Computer Aided Design for Roll Forming Shaped Tubes

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ABSTRACT Shaped steel tubes are more and more widely used in automobile and construction industry. The tooling design method is very important in order to form a shaped tube. The optimum design of a high precision and complex contour tooling is obtained by computer aided design technology. Using CAD method, we can shorten the design time and reduce expenses for manufacturing and set up. Now the design of shaped tube tooling is no longer depending on the designer's experience only. Some successful examples designed by COPRA software technology are discussed and showed in this paper.

Introduction

Shaped steel tubes are widely used in automobile industry and architecture industry. Taking a longitudinal welded tube or seamless tube as mother tube, shaped steel tube are usually produced by the method of roll forming and drawing moulding. Shaped steel tubes can be produced continuously in a tube welding line. Due to the high productivity and the possibility to even keep close tolerances in the finished profile, roll forming method is widely used in mass production. The design of the roll forming tool set is the most important step in the process of making a shaped. Using computer aided design technology, high precision and the optimized design of tooling with complex contour can be achieved. Shortening the period of tool design, cutting down the cost of manufacturing, computer aided design of shaped tubes is no longer a trial-and-error method and no longer only depending on the experience of designer. COPRA is a professional CAD software package for every roll form designer. It can be used in roll form design not only for simple and open sections but also for closed and utmost complex shaped tubes.

Fundamental principles of deformation of shaped tube

1. A linear proportional projection

No matter how complex it is ,the contour of shaped tube can be formed by straight elements

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and arc elements. In the process of deformation, the elements of shaped tube keep a linear topological projection relationship with corresponding element of circular mother tube. The Angle Modification Method is a linear proportional projection of the final profile to the target profile. Figure 1 shows the linear topological relationship that the entity of circular target tube keeps with original shaped steel tube.

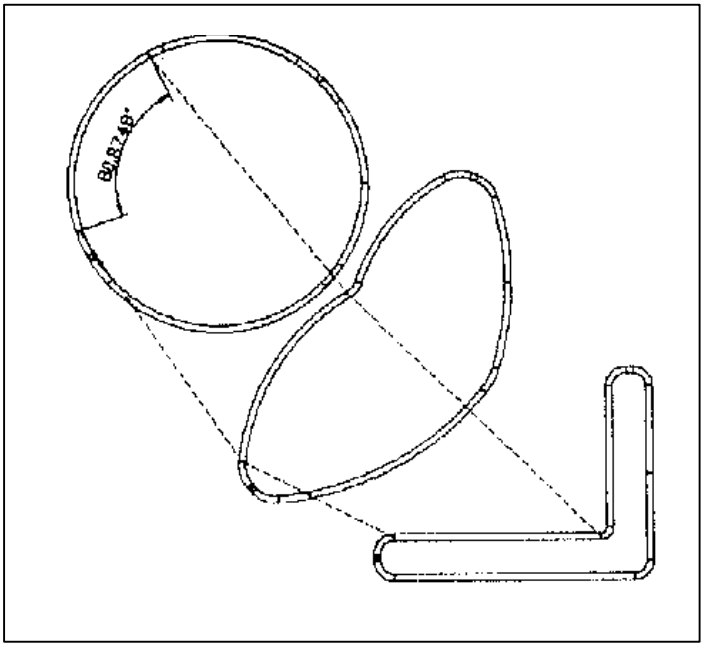


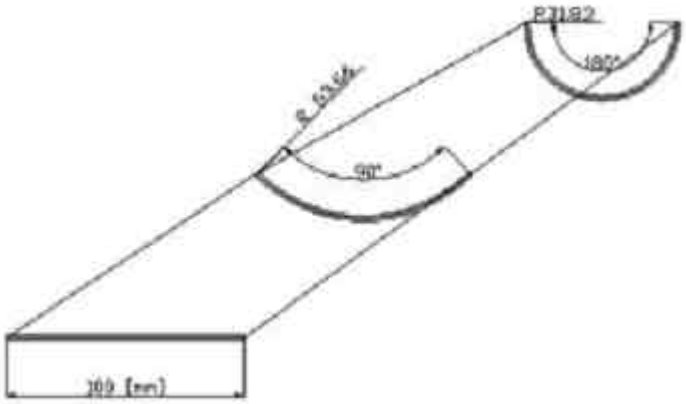
Fig 1 The linear topological relationship between the entity of target tube and final shaped section

