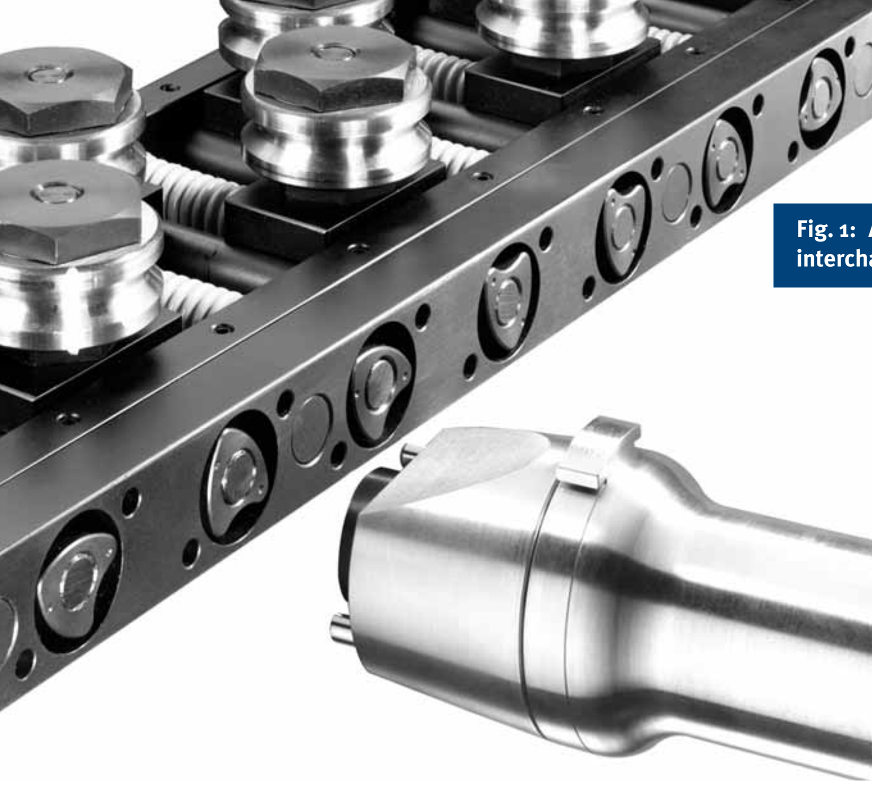

Fig. 1: Automatic actuator with interchangeable head system

Innovative straightening technology

The innovative straightening technology of the intelligent automatic actuator closes the gap between familiar systems based on conventional and semi-automated solutions. Used for the individual positioning of straightening rollers, it consists of an actuator, sensor system, hardware and software. This solution for the defined and reproducible positioning of rollers on straightening units is simple in design and convinces with a good price/performance ratio.

Fig. 2: Semi-automated 2-level straightening system from Witels-Albert

The realisation of the straightening technology with the intelligent automatic actuator CT 1-7 with interchangeable head system ARA 1-7 for the positioning of rollers of a straightening unit RA 7-7 is shown in fig. **1**.

Product quality is a fundamental factor in a company's efficiency. To achieve and maintain a high standard of quality a company has to make continuous efforts and on-going improvements. On international as well as national markets there is a general trend to higher product quality expectations, as anchored in the European and international standards for quality management systems.

For the wire producing and processing industry, the straightening process is turning more and more into an instrument with a decisive impact on quality. True to the motto, "The means is the ends", companies are calling not only for conventional straightening equipment but increasingly for semi-automated systems as well. Instead of simple tools such as screw clamps to adjust the straightening rollers, semi-automated systems use a combination of modern drive and automation technology in conjunction with hardware and software[1].

