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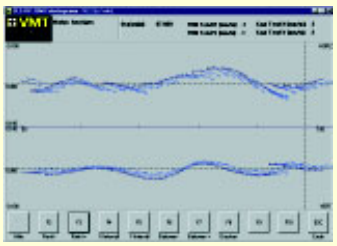
VMT GmbH
Gesellschaft für Vermessungstechnik

SLS-RV Tunnel Guidance System for pipe jacking

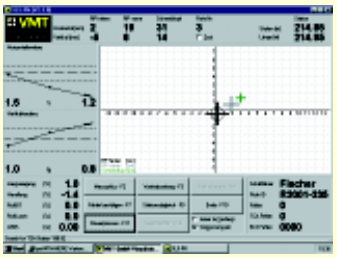
The SLS-RV system enables a laser mounted in the moving pipe to act as a sufficiently stable reference to enable long distance and curved pipejacks to be accomplished

System Features

- Optimal control of machine position
- Deviations from the designed tunnel axis held to a minimum
- Recognition of machine drift right away
- Start steering corrections in time
- Provide a constant display of the position and orientation of the machine
- Enormous time-saving against conventional methods
- Simplify the surveying tasks on complex alignments (vertical and horizontal curves)
- Large amount of information to enable optimal navigation of the TBM
- Robust hardware for tunnelling
- Easy handling and user-friendly software
- Save of all drive related values in system database
- Automatic measurement of pipeline
- Visualization of machine position on external PC (Option)
- World wide modem connection and remote control (Option)

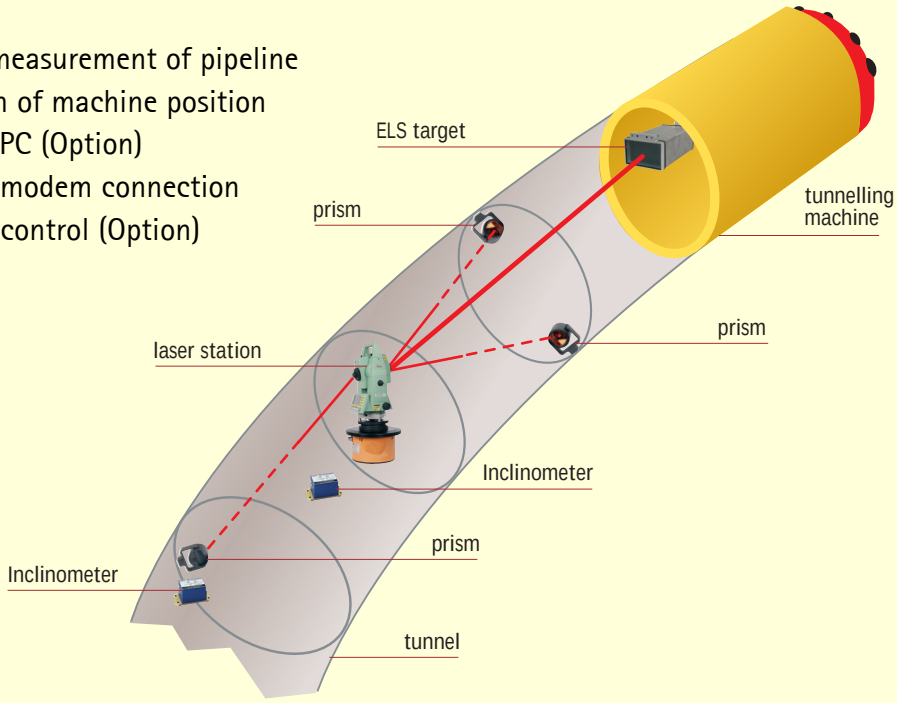


Display of machine Tendencies



Display of TBM Position

Reference Line Editor



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For the guidance of extended distance and curved pipe jacked tunnels

Introduction

Drivers of Tunnel Boring Machines (TBM) need continuous information about how the machine axis is positioned and oriented with respect to its Designed Tunnel Alignment (DTA). At the advance rates of several centimetres per minute that are common now, the driver must have immediate feedback about the consequences of his control actions in order to keep the machine as close as practical to the DTA.

The SLS-RV Guidance System for Pipe Jacking gives users continuously updated information about the spatial position and orientation of the TBM. Thus, through properly controlled steering actions, the TBM can be kept within a narrow tolerance circle around the DTA.

The main reference of the SLS-RV system is supplied by a visible laser beam projected from a Laser theodolite which is initially mounted in the shaft in an area that is relatively stable. This laser beam will typically project for a distance of between 100 – 200 m depending on the power of the laser, the atmospheric conditions in the tunnel and the amount of refraction that the laser beam is subjected to. The laser beam passes through the clear space in the machine and back-up equipment (laser window) to the target mounted on the forward part of the machine. The useable laser to target distance is also dependent on the size of the laser window and the curvature of the tunnel.

