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Optimization Technique to Study the Tube's Hydroforming

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Abstract:- The shaping by hydroforming process involves several complex phenomena and presents several types of nonlinearities (geometric, material, etc.). The development of a hydroforming operation requires a lot of testing to determine with precision the optimum loads of trips and get a room without defects. Advances in digital tools have enabled manufacturers to simulate and optimize their production facilities before launching the production in order to minimize the maximum rate of defective parts. Several techniques or deterministic optimization methods have been proposed over the last decade in order to properly conduct a formatting operation. The majority of these techniques combine the finite element method and optimization techniques.

Keywords:- hydroforming; optimization approach, numerical simulation, finite element, SQP.

I. INTRODUCTION

Hydro forming is a manufacturing process by deformation; it consists in plastically deforming the thin pieces (sheet, pipes). The final shape of the part is determined by a "shape" called matrix. Unlike swaging, there is no complementary matrix thereof is replaced by a fluid under high pressure which forces the piece to take the shape of the cavity of the die. The use of a pressurized fluid allows applying a force in areas inaccessible by other means.

The shaping by hydroforming process involves several complex phenomena and presents several types of nonlinearities (geometric, material, etc.). The development of a hydroforming operation requires a lot of testing to determine with precision the optimum loads of trips and get a room without defects. Advances in digital tools have enabled manufacturers to simulate and optimize their production facilities before launching the production in order to minimize the maximum rate of defective parts. Several techniques or deterministic optimization methods have been proposed over the last decade in order to properly conduct a formatting operation. The majority of these techniques combine the finite element method and optimization techniques.

With these means, manufacturers can virtually simulate their processes; allowing responding to some questions mainly on the feasibility of the room and also on the ability of the loading path out form the part. This coupling can often mark improvement. The optimization work settings hydroforming process involves finding the best route to avoid loading the faults that may arise during hydroforming (buckling, wrinkling, and rupture, etc).

The used methods to develop simple analytical models are based on the theory of plasticity to the membrane tubes, thin and thick. They are useful to optimize key defects, the variation of the axial force based on the internal pressure and the pressure against and wall thinning: The mechanical process parameters: the initial tube material, friction conditions swelling pressure, stroke, etc. The geometric parameters: radiation tools, dimensions of additional parts, length of the initial tube, etc. The control and optimization of certain operating parameters of the process can improve the formability of the material and the robustness of the process [1,2,3].

In this paper we use an optimization technique of different parameters of the hydroforming the tube by varying the tubes thickness by means of the objective function in the least squares sense.

