Spring Wire Straightening

How to determine the straightening range, radius of curvature range and number of straightening rolls needed for your application

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The design of the spring wire straightening process is reflected in the straightening system. Straightening systems consist of a combination of straightening units that create constant material characteristics by adapting to the changing characteristics of the feed material. Every straightening unit and every straightening system has a specific straightening range, which is fixed by the spacing and the diameter of the straightening rolls. The straightening range Δ thus has limits for the minimal and maximal cross-sectional dimensions of material to be straightened. For round wires, for example, the relevant parameters are the minimum wire diameter d_{min} and the maximum wire diameter d_{max}, as shown in Equation 1, below.

$$d_{min} \leq \Delta \leq d_{max} \quad \text{Equation 1}$$

Once the straightening range is fixed with due consideration to the material's cross-sectional dimensions, the next step is to decide on the number of straightening rolls.

Given the difficulty of establishing the number of rolls by mathematical means, use is made of a knowledge base consisting of the linguistic terms (membership functions) of the input and output variables, a rule base, and the inference and defuzzifying mechanisms. The knowledge that is channeled into the fuzzy system (Figure 1, below) is the result of empirically established and verbally formulated rules. It is also based on the results of putting the virtual simulation of the straightening process to actual use.

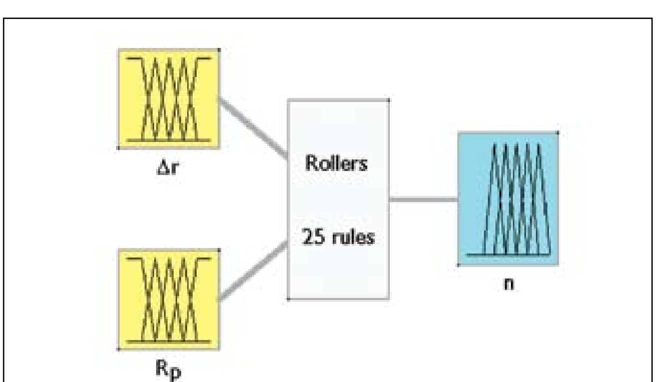


Figure 1: The fuzzy system determines the number or straightening rolls needed.

Via the rule base, consisting of 25 rules, the input variables Δr and R_p are linked to the output variable n (representing the number of straightening rolls). A sharply defined value for the input variable "radius of curvature range Δr" can be calculated

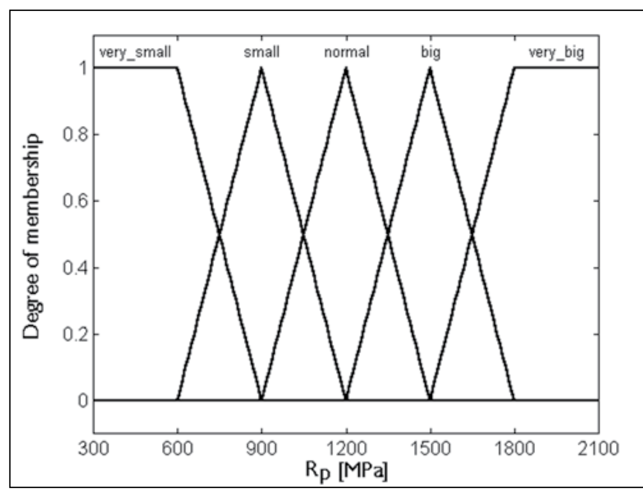


Figure 2: The membership functions (linguistic terms) of the input variable R_p, yield point.