The final section of a shaped tube given by CORPA is constituted by straight lines and arcs. It can be converted from a polyline contour of AutoCAD. After assigning a certain amount of compression given by the designer according to the value of roll forming machine, the s-called flower pattern can be obtained by CORPA automatically. These cross sections are constituted by curves determined geometrically, which are different from the mother tube being determined by a single radius and the final shaped steel tube which is constituted by straight and arc entities.

2. Length of the formed entity

Take the length of neutral line of the circular mother tube as the computing reference in design, and set it equal to the length of corresponding neutral line of the final shaped section without compression. The diameter of mother tube can be calculated by the reference of section’s contour line and the total compressive coefficient.

The length of the reference line of the tube equals the length of the reference line of the final profile (if no compression factor was selected). The diameter of the tube is given by its reference line. For example, a line whose length is given to be 100mm is corresponding to one segment of target tube whose length is 100mm (if compressibility is 0%).



$$L = 2 * 63.66 * \Pi * \frac{90°}{360°} = 100[mm]$$

$$L = 2 * 31.83 * \Pi * \frac{180°}{360°} = 100[mm]$$

Fig. 2 Length of forming entity

3. Compression factor and total compression

During forming of a tube to a final profile, the length of the centre line is shortened due to compression. The degree of shortening can be set by a compression factor in percent. The compression factor defines the total shortening of the length from the tube to the final profile. The total shortening is distributed to the individual forming steps. The compression factor can be set as an absolute value in [mm]. The resulting compression factor as a percentage of the selected reference line as well as the Ø of the original profile are calculated.

Compression factor , also called stretching coefficient, is the ratio of the perimeter of the mother tube and that of shaped steel tube. In the process of forming, to ensure enough material to fill in the pass and take the longitudinal stretching of the material into consideration, an adequate compression factor should be determined. Usually the total compression factor is set between 1%-2%, at the same time the rounding diameter of the mother tube should also be concerned. If the diameter of the tube is very close to a standard tube size, the design and manufacture of a sizing pass can be omitted.

4.Distribution of the deformation

With a uniform distribution method, the percentage of deformation is equal for all passes. The angle of the arc entity is exactly between the corresponding angles of two adjacent passes. The following points should be taken into consideration in the actual design.

A. For easy entering a forming pass, a small compression deformation should be distributed at the beginning stands of mill.

B. To ensure the dimensional precision of the product, a small compression deformation should be distributed at the ending stands of mill.

C. In the driven main passes, larger compression deformation can be defined.

D. Because of the weaker idler passes, a small compression deformation should be defined.

E. Adjust distribution of the compression value according to the difficulty of deformation of adjacent passes and the roll contour.

F. Determine the compression deformation by the complexity of the shaped tube and the total number of passes which can be used.

CORPA can distribute the compression deformation according to the percentage of each selected pass. The sum of percentage distributed to each pass should be 100%.