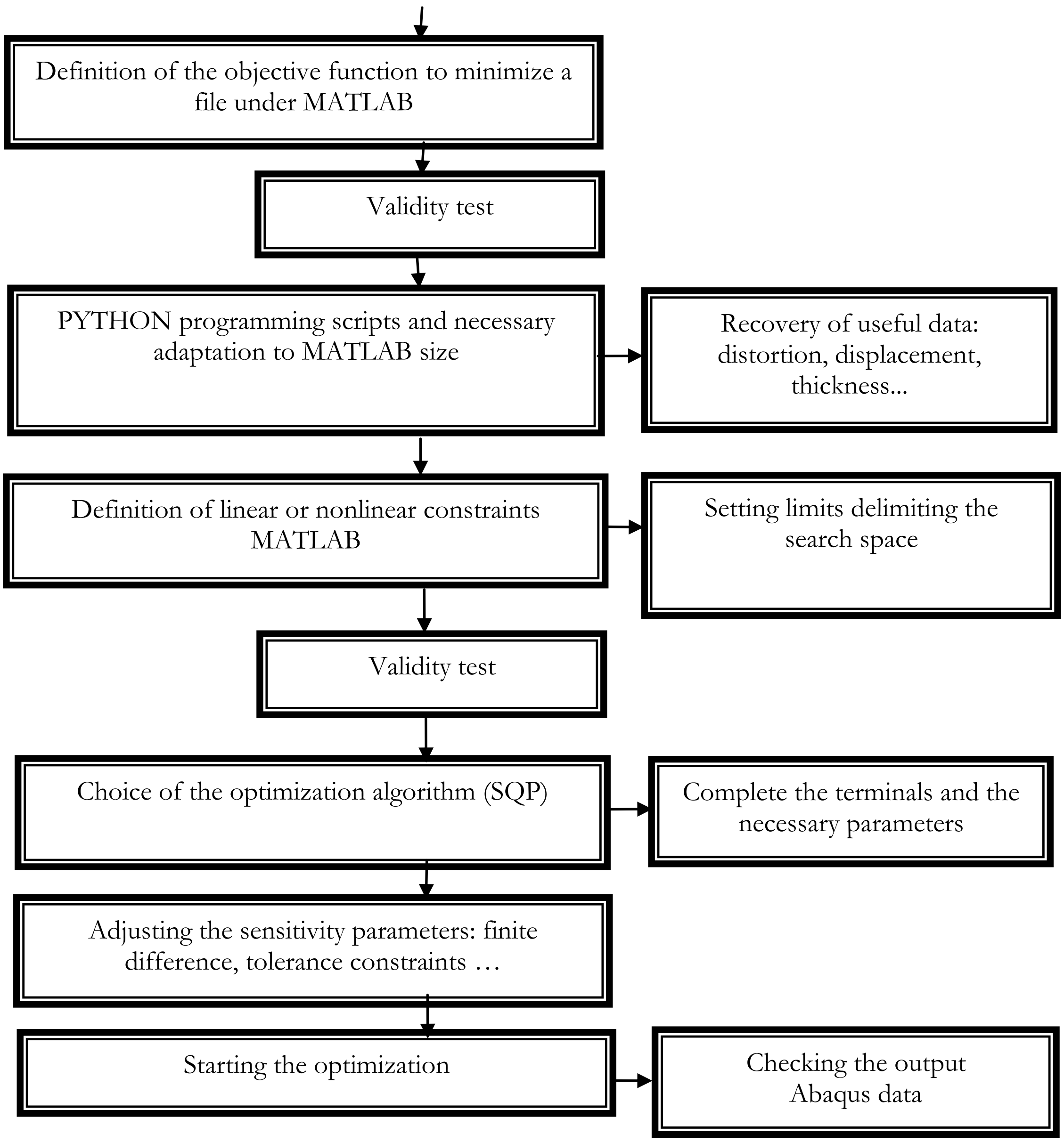

Figure 1: Organigram of the optimization approach

The previous diagram provides an overview of the organizational aspect of the process optimization as it was conducted. The specific needs through programming languages such as Matlab code and Python, is essential to the global success. Thus, the organization must not be neglected in order to escape the complexity of the programming software.

II. STATEMENT OF THE OPTIMIZATION PROBLEM

2.1. DETERMINISTIC SECTIONS OPTIMIZATION

An optimization problem is formulated as a minimization problem and it can be written in the general formula:

$$\begin{cases} \min\limits_{x} \ f(x), \\ \text{such as,} \\ g_i\ (x) \le 0,\ i = 1,....,m, \\ h_j\ (x) = 0,\ j = 1,....,p, \\ x \in S \subset R^n \end{cases}$$

$f(x)_x$ is the scalar function to be minimized, (x) is a vector containing all the optimization variables. g_i gives the inequality constraints. h_j are the equality constraints and S represents the space variables defining the search space.
It denominates local method which converges to a local minimum. Local searches frequently begin from an initial point x_0 with step an initial Δ_0 .These parameters initiate a continuous descent to a cavity of function. Multiple local methods exist.
Most previous and also the most used are defined by a descent direction which is deducted from derivatives of the function as: - steepest method descent - the method of Newton - method conjugate gradient - the methods quasi- Newton method. Global methods are valued by their ability to find more global optima. At cost, these methods are generally expensive, in particular for the problems of large dimension or complex shape which require a considerable time of a calculation besides machine immobilization used to this process. It should be noted that there is no optimal algorithm for all the problems. The final choice of the method is found very directly related to the problem to be optimized.
The mathematical can be posed as:

$$\begin{cases} \min \ : f(x), \\ u.c \cdot g_1 \ (x) = (G_1(x) - G_1^t) \geq 0 : \\ g_2 \ (x) = (G_2(x) - G_2^t) \geq 0 \end{cases}$$

Where $\{x\}$ constrains the deterministic vector of design parameters. $f(x)$ indicates the function objective, $G_1(x)$ and $G_2(x)$ are the two constraints to be taken into consideration. G_1^t and G_2^t are defined as allowable stress.