Fig. **2** shows, by way of example, a 2-level straightening system from Witels-Albert in which one adjustable roller in each straightening unit is equipped with an actuator and a sensor system. It is basically possible, of course, to assign these elements to all the adjustable rollers of a straightening system, in which case the following features become possible:

- Automatic setting of the process material's specific zero line with due consideration for its cross-sectional geometry
- High-precision positioning of the straightening rollers starting from the zero line
- Reproducibility of roller positions
- Minimization of the risk of operating errors
- Minimum deployment of manpower and process material in achieving the required quality of product
- Use of a data base for high flexibility and short set-up times when changing the process material
- Implementation of high adjustment forces
- Operation from any position

These advantages over conventional straightening technology are only to be had at a higher price, of course, which is still a deterrent for small companies in the wire industry. Witels-Albert decided to resolve this conflict by developing a new product in which the

[1] Schneidereit, H.; Schilling, M.: Straightening unit with electronic position control. WIRE 47 (1997) 2, pp. 34–37

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positive features of semi-automated technology are merged with the price benefits of conventional technology. This innovative straightening technology is positioned accordingly between conventional systems on the one hand and semi-automated systems on the other (fig. 3).

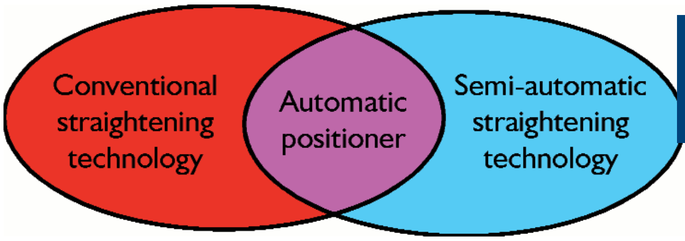


Fig. 3: Positioning of the innovative straightening technology

System description

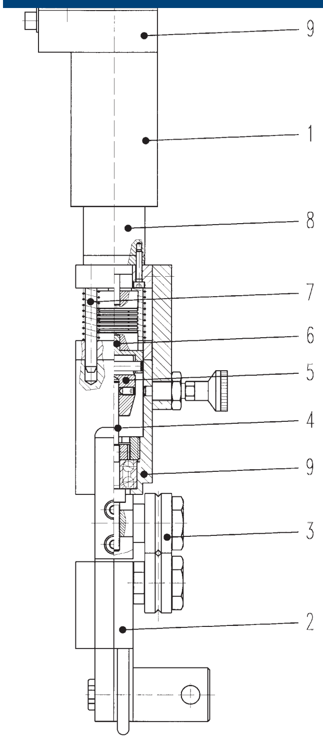
At the heart of the new innovative straightening technology is an automatic actuator specially designed to position the adjustable rollers in straightening units. The revolutionary aspect is that any number of straightening rollers can be adjusted in defined and reproducible manner with a single tool. Flexible tool deployment – as the basic idea behind conventional straightening systems – is thus augmented by the defined and reproducible positioning of straightening rollers – the principle behind semi-automated systems. The component outlay for a comparable semi-automated solution is reduced considerably by using just a single automatic actuator for numerous straightening rollers. With only one actuator and sensor system needed to position several straightening rollers, costs are far lower. The greatest efficiency is achieved if one automatic actuator can be used to adjust the straightening rollers of several straightening systems employed at different locations, e.g. on different processing machines. The functionality of this roller adjustment method and the flexibility of being able to use it for different systems with an intelligent tool open up a new technical dimension for wire straightening.

Fig. **4** and **5** present the innovative straightening technology in schematic form for a simple case of application. Fig. **4** is a front view in the uncoupled state and Fig. **5** a side view in the coupled state of the mechanical sub-system of an automatic actuator 1 together with a straightening unit 2 whose adjustable rollers are to be positioned. The peripheral element sub-system is given in symbolic form.

The mechanical sub-system

The straightening unit 2 is fixed in relation to the automatic actuator 1. The position of the automatic actuator can be varied so that all the rollers 3 of the straightening unit or the rollers of further units and systems can be changed in position one after the other (fig. **4**). Each roller is assigned an adjusting mechanism 4 equipped with a form-fit coupling element 5. A coupling connection for transmission of the torque needed to position the rollers can be effected by inverse-complementary design of the coupling element 6 on the mechanical sub-system of the auto-

Fig. 4: Mechanical sub-system of the automatic actuator and the straightening unit in the uncoupled state, front view