When the laser beam strikes the ELS Target the precise centre of the beam relative to the centre of the target is measured. The horizontal angle at which the laser beam strikes the ELS Target is also determined. Installed within the ELS Target is a dual axis inclinometer transducer to monitor the pitch and roll of the ELS Target. Attached to the front of the ELS Target is a retro-reflective prism. The distance between the laser reference position and the ELS Target is measured by the EDM within the theodolite.

Therefore from the knowledge of the absolute position of the laser reference, the absolute position and orientation of the ELS Target and hence the position and orientation of the TBM can be established.

This information is combined with the desired alignment of the drive to give the machine operator a simple indication of where the machine is, relative to where it should be. The SLS – RV system not only provides a way of measuring the precise position of the TBM at any time – especially during the course of an advance. It presents these results to the operator in a clear, concise manner allowing him to take the necessary corrective measures. Apart from an enormous time saving, it also provides a uniform, smooth tunnel advance closely following the DTA.

In pipe jacking, it is essential to avoid sudden changes in direction and in point loading the outer edges of the pipe, as damage in the area of the seal cannot be tolerated if the water tightness of the drive is to be maintained. Changes in direction cause more resistance to the movement of the machine and all the following pipes, requiring greater hydraulic forces to overcome this increased resistance

In the case of pipe-jacking however, there is one fundamental difference in the supply of the guidance information to the machine operator. This is the positioning of the laser reference in a stable position once the machine has advanced to a point where the laser beam can no longer activate the ELS Target from the start shaft. At this point the laser reference must be positioned within the moving pipe. As soon as the laser reference is no longer in a stable position, it is necessary to accommodate this fact.

The following assumptions are made and additional information is recorded.

The basic assumption that is made in pipe jacking is "the pipe will follow the hole made by the machine". This is not always valid and adjustments are sometimes necessary in the subsequent calculations. However it is a good basis on which to commence this description.

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Operating Principles

The position of the machine is recorded throughout the drive at frequent intervals. When it is necessary to install the laser in one of the moving pipes, the position of the centre of that pipe will be known from the records, i.e. the position of the machine at the same chainage. However the orientation of the pipe will almost certainly be different from that of the machine.

If the laser reference is not in the precise centre of the pipe, any roll on that pipe will cause a positional change for the laser reference. The roll of the pipe is therefore measured by an inclinometer and the roll-corrected value for the laser reference position can be calculated.

In order to maintain the laser orientation at a constant elevation and thus eliminate the effect of any pitching of the pipe from the calculations, the laser theodolite is mounted on a self-levelling platform. This overcomes any movement of the pipe due to both pitching and rolling, and maintains the theodolite within its compensator setting range.

The azimuth of the laser reference is determined with respect to a backsight target. When this backsight target is mounted in a stable position (i.e. the start shaft) the determination of the azimuth is straightforward. However, as soon a it becomes necessary to mount the backsight target into a moving pipe it is also necessary to use the recorded values of the machine position at a given chainage to determine the position of the pipe containing the backsight target at the same chainage. It is also necessary to monitor the roll of the pipe with an inclinometer to give a roll-corrected position for the backsight target.

Using these values to precisely determine the instantaneous position and orientation of the laser reference, it is possible once again to show the operator the position of the tunnelling machine in relation to the desired alignment.

In practice however, the accuracy achieved by following these basic assumptions together with external effects such as irregularities in pipe manufacture, extreme overcutting or a tight radius curved alignment, is not sufficient to achieve the required tolerances specified for the drive. It is therefore necessary to carry out periodic control surveys to replace the recorded machine position data with measured survey data. These control surveys should be carried out at intervals of not greater than every 100m.

It has also been found that the dynamic behaviour of the pipes due to variable ground conditions and the varying hydraulic forces applied during the mining operation show significant differences to the measurements taken during static control surveys. It has therefore proved necessary to update the recorded data on the course followed by the pipes between control surveys.

The advent of motorised laser theodolites has enabled a more frequent, automatic measurement cycle to be undertaken between control surveys.

This measurement cycle not only gives updates on the position and orientation of the laser but also of the position of a reference pipe a short distance ahead of the laser. The position of this reference pipe is recorded and stored as the reference line which the system uses as its working record of the pipe line's position. This reference line can be modified (smoothed) by the user to take into account the anomalies that occur during this precise measurement cycle to produce a more realistic reference for guiding the drive. The complete system is installed in the front region of the pipeline, where refraction typically does not cause significant problems.

A VMT concept Laser Theodolite

System Components

All components have been extensively tested on running TBM's and have been thoroughly tried and tested in the harsh environment of numerous pipe jacking projects. They are briefly described below

Active ELS (electronic laser system)

The Target receives the laser beam. It determines the point of incidence in a horizontal and vertical direction. In addition, the roll and pitch are measured by integrated inclinometers. The yaw angle is ascertained from the angle of incidence of the laser on the ELS. The ELS is fixed to the TBM body, its position having been determined when it was installed. A prism for electronic length measurement is mounted directly below the ELS.