2.2. Application of the tube in hydroforming processes

In a forming process, it is common to want to master the different thickness during the process to avoid sudden failure by thinning. Therefore, the formulation of the objective function in the least squares sense gives the following form:

$$\min \ f(x) = \sqrt{\left(\sum_{i=1}^{M} \left| \frac{e_i - e_0}{e_0} \right|^2 \right)}$$

with e_i represents the instantaneous thickness. e_0 represents the initial thickness.
It is a question of minimizing $f(x)$, deducing it for the hydroforming process the vector $\{x\}$ of the design variables which also define the load path during operation of the process should be: $\{x\} = \{p_1, p_2, d_1, d_2\}$,
p_i symbolizes the forming pressure for $i = 1$ and 2 d_i is the driver displacement in meter punches $i = 1$ and 2 .
We have here the couple value (p_i, d_i) which is equal to 0, which gives us a total of 6 considered system design variables. In our case, the working domain can be outlined according to [1], taking into account several criteria related to the process forming limit prediction. The three development constraints determine the limits of the process states which delimited the feasibility of solutions. Thus, the definition of constraints appears implicitly related to boundary conditions of the process in relation to those previously studied.
-**The constraint 1** imposes a maximum limit for forming pressure to avoid bursting of the tube structure according [3] :

$$p_{i\max} = R_m . \left(\frac{2.e_0}{\phi - e_0} \right)$$

Application:

$$p_{i\max} = 295. \left(\frac{2.1}{20-1} \right) \approx 31MPa = g1$$

-**The constraint 2 i**mposes a limit on major deformations (ε_1) and minor deformations (ε_2) as proposed M.Koç [1]. This prevents deformities such as splintering and buckling during the forming tube. So we set the following condition:

$$\varepsilon_1 + \varepsilon_2 \leq n$$

Here n is the strain hardening exponent of the law equal to 0.24 behaviour for the material concerned. The implicit constraint inequality gives:

$$g_2 = \varepsilon_1 + \varepsilon_2 - 0.24 \leq 0$$

- The constraint 3 focuses on limiting the risk of wrinkling or buckling located at the beginning of forming cycle. These define the feasibility domain, by imposing the border in pure shear lowered by 5% is permissible:

$$g_3 = \varepsilon_1 + \varepsilon_2 - 0.05 = 0$$

- The constraint 4 imposes a minimum limit on the forming pressure to avoid wrinkling the beginning of each cycle and between successive forming step is:

$$p_{i\min} = \sigma_e . \left(\frac{2.e_0}{\phi - e_0} \right)$$

σ_e = constraint of material flow at the beginning of plastic phase in MPa corresponding to $R_{p0.2}$ in practice. ϕ = tube diameter in mm; e_0 = tube thickness in mm.

Application:

$$p_{i\min} = 94.\left(\frac{2.1}{20-1} \right) \approx 10MPa$$

This pressure gives the minimum limit of the definition of terminals is explicit constraints on each design variable. Indeed, it is appropriate to set bounds recent to reduce the working space of the algorithm used. Furthermore, the terminals are enabled by digital testing.

-**The Constraint 5 s**ituates on five geometric control points in sensitive areas to default final forming. (see figure below) These references points validate the dimensional with a global tolerance of 0.15mm after optimization.

