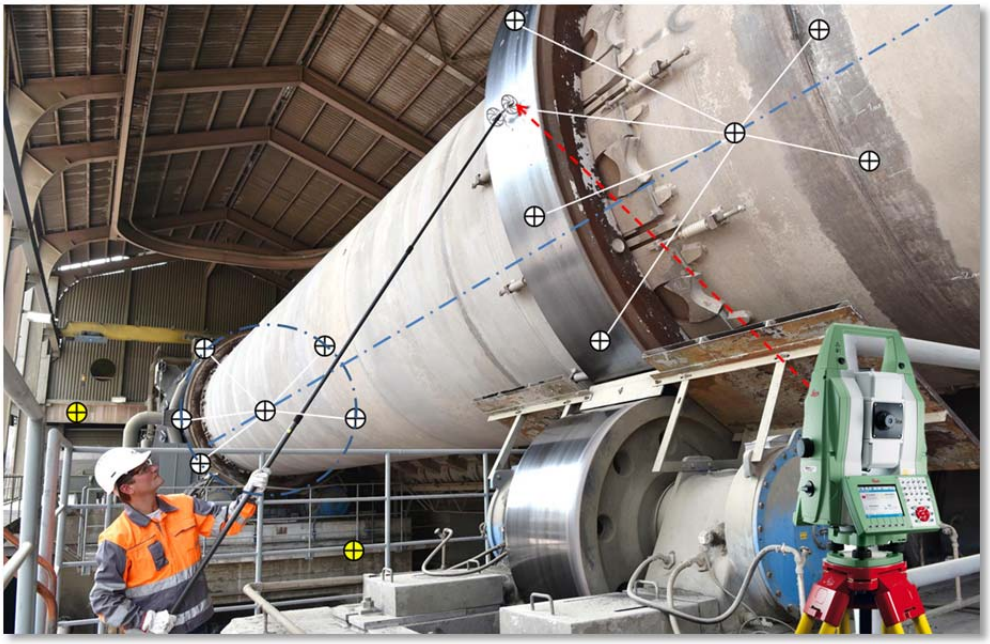
2 Measuring Principle

The Kiln Axis Alignment System is a specialized surveying method which is based on measured points in the 3D space on and around the kiln. The required points are measured with a state of the art laser theodolite with robotic function; a so called Total Station.



The software, the Measurement Studio, fits ideal circles / ellipses into the measured points, calculates automatically the centers of the tires and provides their deviation to a straight line. This deviation of the actual kiln axis to the straight line is the value for how much the kiln is misaligned.
In order to achieve the required accuracy of +/- 1…2mm, the kiln axis has to be measured from both sides of the kiln; therefore two measurement locations (called stations) are required.
For the calculation, two types of points need to be measured, the reference points to combine / merge the different stations and the tire points to calculate the tire centers.
A great feature of the here used theodolites is the automatic target recognition (ATR), which works perfectly with our target prisms and allow precise measurement without specialized surveying knowledge.
The kiln axis can be measured during normal operation as well as in stopped condition

3 Supported Theodolites and Licensing

Up to now, the following theodolites (Total Stations) are supported: **Leica TS60**, MS60, TS50, MS50, TS16, TS15. More brands and models will be added in future.
The TS60 is the recommended model due to its precision and tracking capabilities.
Make sure the GeoCom Robotic Interface is activated. Please contact your local Leica dealer to get the activation key.

Needed:	**827664**	**GeoCom Robotics TS/MS License key**
Not needed yet	827663	GeoCom Imaging TS/MS License key
Not needed yet	827665	GeoCom Video Streaming TS/MS License key
Not needed	827666	Virtual GeoCom TS/MS License key

To activate your theodolite in the Measurement Studio please send the type and the serial number of the theodolite to info@tomtom-tools.com. The activation of one theodolite is part of the tool kit. The number of users and PCs is not limited.

4 Measurement Setup

The proper setup of the kiln axis measurement is the key point where most attention should be paid. Some kilns are easy to measure, because there is a free view to all the tires on both side of the kiln. Some kilns are difficult to access because there are many obstacles like air ducts and walkways next to the kiln.
If there is the chance, it is recommend to start and to become familiar with the axis measurement system on a kiln which is easy to access.

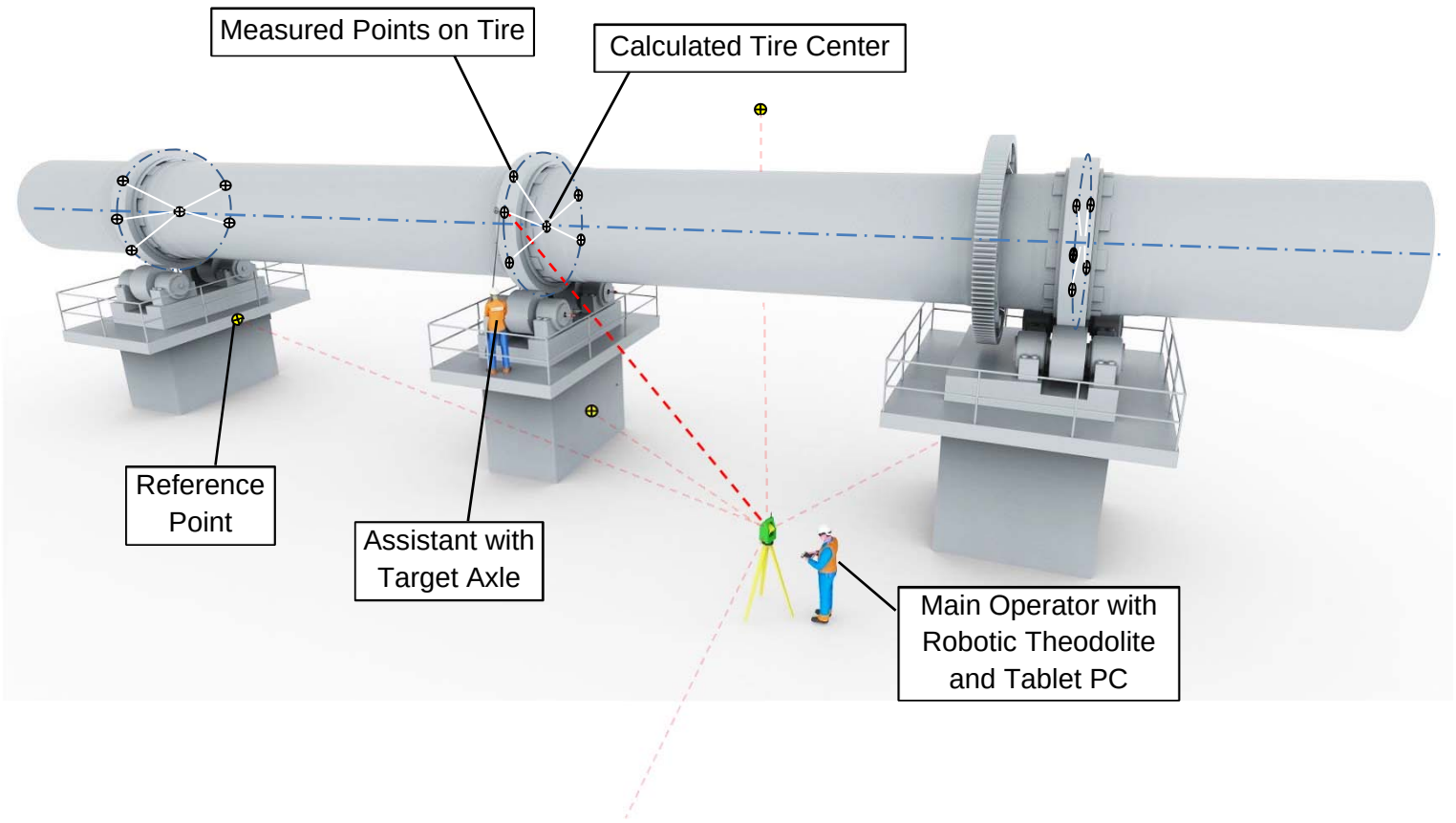
4.1 Station (Location of Theodolite)

A station is the location of the theodolite where it is placed to measure.
Two stations are typically required to measure the kiln axis of a rotary kiln; one station to cover the right side of the kiln and one station for the left side. In case the kiln is surrounded with obstacles, which do not allow the free view from one station to all the tires, additional stations will be required.
Finding the “best” stations is the key to measure the kiln efficiently with high accuracy.

The following points should be considered while searching for stations:

a) Is the place safe and free of dust
b) Is it not too hot for people or the theodolite?
c) Can all kiln tires be seen?
d) Is the place stable, not vibrating and not affected by the people moving around?
   Preferable measure from the ground or from concrete structures
   Steel structures might not be sufficiently stiff

The picture below shows the typical setup:



4.2 Reference Points

The Reference Points, sometimes also called “common points” are needed to merge the measurement points from different stations to one complete 3D model. Therefore they have to be placed where they can be seen / measured by the theodolite from all the different stations.
Theoretically there are only 3 common reference points needed to merge two stations.
But each measurement of each point has a small inaccuracy of about 1mm, therefore it is recommended to add more reference points, it will reduce the final inaccuracy of the merged data. A good number of common reference points are 5. In case one got lost or shifted, there are still 4 points left, which should be enough.

Please respect the following rules for the reference points:

a) Look for places which can be seen preferable from all the stations
b) The reference points should be distributed around the kiln area in a way that the covered volume is as big as the kiln
c) The reference points should be spread around the station in different directions
d) Look for concrete and stiff steel structures
e) Be careful on high thin steel structures they might vibrate or are affected by wind and changes of the sunlight
f) If there is the possibility attach the reference points on steel structures close to the ground and concrete foundations where not much changes due to vibration and thermal expansion are expected.
g) If reference points are attached to walk ways and platforms, make sure there are no relevant changes while people are moving.
h) Do not attach reference points on crane structures in case it is in use, because the position might not be stable
i) Make sure the base magnet is sticking sufficiently strong to the base material. In case there is too much dust and dirt on the surface, clean it first to get sufficient magnetic force
j) Attach the reference points to straight surfaces; do not attach them on round tubes as railings or posts

Typical locations for reference points are:

- Kiln piers (toe plates on railing close to concrete)
- Structure of walkways near the kiln (close to concrete base)
- Main structure of pre-heater tower
- Large silos
- Strong posts of railing (close to concrete)
- Window or door frames of buildings
- Roof structures

Note:
In the beginning it might be a bit difficult and time consuming to find good stations and the right spots for the reference points, but it is well invested time.