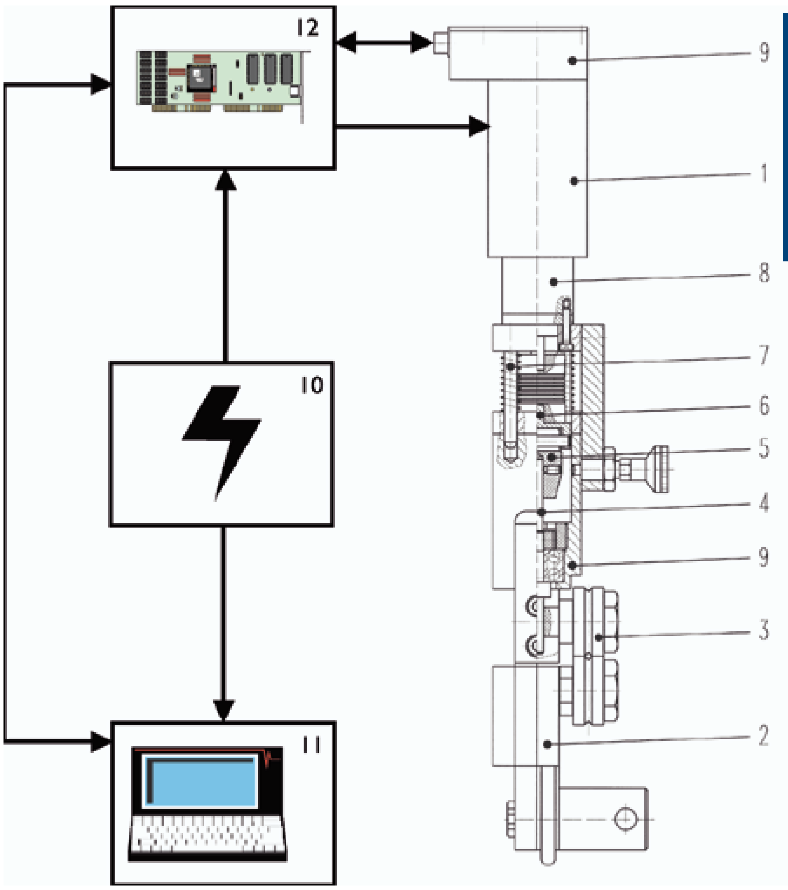


Fig. 5: Peripheral element sub-system and the mechanical sub-system in the coupled state, side view

Set of rollers to be adjusted in the example

System	Roller index	Calibration offset [mm]	Angle of rotation offset [°]	Outer roller diameter [mm]	Groove width [mm]	Groove angle [°]	Spindle pitch [mm]	Direction of rotation
ER 7-3	2	-3,553	10,5	31	3,2	90	0,75	0
ER 7-3	4	-3.559	-20,5	31	3,2	90	0,75	0
ER 7-3	6	-3,550	30,0	31	3,2	90	0,75	0

matic actuator, provided the coupling elements 5 and 6 have a coincidental angle of rotation essential for such a form-fit connection. Thereby the number of revolutions of the movable limb does not have to be identical with the stationary limb of the respective angle. Defined and reproducible roller positioning requires not only a coupling connection between the elements 5 and 6 but also a connection between the mechanical sub-system of the automatic actuator and the straightening unit (fig. 5) via the coupling mechanism 7. Like the coupling connection, this connection is of form-fit design to provide the counter-bearing necessary for torque transmission and to fix the automatic actuator temporarily to the straightening unit. The torque for a positioning operation is provided by the actuator 8, which has a positioning sensor 9 at its second shaft end.

The peripheral element sub-system

Adjustment of a roller is performed by interaction with the system of peripheral devices (fig. 5) consisting of a power supply unit 10, a PC 11 and a basic automation unit 12. The power supply unit feeds both the PC and the basic automation unit with the necessary voltage. Data is exchanged between the PC and the basic automation unit in both directions via a serial port (RS 232). A user interface for operating the automatic actuator is provided by the PC and the application software installed on it.

The actual position of the actuator 8, which in the coupled state correlates with the position of the respective roller, is scanned by the position sensor and can be identified via the basic automation unit with integrated output module. A 16 bit microcontroller not only performs all control operations but also calculates the path needed for a defined movement sequence using the following parameters: start position, target position, acceleration, speed and delay. The operating system enables functions such as initialization by current index and communication via the serial interface.