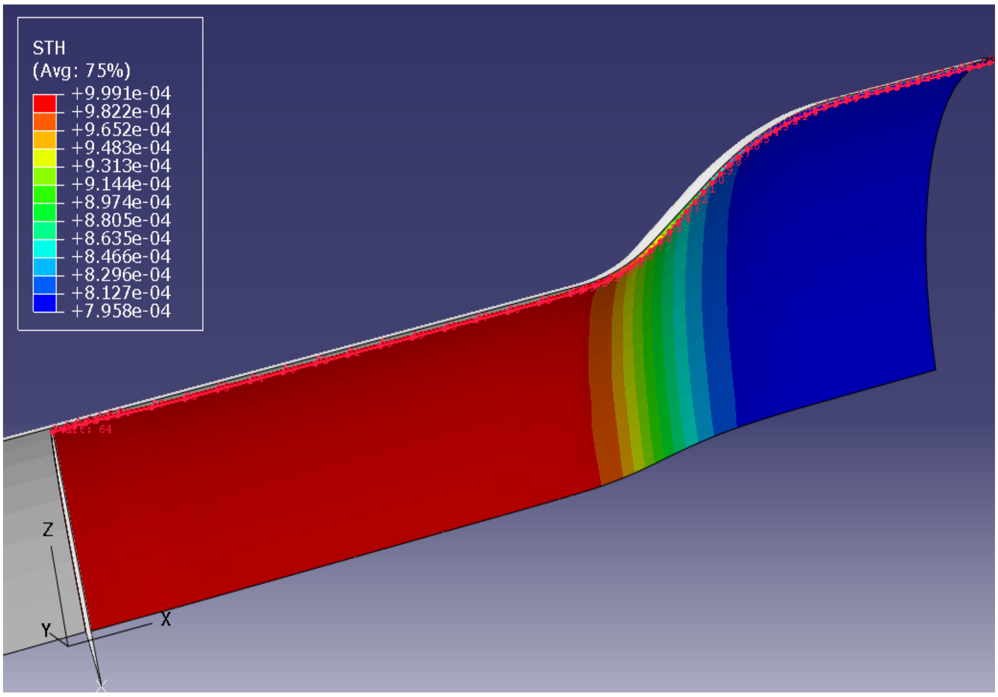

Figure 2: Report of thicknesses optimization before

The figure above shows the thickness of nuances concerning the simplest form of hydroforming already studied in the previous paragraph. The dimensions are identical [4,5].

2.3. Results of the tube optimization

First, it is interesting to visualize the effect of design variables on the distribution of thicknesses in the initial state of the elements (Figure 2.) to optimized state (Figure 3.).

