Treatment room with patient table and retracted verification system on the ceiling

Beckhoff Embedded PC and TwinCAT CNC control complex movement mechanics for cancer treatment system

Patient positioning with high accuracy of ± 0.3 mm

Local cancer treatment methods include X-ray treatment with photons and irradiation with protons. In both techniques the direction of the beam can be determined accurately. With proton irradiation, the irradiation range can be controlled more precisely, thereby minimizing the harm to the surrounding healthy body tissue. During this procedure the positioning of the patient plays a key role in the treatment.

A synchrotron accelerates the protons to 60 % of the speed of light (180,000 km/s, equivalent to 250 MeV of kinetic energy), which can penetrate the body up to 38 cm deep. If the irradiation target, i.e. the tumor, is closer to the surface, the protons have to be slowed down so that they stop right inside the tumor, where they deposit their maximum dose and activate their cancer-killing effect. Targeted bundling of the proton energy reduces the total radiation dose in the healthy tissue to a third or less (depending on the respective tumor geometry) compared with X-ray treatment with the same tumor dose, i.e. in the area before the tumor the dose is low, in the area after the tumor the patient remains radiation-free. This requires exact positioning of the patient and equipment with high repeat accuracy.

Embedded PC as controller, Control Panel as interface unit

The National Centre for Oncological Hadron Therapy (CNAO) in Pavia, Italy, commissioned the Swiss company Schär Engineering AG to develop a movable patient table with six degrees of freedom. This enables the patient to be positioned in the fixed-beam treatment rooms with an accuracy of ± 0.3 mm.

The project was realized in cooperation between Schär AG, who was responsible for the mechanical design and implementation, and Odevis Automation AG, who developed the electrical concept and the control software.

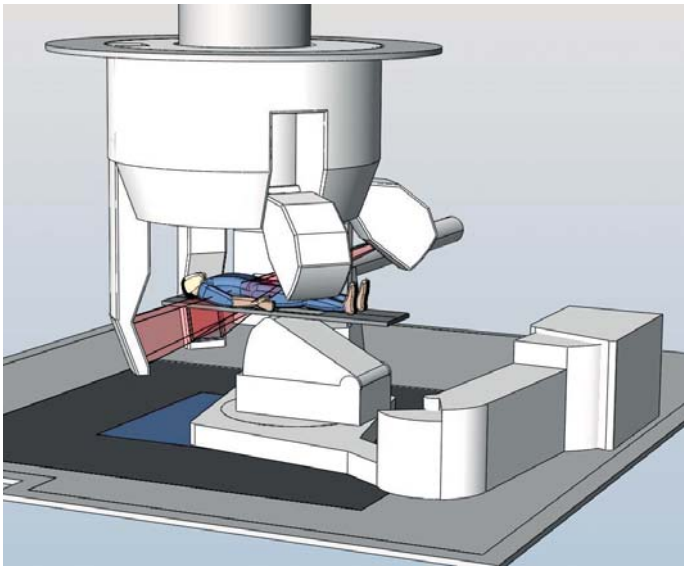
A Beckhoff CX1030 Embedded PC with TwinCAT CNC functionality was used to realize the complex control tasks and the transformation of the mechanics into movements of the individual axes. "One of the reasons for bringing in Beckhoff was the complex transformation of the mechanical motion to the corresponding axes. The project started in 2007, and the first patient was treated successfully in October 2011" said Thomas Niederhammer from Odevis Automation. The control program was written in the programming language ST (Structured Text), one of several available IEC 6131-3 languages.

A Beckhoff CP7911 Control Panel with DVI/USB interface and customized keypad serves as user interface. The HMI application software, written in C# by Odevis, uses the TwinCAT ADS communication interface as a data link for control purposes. The connection to the Panel in the treatment room with a DVI/USB interface and a cable length of more than 20 m was achieved using a CU8810 DVI splitter from Beckhoff. TwinCAT ADS was also used to link a second user interface in the local control room with the CX1030.