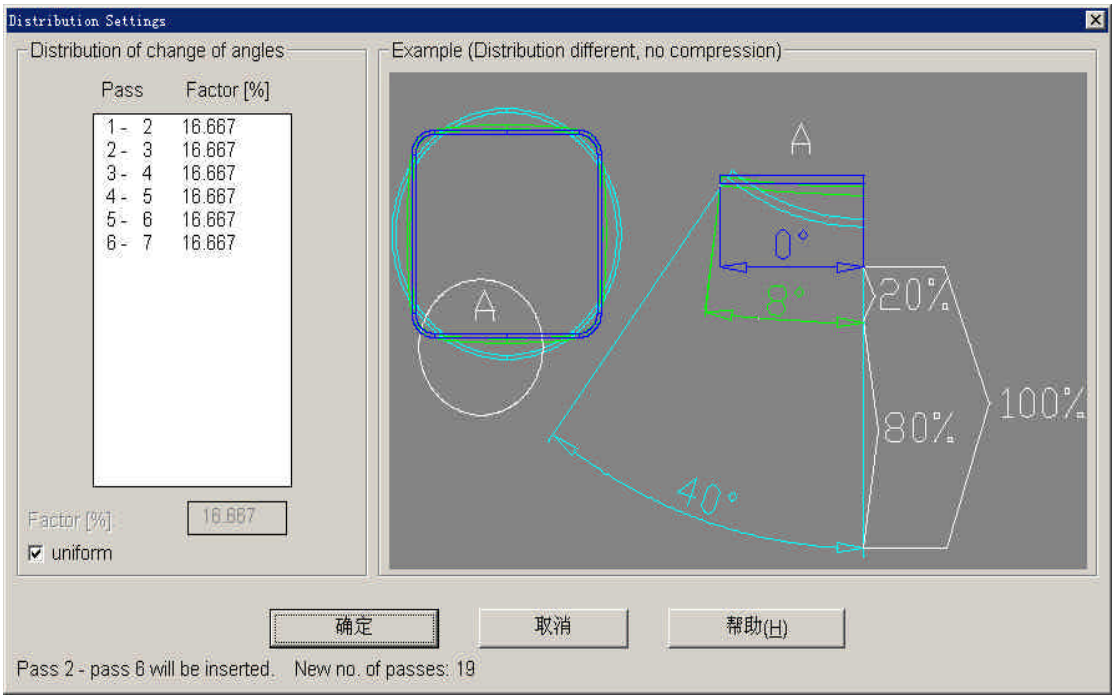


Fig. 3 Distribution of deformation

5. Optimization and iteration

It is most important to determine the flower (tube cross section) data of each pass. COPRA calculates respective geometrical entity data using an iteration method. 3 different optimization methods are offered by CORPA. The designer sets the acceptable gap width (optimisation tolerance) and the time limit for optimization and iteration. Using the Deformation Technology Module of CORPA , theoretical stress and strain values can be analysed (by using the wire frame model provided by the software program) and the design result can be evaluated and modified .

Examples of a CAD shaped tube

Using the shaped tube module of CORPA, the author designed a large number of shaped tubes with multiple specs and different sections, and the design has been applied to practice successfully. Using the integrated CAD/CAM technology of roll forming, the correspondence of design reference, manufacturing reference and mounting reference can be obtained very accurately in each pass.

The contour data made by CAD are converted by an interfacing software program to numerical control codes (CNC), and then directly transferred to a numerical controlled

machine (through the computer communication RS232C port). In order to eliminate heat treatment distortion, precision turning is adopted after heat treatment.

Having taken the mounting reference, equivalent axial length of the main pass roll and similar height of rolls in idler pass into consideration, the set up of the roll set has become a quite easy job – even if carried out with high precision.