Optional features

Additional specific elements are possible as alternatives to the example described above. First to mention is an interchangeable head system that enables an automatic actuator to be used for different types of straightening units such as the units PS, PR, RA, RB and ER from Witels-Albert, whereby the size of unit can also vary. Using a simple mechanism it is possible to fit the automatic actuator with the right interchangeable head to suit the specific type and size of straightening unit.

If required, the peripheral sub-system can be extended to include a system interface, a documentation unit, an identification system and an operator terminal. A system interface is recommendable if the user wants information to be exchanged with higher-level automation units such as a machine control system. A documentation unit enables the user to record the configuration of the automatic actuator as well as the data related to specific straightening processes such as the cross-sectional dimensions of the process material and the settings of the adjustable rollers. An identification system relieves the user of having to preselect which roller is to be adjusted. Roller identification is then performed automatically prior to coupling with the straightening unit and with the adjusting mechanism of the straightening rol-

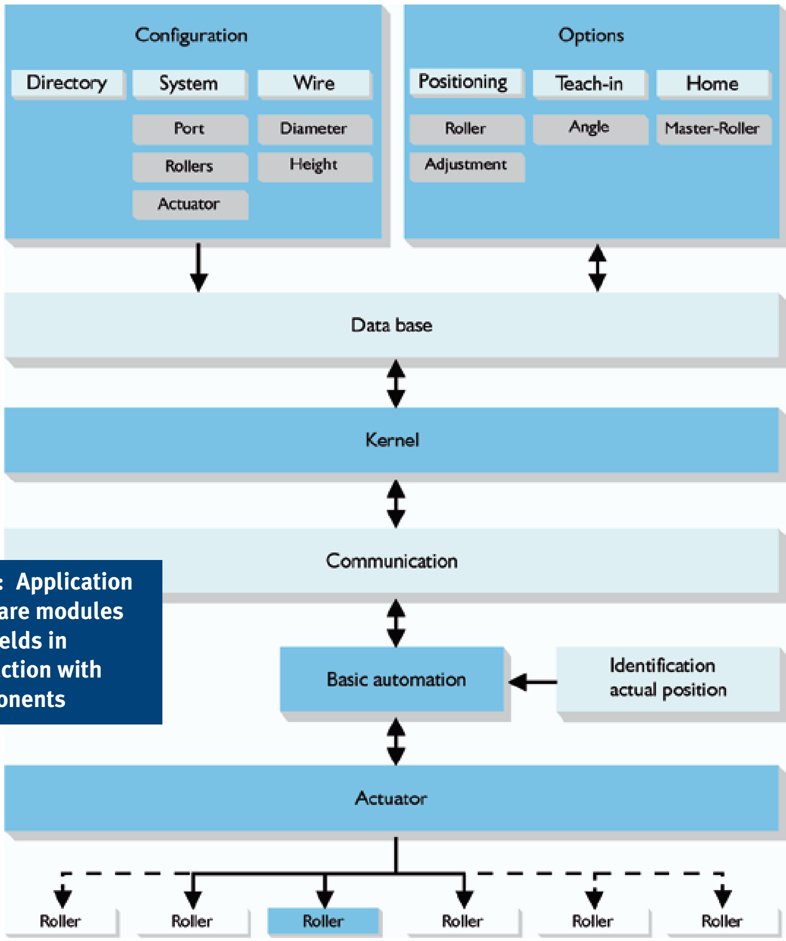


Fig. 6: Application software modules and fields in interaction with components

ler. For this purpose, each straightening roller has a data carrier with a specific roller index, which is scanned by a contactless reading unit linked to an electronic evaluator in the form of a PC card. As an alternative to the user interface provided by the PC and application software, an operator terminal can be used to set up a second terminal. In this case the terminal is positioned between the mechanical sub-system of the automatic actuator and the PC in the direct vicinity of the straightening process.

Mode of operation

The mode of operation will be explained with fig. **5** and with reference to fig. **6**, which shows how the modules and fields of the application software interact with components of the mechanical and peripheral subsystems.