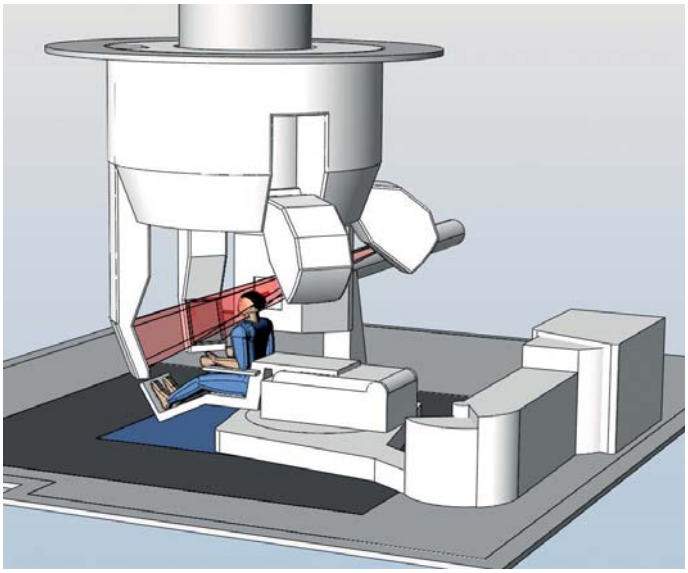
The DIN rail-mountable CX controller enables direct connection of all signals via EtherCAT Terminals. EtherCAT is also used for the communication with the drives. In addition to various digital and analog I/O modules, EL6021 EtherCAT Terminals are used for serial communication with a barcode reader and EL500x SSI encoders are used for measuring the axis positions, as are terminals for weight measuring.

TwinCAT CNC: transformation with simulation

Beckhoff developed the complex kinematic forward and backward transformations for the positioning according to the client's specifications and made them available as CNC transformations. This enables the position and orientation of a defined point on the patient table to be transferred to the ISO beam center of the room coordinate system in the treatment room through Cartesian target point specification. In addition, a mechanics simulation model was developed for internal software tests.



X-ray verification with table



X-ray verification with chair

Exact positioning of the patient relative to the treatment beam

For proton therapy, precise positioning of the patient is essential and is ensured by various means: a table that can be customized for individual patients, high-precision positioning of the patient table in the ISO center of the treatment beam, and X-ray-aided position control. The robust design of the patient table enables patients weighing up to 200 kg (440 lbs) to be treated while reclining on a table or sitting on a chair. The position of the treatment area must be maintained with high precision. The maximum permitted deviation relative to the room coordinates is ± 0.3 mm.

In order to achieve this, the patient table/chair is calibrated precisely. The mechanical position is corrected such that it is absolutely identical to the position in the room coordinate system. The spring deflections arising from the position of the patient on the table or the chair and their weight also have to be corrected via the software.

The extendable X-ray verification system also operates within a precision window of less than ± 0.1 mm. Additional visual position monitoring is facilitated by a system with three cameras that check the patient position via markers.

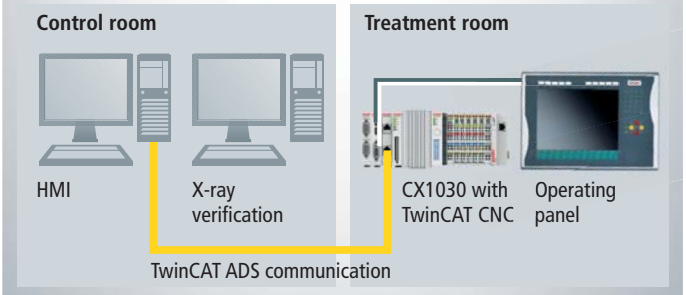
Treatment procedure with remote operator interface

Before the radiation treatment commences any deviations of the tumor relative to the CT are detected with the aid of a verification system and compensated via the patient table. To this end, the X-ray panels must be extended via the operating panel. Once the alignment is approved, the treatment is carried out and a correction vector for the tumor is calculated in an external software platform. Any deviation is then compensated via the patient table. Part of the treatment is carried out from a control room located opposite the treatment room. The medical staff is in contact with the patient at all times via cameras and radio. Operation in the control room takes place via the HMI on a standard PC, which communicates with the controller via ADS and a control box with two-hand operation which mimics the two-hand operation on the operating panel in the treatment room.

Embedded PC control system with numerous monitoring functions

In addition to a Pilz safety controller, the Beckhoff Embedded PC control system features a range of monitoring functions. All shaft encoders at the individual axes are implemented with redundancy and are monitored for different functions. Collision monitoring takes place via digital signal transducers and a programmed 3D object and room monitoring system ensures that the system is safe.

Beckhoff CP7911 Control Panel with emergency stop button and customized keypad



Schematic system configuration with the control room and treatment room

Further Information:

www.odevis.com

www.cnao.it

www.schaer-engineering.ch