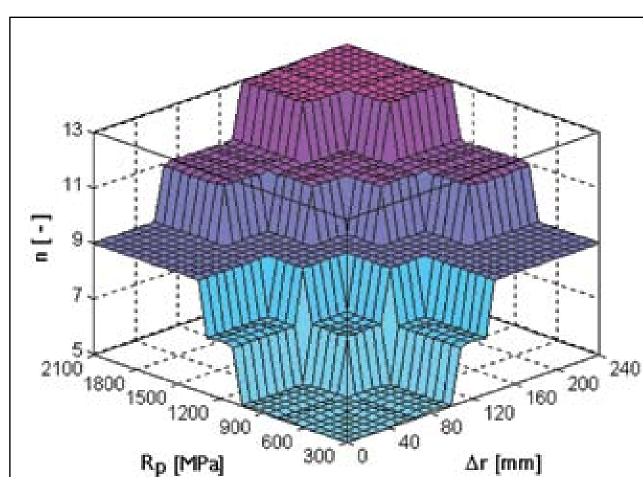


Figure 3: Conversion chart for determining the number of straightening rolls.

with Equation 2, below. The variables r_{max} and r_{min} are the maximal and minimal radius of curvature determined with Equation 2.

$$\Delta r = \left| r_{max} - r_{min} \right| \quad \text{Equation 2}$$

The membership functions of the input variable yield point R_p are laid down in Figure 2, page 53. The fuzziness is particularly evident in the overlapping of the variable sets. For example, an elongation limit R_p = 800 MPa at 33% (degree of membership µ = 0.33) is assigned to the set *very_small* and at 67% (degree of membership µ = 0.67) to the set *small*.

Use of a suitable inference mechanism and a specific defuzzifying method results finally in a specific conversion chart, as shown in Figure 3 on page 53, which can be used at any time to generate a sharply defined output variable for a set of sharply defined input variables. Table 1, above, presents derived values of *n* (the number of straightening rolls) for a number of discrete values of the input variables R_p (yield point) and Δr (radius of curvature range).

Range of initial curvature radius Δr *[mm]*	*Yield point* R_p *[MPa]*	*Number of straightening rolls* n *[-]*
0	1000	5
60	1000	7
100	1000	9
100	2000	11
160	2000	13

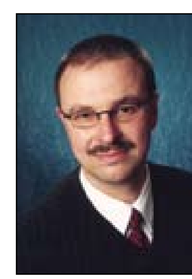
Table 1: Values for the number of straightening rolls *n* calculated with fuzzy logic.

Figure 4: Semi-automatic straightening system.

In addition to the straightening range and number of straightening rollers, the way in which the straightening rolls are positioned has a major impact on the straightening process. After all, it is the positioning of the straightening rolls that influences the bending operations and, hence, the residual curvature.

Witels-Albert has developed various levels of technology, which differ in their degree of automation. In conventional straightening systems, simple tools are used to position the rolls. Another possibility is adjusting elements equipped with a position gauge or vernier scale. Advanced straightening technology featuring a high degree of automation, such as semiautomatic straightening units and systems (Figure 4, bottom left) or automatic roll actuators (Figure 5, above) can position the straightening rolls with reproducible high precision within a very short time. Software is a key component of the overall system at each of these two levels of technology. Whatever the degree of automation, Witels-Albert uses the SimDATA program (Figure 6, below) to determine the roll-adjustment values.

Figure 5: Automatic roll actuators.



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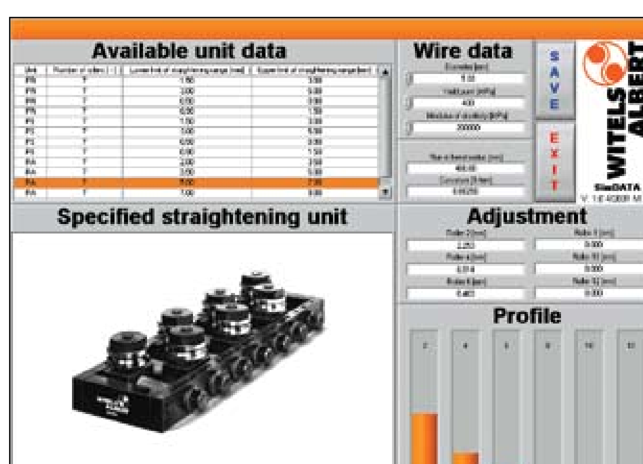

Figure 6: SimDATA software determines roll-adjustment values.

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