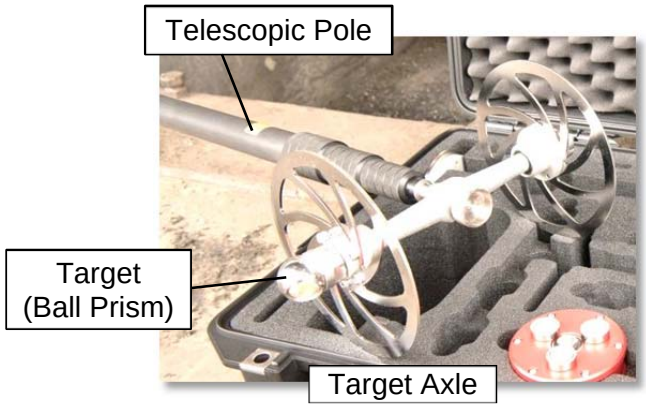
The following pictures show a reference point, which consists of the following components:

1. Base Magnet
2. Prism Holder
3. Ball Prism

The **Base Magnets** are very strong to keep the position without any movement during the measurement campaign. These Base Magnets could also remain at site, which would make the next time the setup quick and easy.
The **Prism Holders** are attached by another magnet to the Base Magnets. The Prism Holders maintain their center position and height, but can be turned freely around their vertical axis. This allows the adjustment of the prism into the direction of the theodolite. The 45° shape of the Prism Holders gives a maximal range to the Ball Prisms.
The **Ball Prisms** are reflectors which send the laser beam from the theodolite back to it. Therefore the prisms have to be directed toward the theodolite. The spherical shape allows adjustments to the different stations without changing the position of the reference point, which is in the center point of the ball.

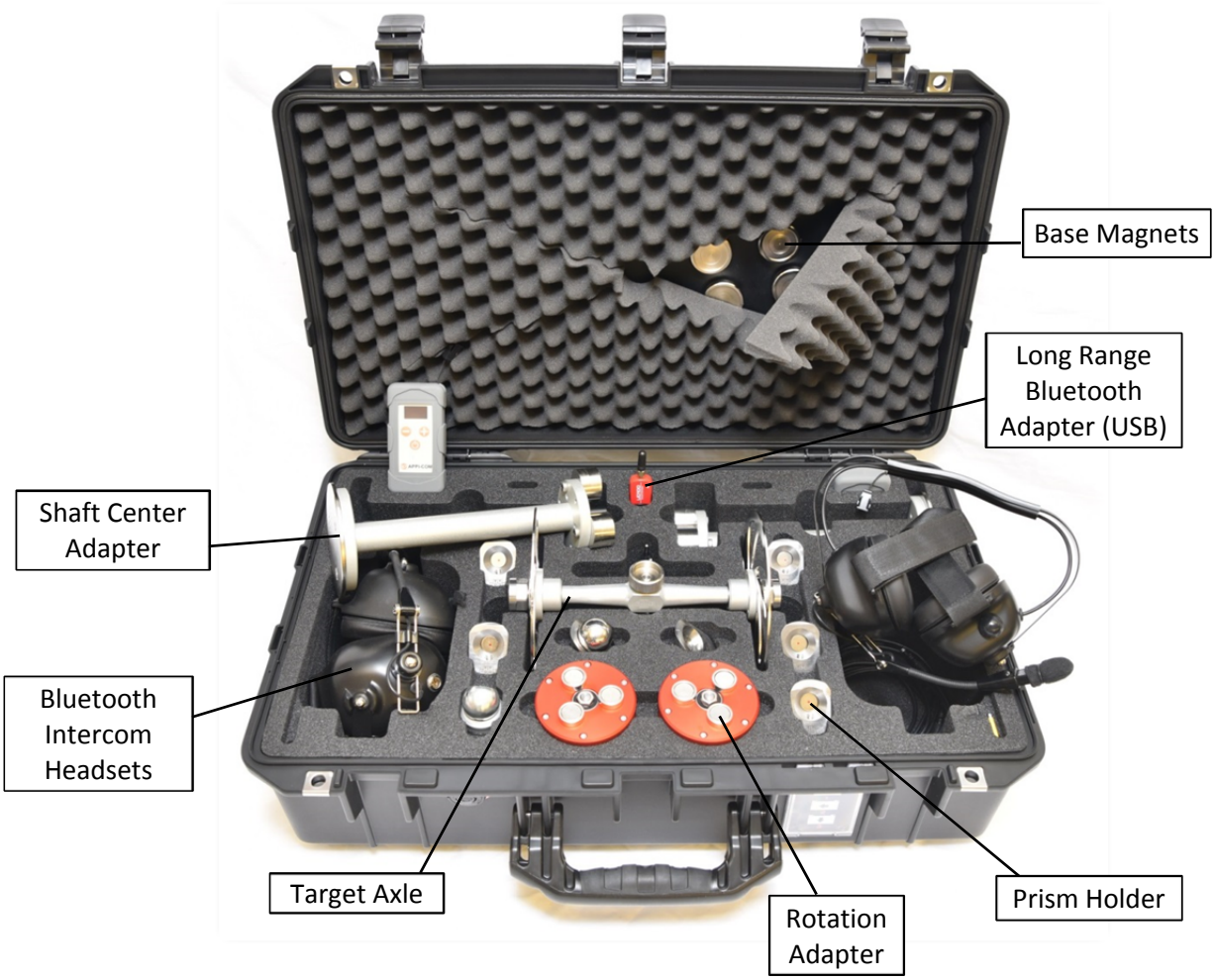
4.3 Target Axle

The Target Axle is used to acquire points from the outer diameter, the running surface of the kiln tires. The axle is equipped with two ball prisms, the targets, whereof only one is used for the measurement at the time. The ball prisms are located in the center of the wheels, which results in a constant distance to the tire center independent on the position of the target axle. To facilitate the acquisition of points over large areas around the tire the target axle is mounted on a telescopic pole. The target axle is placed by the assistant to different positions around the kiln tires. Sidewise the prism in use should be located approximately in the middle of the running face of the tire.



4.4 Bluetooth Intercom

The communication between the main operator at the theodolite and the assistant at the kiln is crucial for safe and efficient work. Therefore the tool kit is equipped with Bluetooth intercom headsets. The main operator can give easily instructions to the assistant where the target axle should be placed to have a clear view from the theodolite.



4.5 Tablet PC

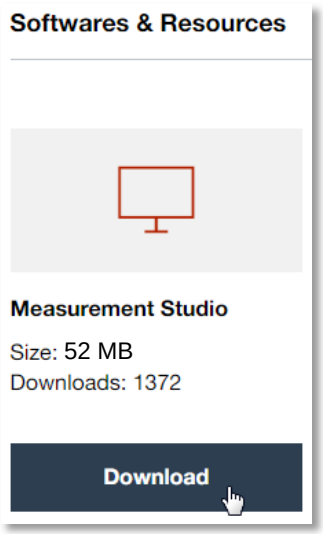
In the scope of supply of the Kiln Axis Alignment Tool Kit is the following tablet PC included:
(But any other PC which is running with Windows 7 or higher can be used)
Panasonic FZ-G1 with the following extras:

- Integrated TomTom-Tools Long Range Bluetooth
- Large Battery for long working time
- Water and dust resistant key board
  (can be attached when required, e.g. for work in office)
- Mobility Bundle for easy carrying at site

5 Software:

5.1 Software Installation:

The software (**TomTom-Tools Measurement Studio**), which is used for the Kiln Axis Alignment and for all others of our tools, is pre-installed on the tablet PC and comes along with the tool kit on a USB Memory Stick. Nevertheless it is recommended to **install the software from** www.tomtom-tools.com , where always the latest version is available.
During any start of the Measurement Studio, it is checking for updates if the computer is connected to the internet. In case of available upgrades the user gets asked if they should be downloaded and installed.
Please keep your PC up to date.