Controller Unit

At laser station supplies power for theodolite, AD-12, inclinometer, backsight target inclinometer and length measurement system. It multiplexes data from inclinometers, length measurement system and laser theodolite and provides data communication with the control PC.

Laser Theodolite

The VMT concept Motorized servo Laser Theodolite, (Leica TCA1103 / ATR / GUS74) complete with PC control and automatic target recognition (ATR2), allowing precise targeting of the prism, is a precision

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The Guidance Sytem
is operated by Touchscreen

geodetic measuring instrument for measuring (horizontal and vertical) angles and distances and projecting a visible laser reference beam.

Automatic tribrach AD-12

Automatic tribrach for self-levelling of the laser station within a ±10 gon range. Levelling is carried out continually with an accuracy of ± 1 mgon.

Inclinometer on laser station

Inclinometer fixed on bracket of total station, determines the current roll angle of the station and transmits this data to the control PC via the Controller Unit.

SLS-RV Industrial PC

Computer station at operator position where all the data determined is automatically combined and evaluated. The information is displayed on the monitor in numerical and graphical form. The TBM position can thus be seen at a glance. Used for evaluating and saving all geometrically relevant measured data.

Backsight target.

Standard, round retro-reflective prism as rear backsight target. Used in automatic mode as direction reference. Recognised and measured by the ATR2 target recognition unit.

Inclinometer at backsight target

Fixed inclinometer on the bracket of the backsight target, determines the current roll of the station and transmits the data to the Controller Unit.

Left and Right reference-point prisms in front of the laser station

Two Standard round retro-reflective prisms known as reference targets are located in a reference pipe approx. 12 m in front of the laser station. Their purpose is to allow measurement of the actual position of the advancing tunnel as directly in front of the laser station as possible, so that any variance between the pipes measured position and that of the theoretical position of the TBM at the same station can be determined.

Length measurement system

Wheel mechanism mounted in start shaft on pipeline. When the pipeline is inserted by means of the main jack system, the impulses generated by the measurement wheel are transmitted for computation.

Set of Interconnecting Cables

All cables to connect the individual components of the system.

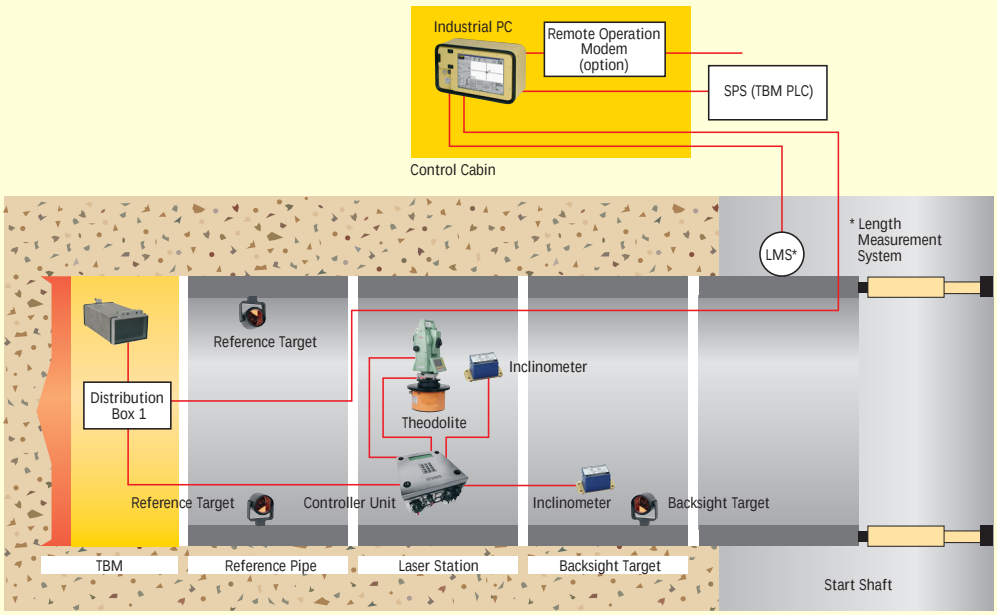
TBM Position Software module

It forms the heart of SLS-RV system. It receives data from all the above-mentioned components. The TBM position is calculated in the Tunnel Advance Software. Display is graphical and numerical. Ease of operation is ensured by the Windows user interface.

Reference Line editor

A graphical module allows the reference point axis generated to be checked and edited when necessary. It allows smoothing, removing of erroneous values, and allows a new reference point axis to be generated following a control survey.

Hardware Configuration



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