All the adjustable rollers of a straightening unit (fig. **5**) or of one or several straightening systems are assigned to an operating set. One roller of this set is referred to as the master roller and the remaining rollers as the slave rollers. Upon delivery, the position of the slave rollers is defined by a mechanical limit. This limit is both a design-dependent extreme position of the actuator and a travel stop. For each roller and its related adjusting mechanism the user has to configure various parameters, e.g. the roller index, calibration offset, angle of rotation index, roller outer diameter, groove width, groove angle (for special grooves: groove height and/or additional geometrical data), spindle pitch and direction of rotation. The table summarizes the set parameters found in the straightening roller field of the Configuration/System module (fig. **6**) for the given example.

Other parameters requiring configuration (fig. **6**) include the work directory of the application software (Configuration/Directory), the transmission rates and data format for the serial communication (Configuration/System/Interface), the designation of the actuator 8 (Configuration/System/Actuator), and the cross-sectional dimensions of the process material (Configuration/Wire/Diameter/Height).

Apart from the cross-sectional dimensions of the process material, viable default values are already entered by the manufacturer for all the parameters so that normally nothing has to be changed.

The user can select not only routines designed to guarantee a high level of availability and reliability of the automatic actuator but also options (fig. **6**) for coupling with the adjustment mechanism of the master roller (Options/Teach-in), the initialization of the actuator 8 (Options/Home) during start-up, and the adjustment of the straightening rollers (Options/Positioning) during work with the automatic actuator.

When the automatic actuator is started, the first step involves coupling with the adjusting mechanism of the master roller. To produce a form-fit connection it is possible to align the coupling element in teach-in mode (fig. **6**) by specifying an angle of rotation (in the range between 1° to 360°) with free selection of the direction of rotation.

Defined positioning of a roller is possible only if the actuator 8 was previously initialized in the second start-up step using data from the positioning sensor concerning a specific geometrical position of the master roller. The specific geometrical position of the master roller is equivalent to a limit position. Limit positions are usually signalled by switches such as inductive proximity switches. A different approach is taken on the automatic actuator. During adjustment of the master roller for initialization of the actuator 8, which is triggered by the option Home, the current required for the adjustment is identified by the basic automation unit. When the master roller moves freely, the current flows at one level. When it comes up against the mechanical limit, the current rises. This increase in current above the constant level is the defining event for the initialization.

After the actuator 8 is initialized in relation to the geometrical limit position of the master roller it is possible to position the master roller or any slave roller. The operator has to select the option Positioning (fig. **6**), which as input values requires information about the index of the roller to be adjusted (Options/Positioning/Roller) and about the value of the adjustment starting from the wire-specific zero line (Options/Positioning/Adjustment). If the automatic actuator is not yet coupled with the adjusting mechanism of the roller to be adjusted, the angle of rotation of the coupling element of the automatic actuator is changed in the uncoupled state so that it coincides with the coupling element of the adjusting mechanism of the roller to be adjusted. The angle of rotation offset (Configuration/System/Rollers) and the actual positions of the roller last adjusted and the roller to be adjusted are channelled into the calculation of the optimum time value for changing the angle of rotation of the coupling element.

After the coupling element of the automatic actuator is connected to the coupling element of the adjusting mechanism of the roller to be adjusted, positioning is performed on the basis of the cross-sectional dimensions of the process material (Configuration/Wire/Diameter/Height), the adjustment value (Options/Positioning/Adjustment) and the parameters in the straightening roller field of the Configuration/System module (fig. **6**).

All the data and information which have to be entered in the course of configuration are saved in a data base (fig. **6**), as are the values of all the relevant parameters of each control operation performed by the automatic actuator together with a plain-text description of the type of operation and an indication of the system time and system date. Saving and loading the adjustments under a specific name assigned, for example, to a particular product enables the defined setting up of the straightening unit at any time independently of the operator. The core (fig. **6**) of the application software installed on the PC organizes the overall sequence and carries out any essential calculations. Information is exchanged between the core and the basic automation unit by means of the communication module. The basic automation unit controls the actuator 8 (fig. **6**) which generates the torque needed for all the rollers combined within a set to be positioned in any order. ■