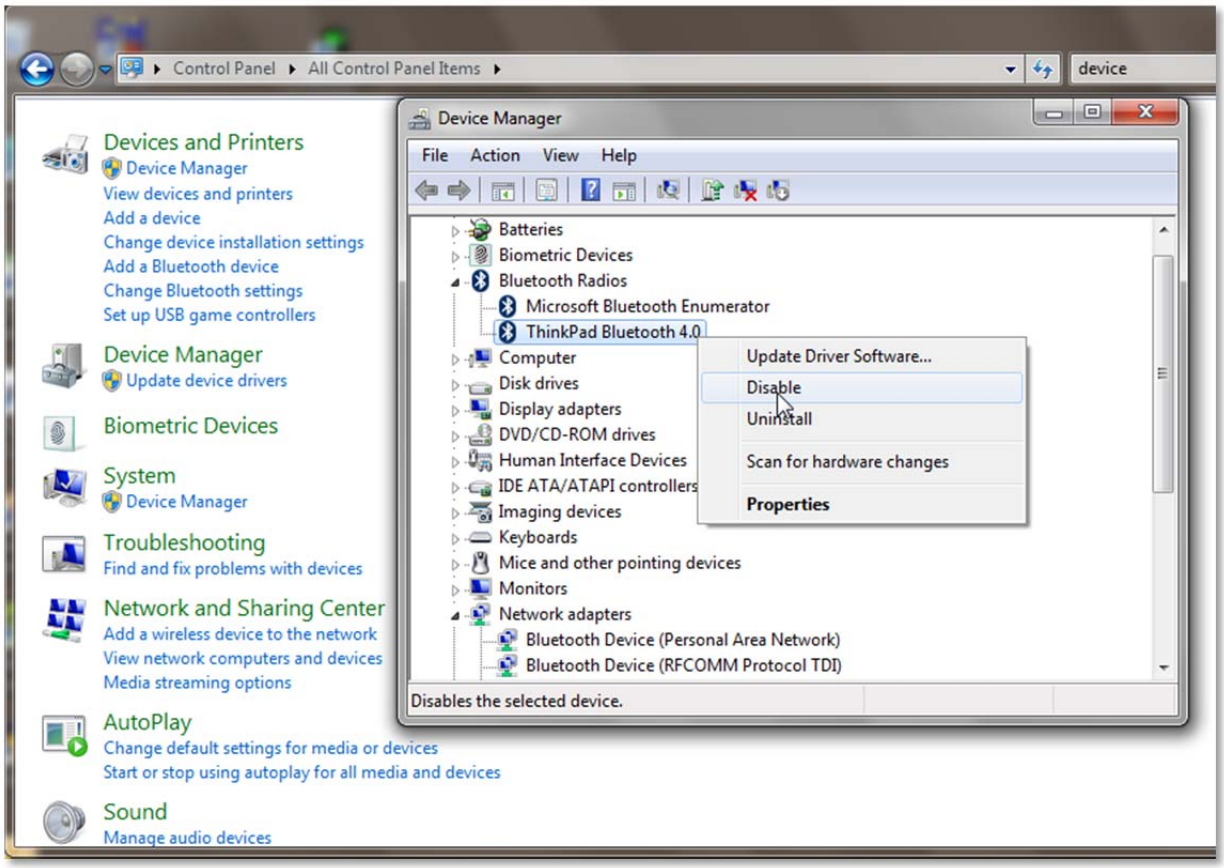


5.2 Bluetooth Adapter

To ensure, the data connection between the different tools, here the theodolite and the PC is reliable, even in the difficult environment around a rotary kiln, the tablet PC is equipped with a Long Range Bluetooth adapter. In case you use another computer, it is recommended to use the Bluetooth adapter (Parani UD100), which comes along with the tool kit.

Note:

- The TomTom-Tools are designed to communicate **only with the generic Windows Bluetooth Stack**. If there is another Bluetooth software installed (e.g. Toshiba, Widcomm, Intel, ThinkPad,…), **deactivate it in the Device Manager** as shown below:



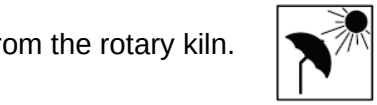
- Then plug the Bluetooth adapter UD100.
  Windows will recognize the new hardware
  and automatically install the suitable Windows driver
  (Windows generic Bluetooth)

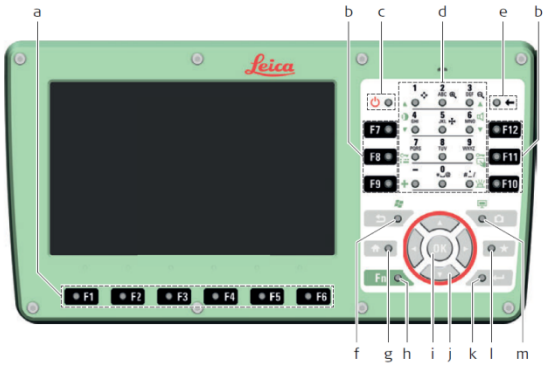
- The Device Manager will show the following:
  - Generic Bluetooth Radio
  - Microsoft Bluetooth Enumerator
  - the not required Bluetooth is down
    (indicated by the small arrow at the Bluetooth icon)

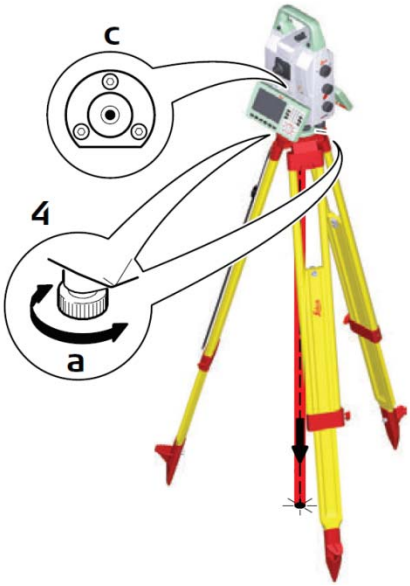
6 Start the Tool:

6.1 Set up the Total Station

Shield the instrument from direct sunlight and the heat radiation from the rotary kiln.
Avoid uneven temperatures around the instrument.







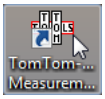
a) Function keys F1-F6
b) Function keys F7-F12
c) ON/OFF
d) Alphanumeric keys
e) Backspace
f) Esc
g) Home
h) Fn
i) OK
j) Arrow keys
k) Enter
l) Favorites
m) Camera

Step Description

1. Extend the tripod legs to allow for a comfortable working posture.
   Position the tripod at Station 1 (as described in chapter 3.1).
   Ensure that the tripod plate is roughly horizontal.
2. Fasten the tribrach and instrument onto the tripod.
3. Turn on the instrument by pressing the ON button (c).
   Select **Settings/TS instrument/Level & compensator** to activate the electronic level.
4. Use the tribrach foots crews (a) to center the electronic level (b)

For more details please consult the user manual of the Leica Total Station

6.2 Connect the theodolite (Total Station) with the PC

Start the Measurement Studio on the computer by clicking on the icon. 

To connect the theodolite or any other tool for the first time it has to be paired with the PC.
To do so, follow this sequence:

- Switch on the theodolite by pushing the ON button (c).
- At the PC, click on “Tools / Bluetooth Devices / Add a device”
- Wait until the tool got found
  Note: Depending on the search speed of the computer, it might take up to one minute.
- Select the device, which has to be connected; (here the theodolite) and click “OK”

Fig. 6.2.1 (Add Device)

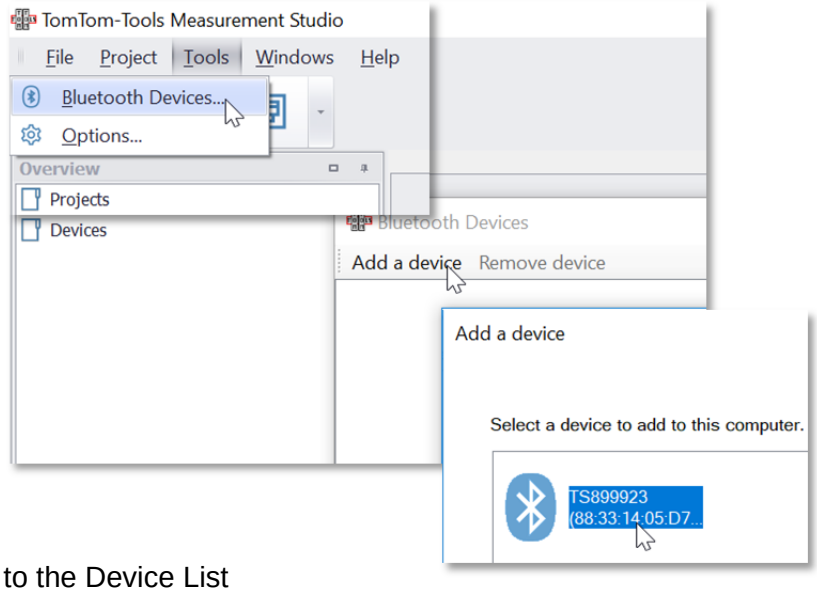
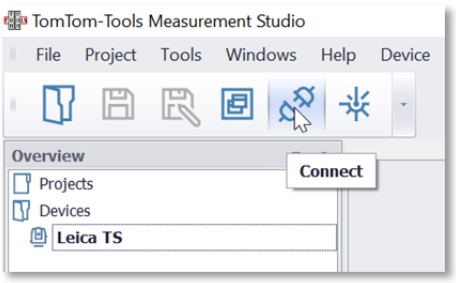


Fig. 6.2.2 (Connect Device)

- The theodolite is added to the Device List
- To connect the theodolite, click on the “Connect” Button



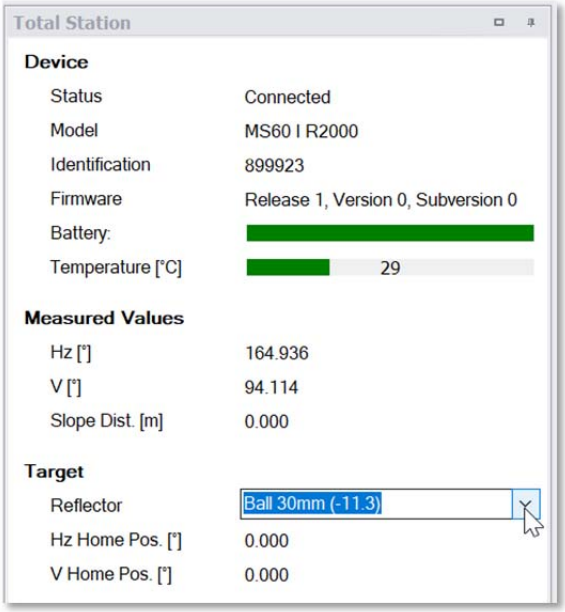


Fig. 6.2.3: Main Parameter of Total Station
The main parameters are shown in the bottom window at the left side.

The ball prisms which are used for the kiln axis measurement are selected by default
Ball 30mm with the prism constant of
-11.3mm (Leica: +23,1mm)

7 Measurement:

7.1 Open a new Project

A new project file has to be generated
by clicking on “Project / Kiln Axis”

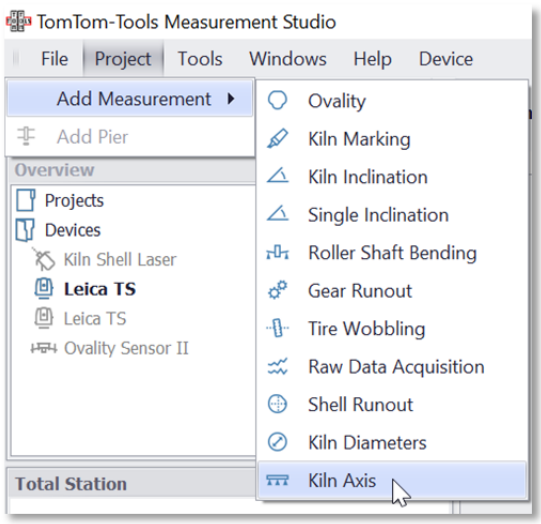


Fig. 7.1.1

7.2 Measure the Reference Points

The theodolite is placed at Station 1.
Now the reference points (common points) can be measured.
To do so, perform the following steps:

- Add a reference point in the software by clicking on the button “Add Reference Point”.
- To avoid any mix up of the reference points, it is recommended to change the name of the reference point to a unmistakable name (e.g. preheater tower, pier 2,…)
- Direct the theodolite manually towards the first reference point. It has not to be precisely therefore the rough finder on top of the theodolite or the laser pointer are sufficient
- Make sure the ball prisms of the reference points are looking into the direction of the theodolite
- Click on the Start Button (or F5)
- The theodolite will search for the prism and the first Reference Point will be measured automatically. The coordinates are displayed in the table as shown in Fig. 7.2.3.