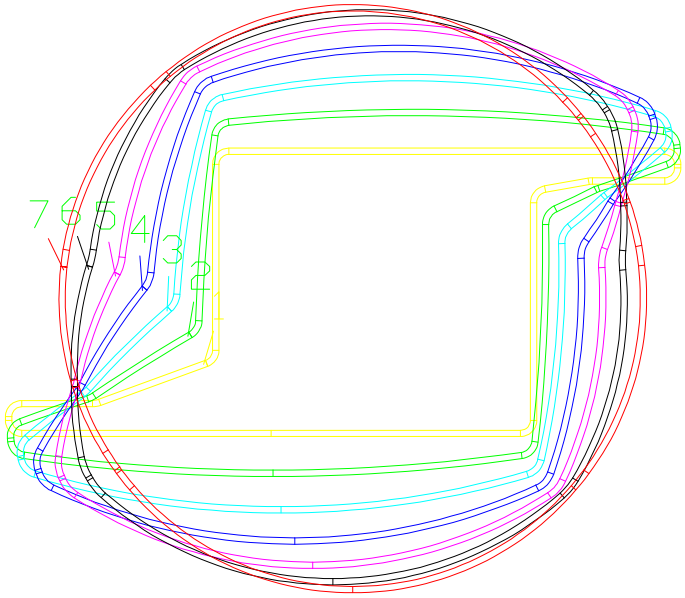


Fig. 4 Forming of a special shaped tube

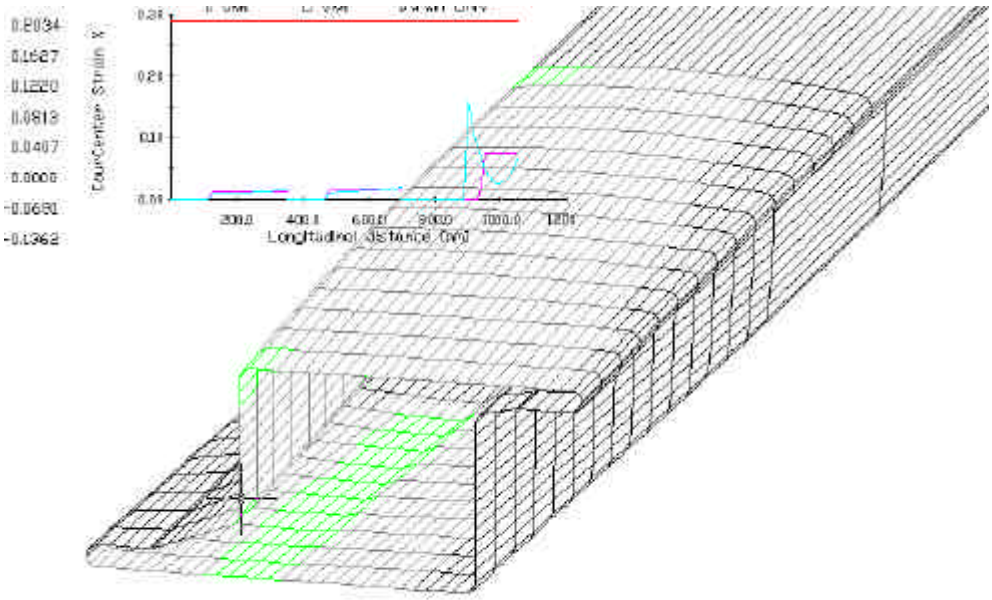


Fig. 5 Simulation by Deformation Technology Module

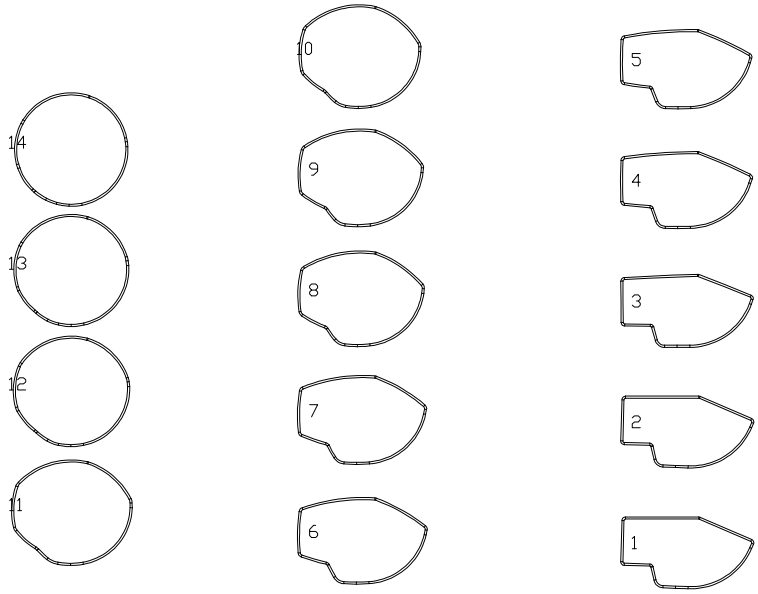


Fig. 6 Steps of forming a special tube

Reference

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