Fig. 7.2.1 (Add Reference Point)

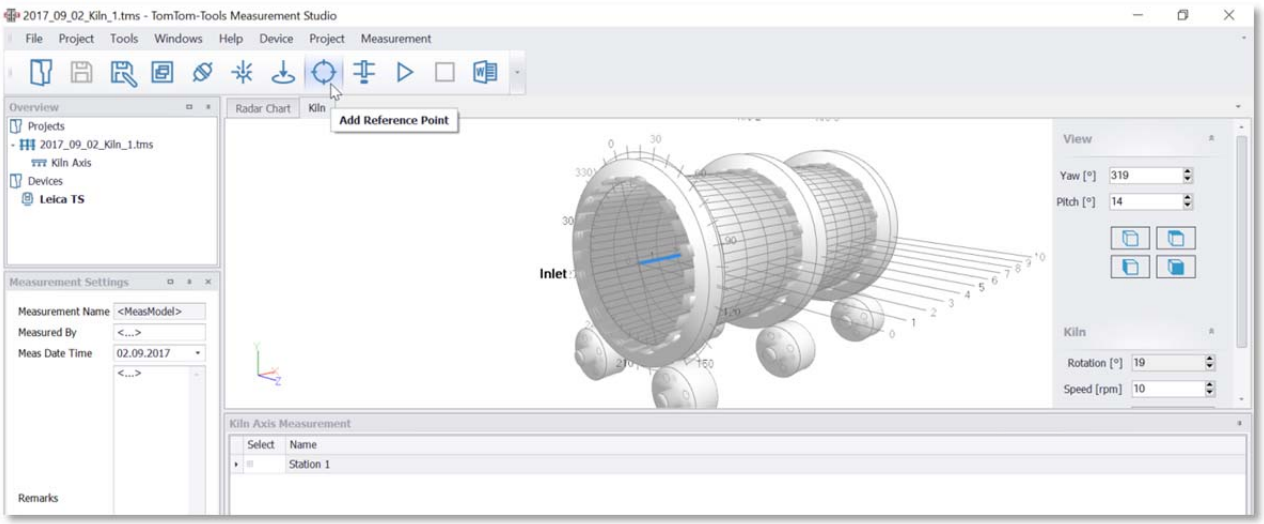


Fig. 7.2.2 (Activate the Laser Pointer)

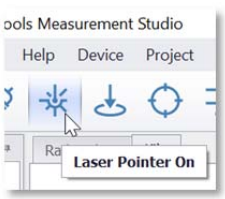
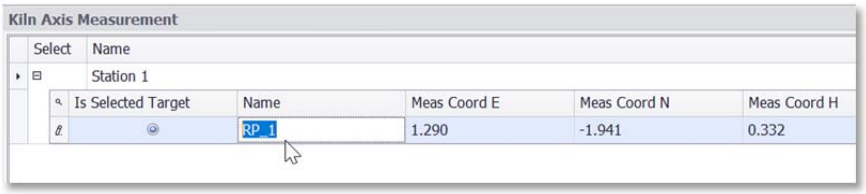
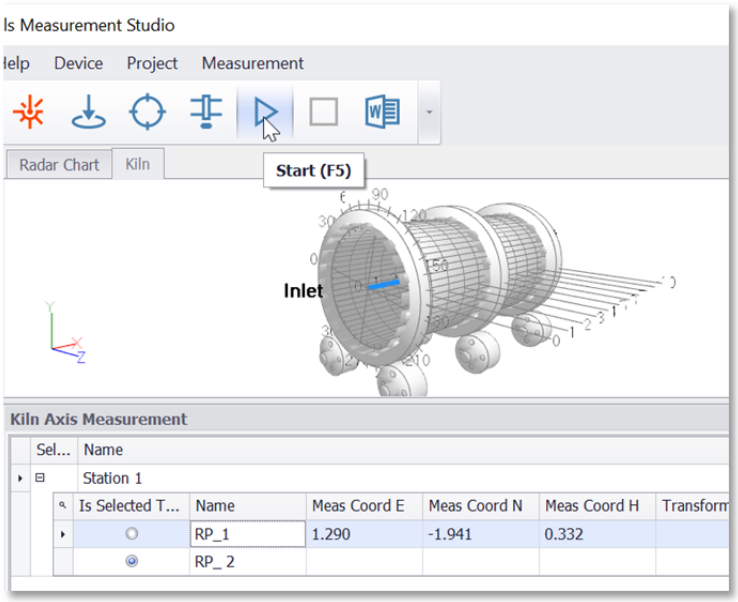


Fig. 7.2.3 (Reference Point 1 is measured)



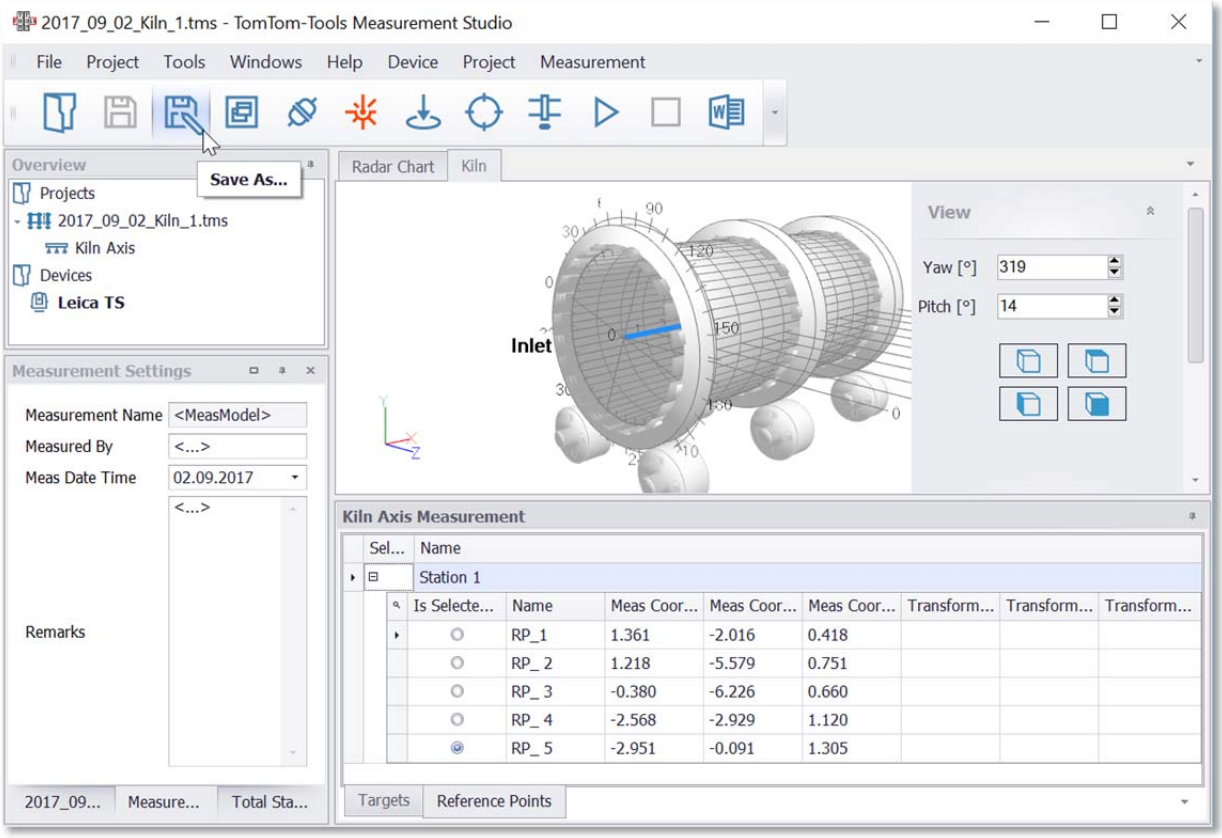
Measure all the Reference Points by repeating the above mentioned sequences.

Fig. 7.2.4 (Start measurement of Reference Point 2)



Tip: Save the file frequently

Fig. 7.2.5 (All Reference Points are measured)

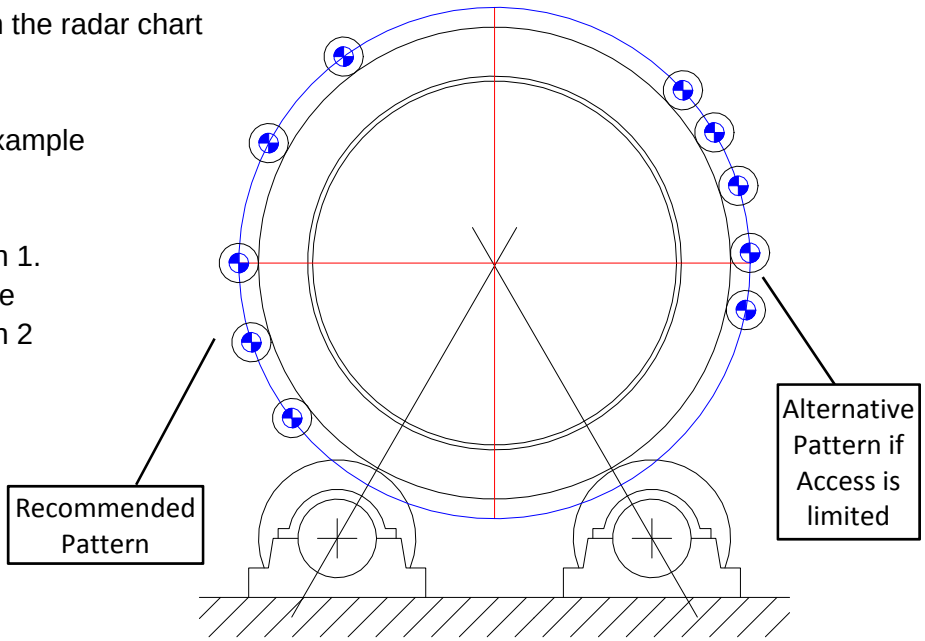


7.3 Measure the points on the tires

To measure the required points from the outer surface of the tire, the Assistant is up at the pier and holding the target axle via telescopic pole onto the tire, as described in chapter 4.3.

It is recommended acquiring about 5 points at each side of the tire.
Sometimes there are obstacles which do not allow to measure as per recommendation.
In that case increase the number of points where the access is given and review the plausibility of the results in the radar chart (described later)

The Fig.7.3.1 shows an example of measured points.
The points on the left side are measured from Station 1.
The points on the right side are measured from Station 2 with restricted access.



- Navigate in the Measurement Studio to the table with the tires by clicking on the Tap “Tires”
- Select the tire which will be measured
- Get the confirmation with the assistant by Bluetooth intercom that he is ready, the Target Axle is running stable on the tire and the prism is directed towards the theodolite.
- Direct the theodolite into the direction of the target axle and start the measurement by pushing the Start Button (or F5)

Fig.7.3.2 (list of tires with the select button)

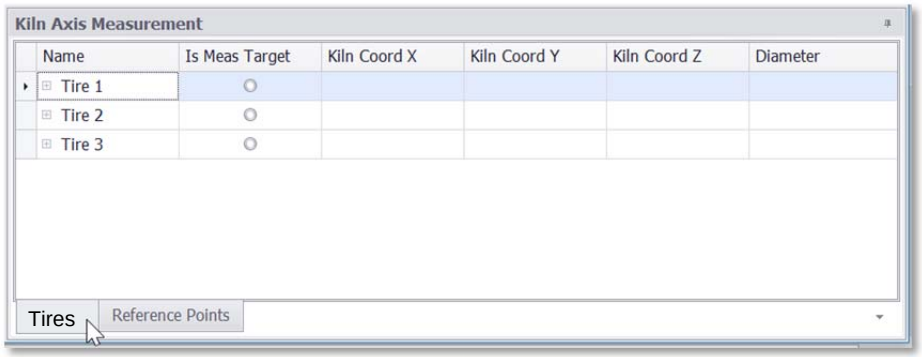
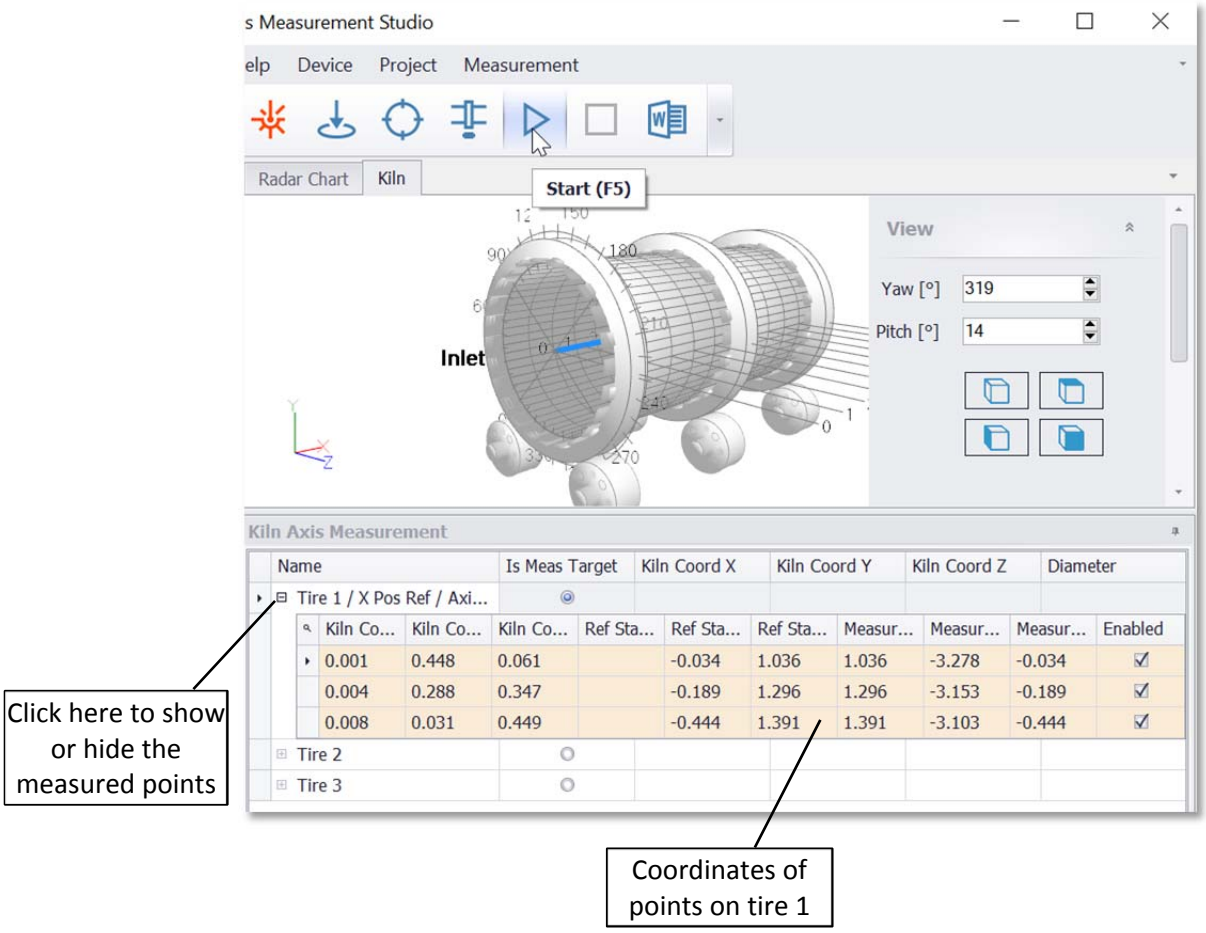


Fig.7.3.3 (coordinates of the first 3 measured points on tire 1)



When tire 1 is measured, select Tire 2 and measure the points at tire 2 the same way. Save the file (preferable under a new name)

Fig.7.3.4 (select Tire 2)

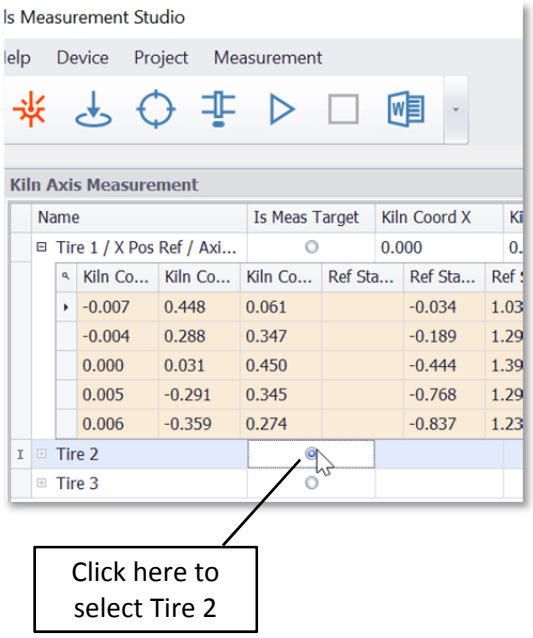


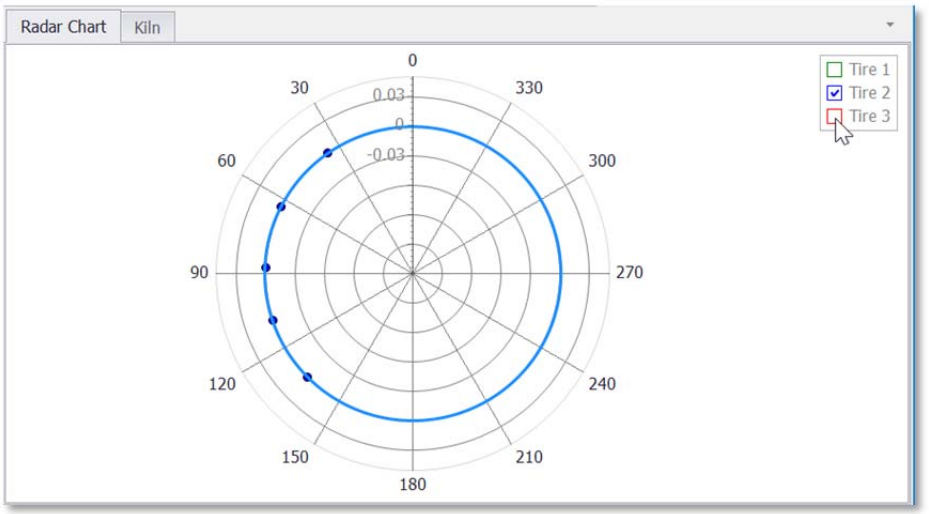
Fig.7.3.5 (First measured point on Tire 2)

When Tire 2 is measured, continue on the remaining tires until all are measured
The list will be filled as shown below:

Fig.7.3.6 (All tires are measured from Station 1)

The points from the tires can be visualized in the Radar Chart where possible errors can be identified.

Fig.7.3.7 (Radar Chart shows measured points on tires)

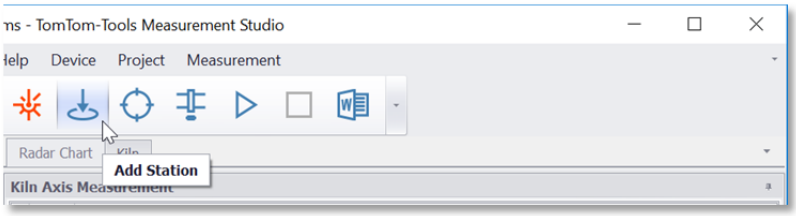


7.4 Relocate the theodolite to Station 2

To reach the required accuracy, the kiln has to be measured from the other side as well.

- Therefore move the theodolite to the second Station and set it up properly
- Adjust the ball prisms of the Reference Points that they are now directed to the theodolite at Station 2
- Add in the Measurement Studio a new Station by clicking on the button “Add Station”

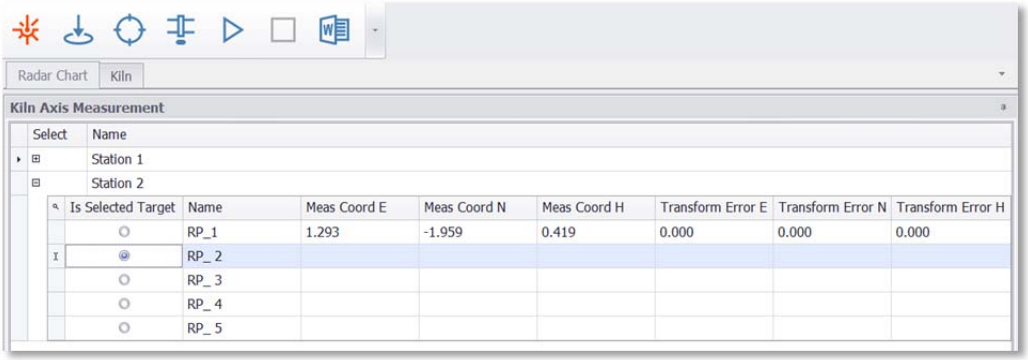
Fig.7.4.1 (How to add a new Station)



7.5 Measure the Reference Points from Station 2

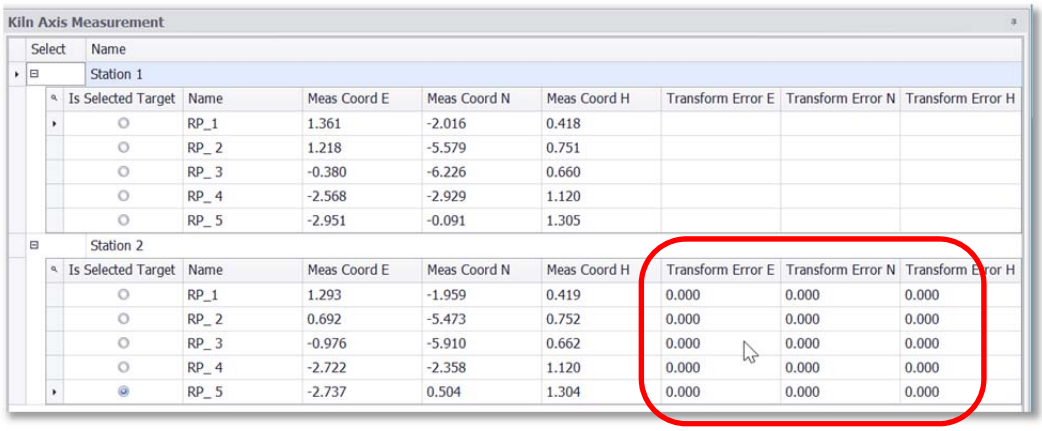
- Select Station 2
- Select the Reference Point to be measured
- Direct the theodolite towards the selected Reference Point and click the “Start Button”

Fig.7.4.2 (Select Station 2 and the Reference Point to be measured)



- Verify the quality of the Reference Points when all are measured from Station 2. The deviation which is shown in the list as Transformation Errors should not be greater that 1mm per point. Otherwise the respective Reference Point should be disregarded for the merger of the coordinate systems.
- Save the file again (preferable with a new name)

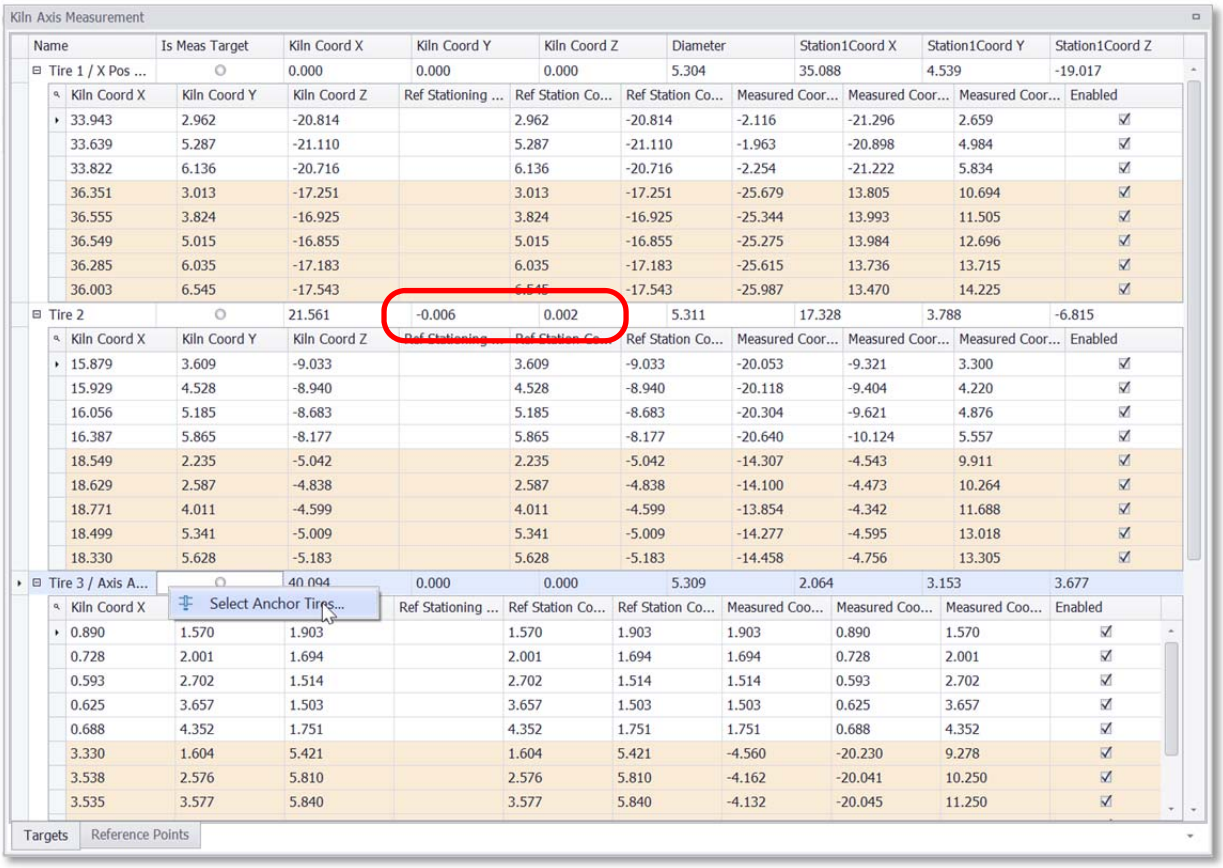
Fig.7.4.3 (Transformation Errors of the Reference Points)



7.6 Measure the tires from Station 2

- Select the tire to be measured in the list
- Measure the points with the help of the target axle as described above
- The values of the tires will appear in the list
- The orange background is indicating the points which are measured from the current Station
- The measurement is finished when all tires are measured from both sides

Fig.7.6.1 (complete table with 3 tires measured from both sides)



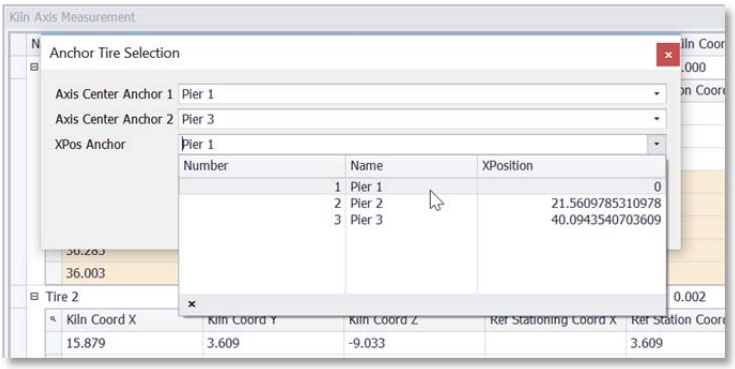
8 Evaluation of the Results

8.1 Selection of the Anchor Points

The Anchor Points are two points of the kiln axis which are considered as fix and will not be changed. In our example we select the tire 1 at kiln inlet and tire 3 at kiln outlet.
Typically the drive of the kiln is near the inlet tire; therefore special attention has to be paid to any corrective moves at the inlet tire because it will affect the gear mesh.

- To select the Anchors click the right mouse button and open the selection window

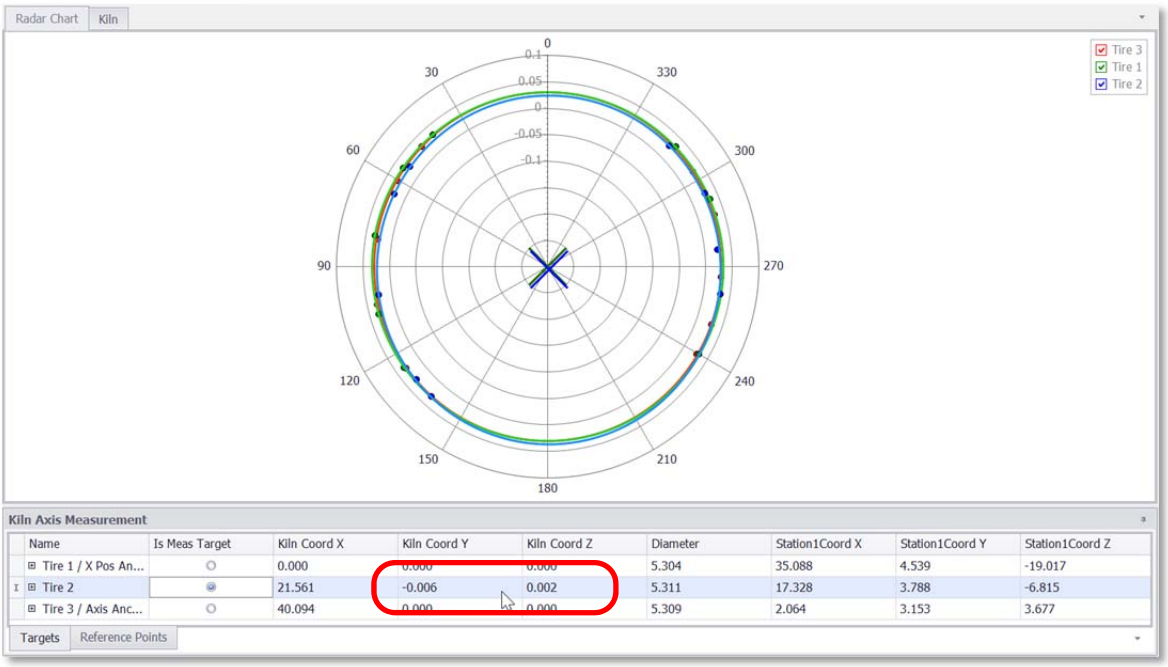
Fig.8.1.1 (Anchor Selection Window)



8.2 Deviation of the Kiln Axis

The deviations of the tire centers from the straight line between the two Anchor Tires are the results of the Kiln Axis Measurement.
Our example kiln has only 3 tires whereof the middle tire is the one which is deviating from the straight line between the selected Anchor Tires 1 and 3.
The deviation values can be found in the table Fig.7.6.1.
To get a better overview, the tire points can be hided.
Open the Radar Chart to verify how precisely the measured points are matching with the fitted circle / ellipse.

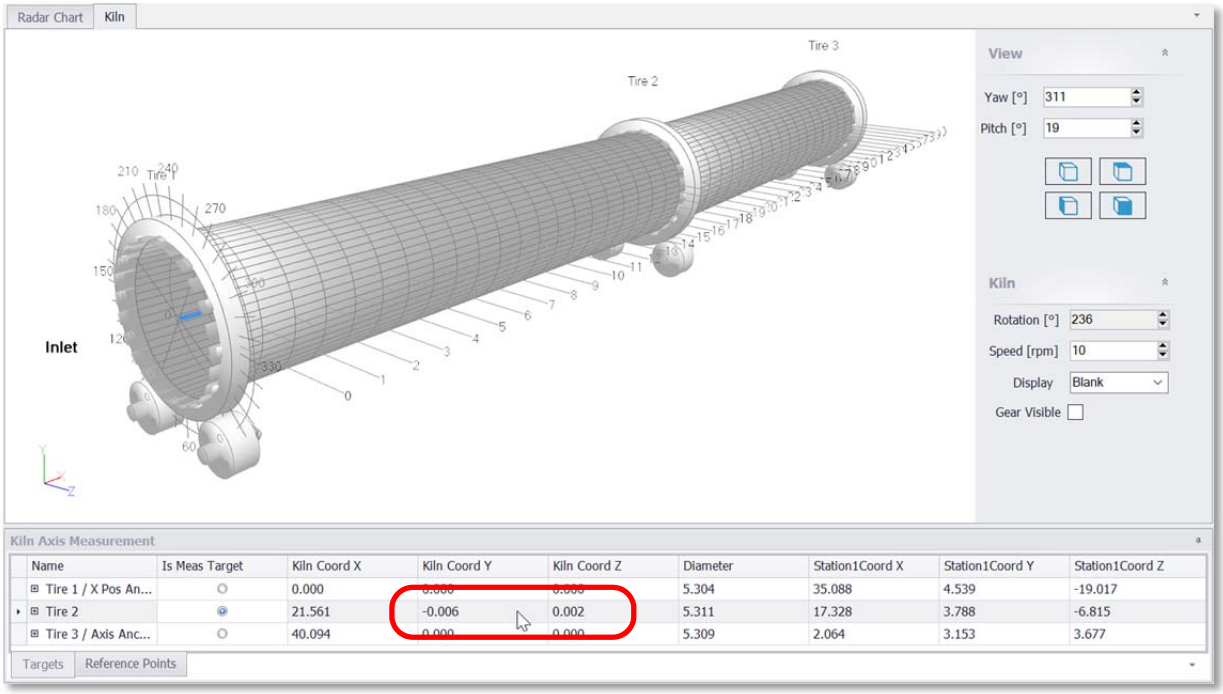
Fig.8.2.1 (Radar Chart of measured tire points, with fitted circles and tire centers)



As shown in the table, the tire 2 is 6mm low and 2mm misaligned towards the right side.
The coordinate system in the lower left corner is indicating the Y and Z directions which are important for the axis alignment.

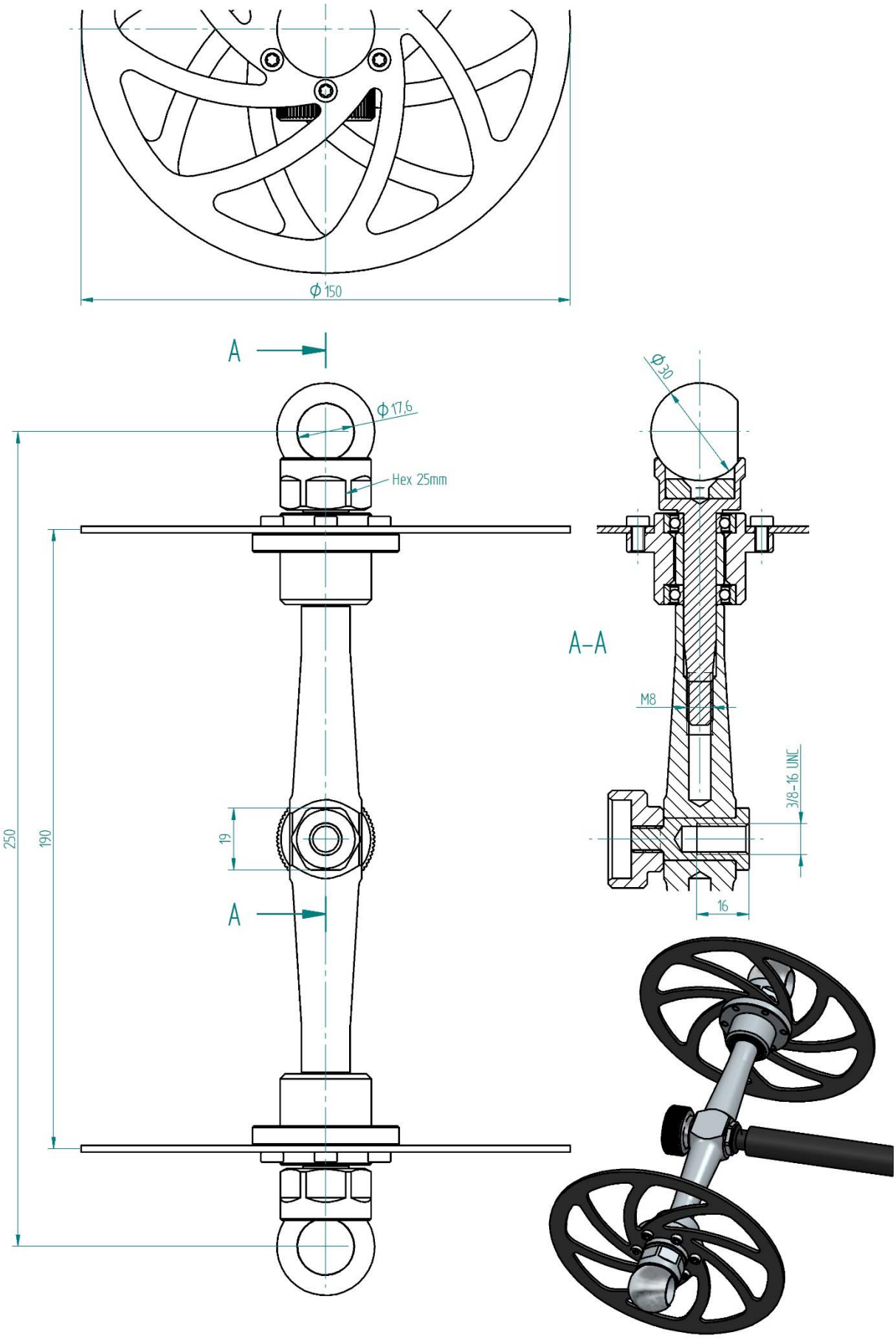
- Positive Y-values are indicating that the tire is too high
- Positive Z-values are indicating that the tire is towards the right side (view from Inlet)

Fig.8.2.2 (3D view of kiln with coordination system)

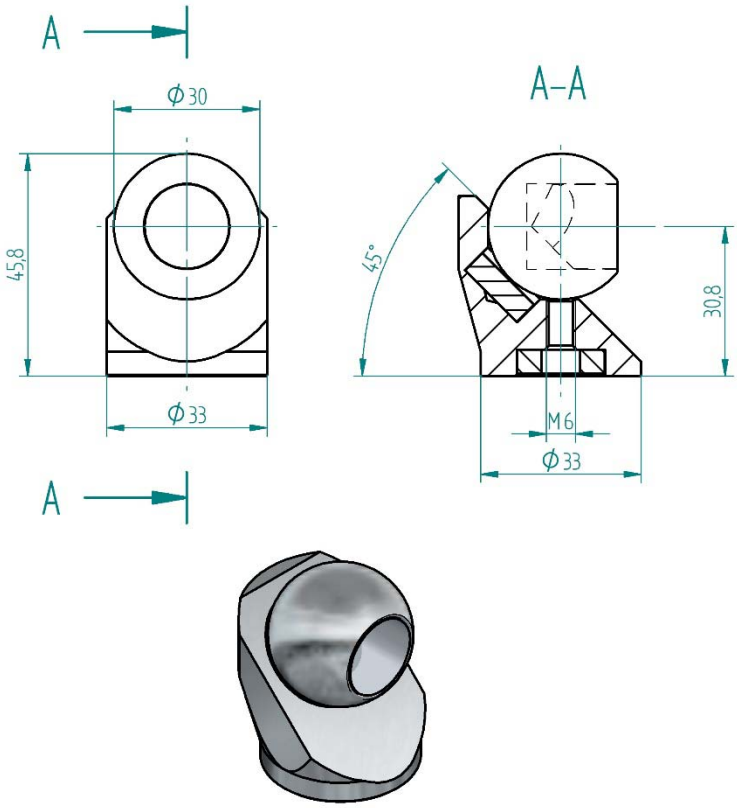


9 Dimensions

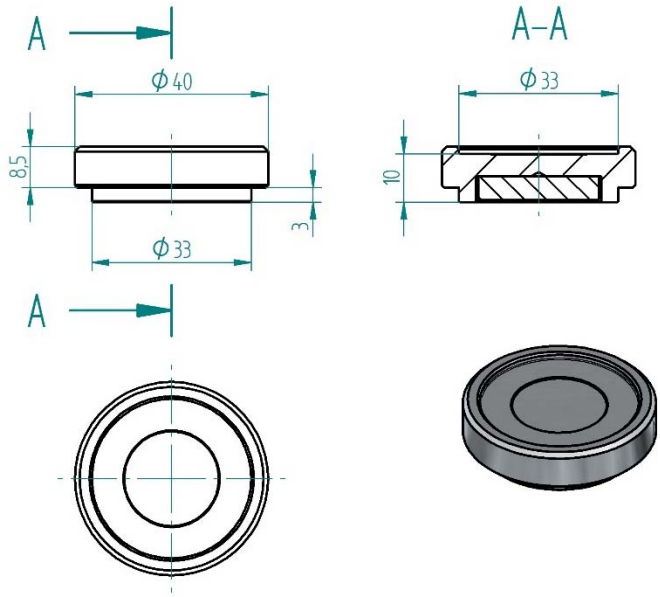
9.1 Target Axle



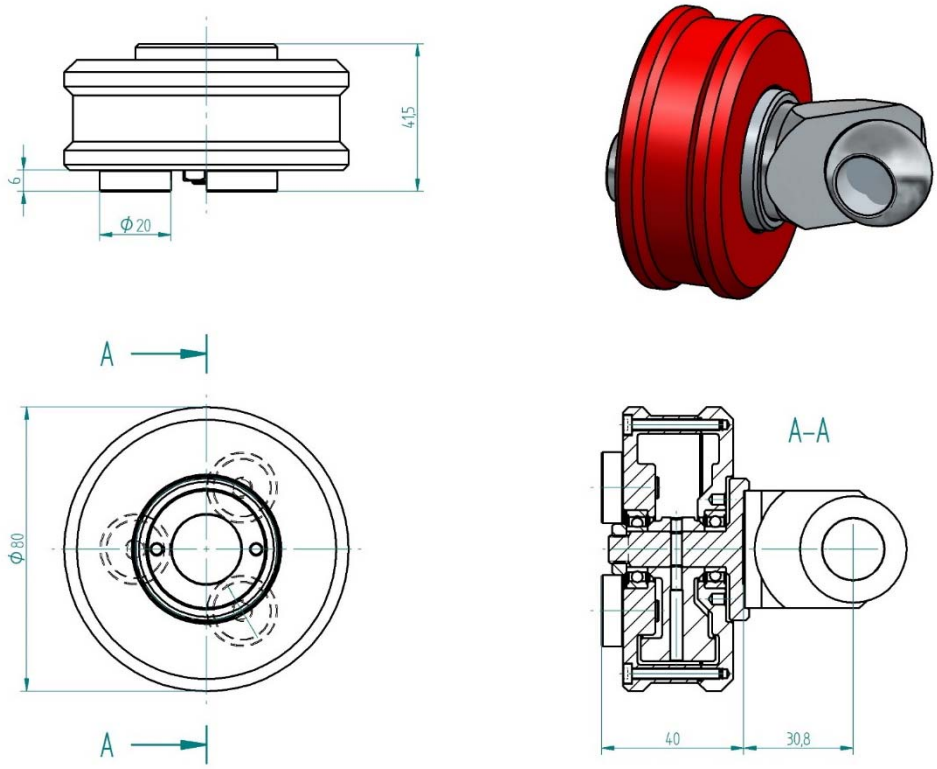
9.2 Prism Holder



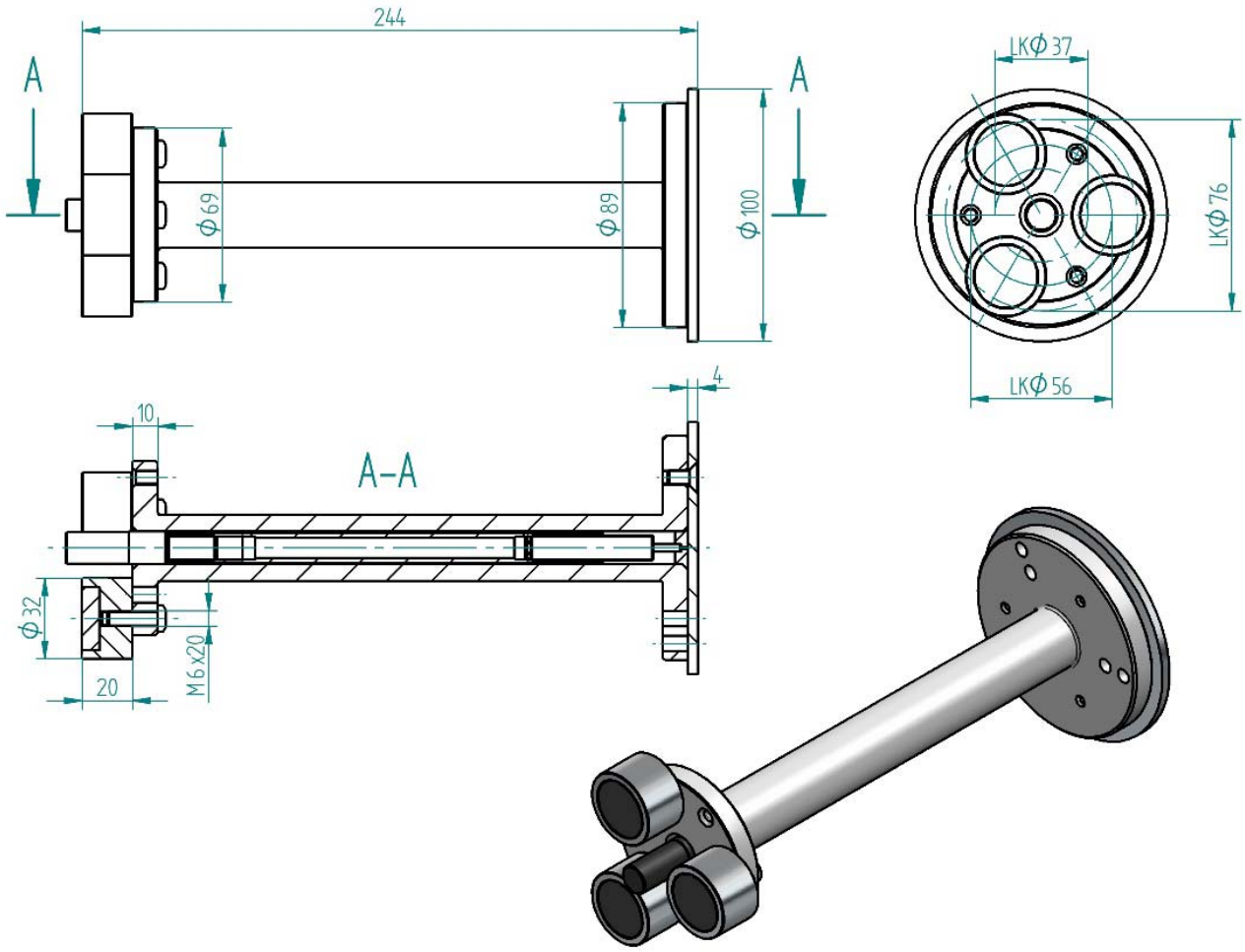
9.3 Base Magnet



9.4 Rotation Adapter



9.5 Shaft Center Adapter



10 List of Components

The following items are included in the Kiln Axis Alignment Kit:

	Item Name	Pieces
1	**Transport case** with foam cushioning Peli 1555 Air, 63 x 40 x 21cm, black	1
2	**Target Axle** with magnetic target holders for target ball diameter 30mm, wheel diameter 150mm	1
3	**Shaft Center Adapter** with heat resistant magnets	2
4	**Allen Key** 4mm for Shaft Center Adapter	1
5	**Rotation Adapter** for target holders	2
6	**Prism Holder** 45° design, height 30.8mm, for ball diameter 30mm	10
7	**Ball Target** with triple prism (stainless steel) ball diameter 30mm, reflector diameter 17.5mm prism constant: -11.3mm (Leica: +23,1mm)	12
8	**Base Magnet** (stainless steel) diameter 33mm, height 10mm, magnetic force ~400N	10
9	**Bluetooth Intercom Headset**	2
10	**Battery pack** for Headset	4
11	**Battery charger** for Headset including USB cable	2
12	**USB power adapter** (100-240 VAC),	1
13	**Long range Bluetooth antenna** for head set	2
14	**Long range USB Bluetooth adapter**, Sena Parani UD100	1
15	**USB flash drive** with software and manual	1
16	**Telescopic Pole** for target axle (made of high strength carbon fiber tubes) lengths: collapsed: 154cm, fully extended: 675cm	1
17	**Protection tube casing** for Telescopic Pole length: 163cm, diameter 6cm	1
18	**Transport bag** for Telescopic Pole (with sufficient space to accommodate the tripod from the theodolite as well)	1
19	**Industrial 10.1” Tablet PC** (Panasonic FZ-G1) with pre-installed software including integrated TomTom-Tools Long Range Bluetooth large battery pack, transport bundle and large corner guards	1
20	**Charger** for Tablet PC (100-240 VAC),	1
21	**Industrial Key Board** for Tablet PC (English)	1