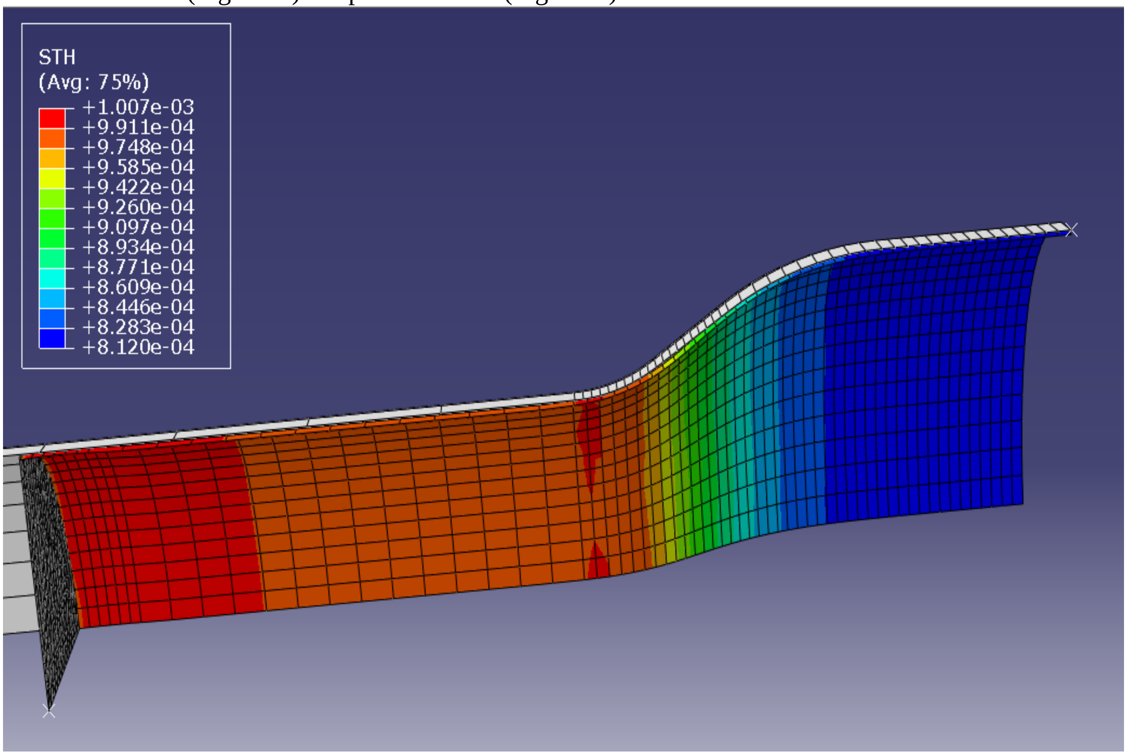

Figure 3: Report thickness after optimization

Figure 3 highlights the case optimized with respect to the initial state through a global visualization on 1132 studied elements. Direct gain is observed on the thinning of almost 2% on the minimum value. This amelioration takes the forming a sensitive area where a crack may occur in the case of excessive thinning [6].

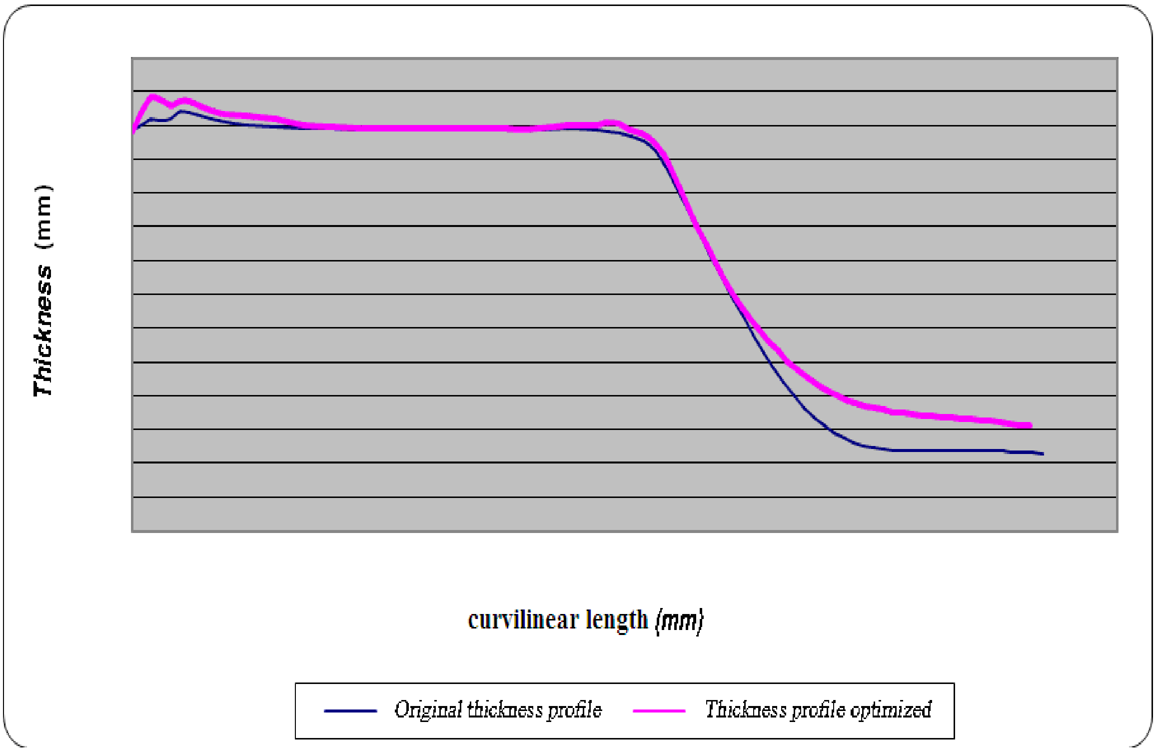

Figure 4: Report of thicknesses of the profile nodes chosen after optimization

The report (Figure 4) following the nodes profile of (Figure 2) shows more precisely the actual impact of process optimization on the thickness distribution. Indeed, the latter seemed more homogeneous without losing the quality of that found on the rest of the tube. To this end, the total length of the tube loses 0.7mm relative to the initial deformed configuration the action of the optimization focuses on the expansion region of the tube where one notes therefore better rigidity in this location.

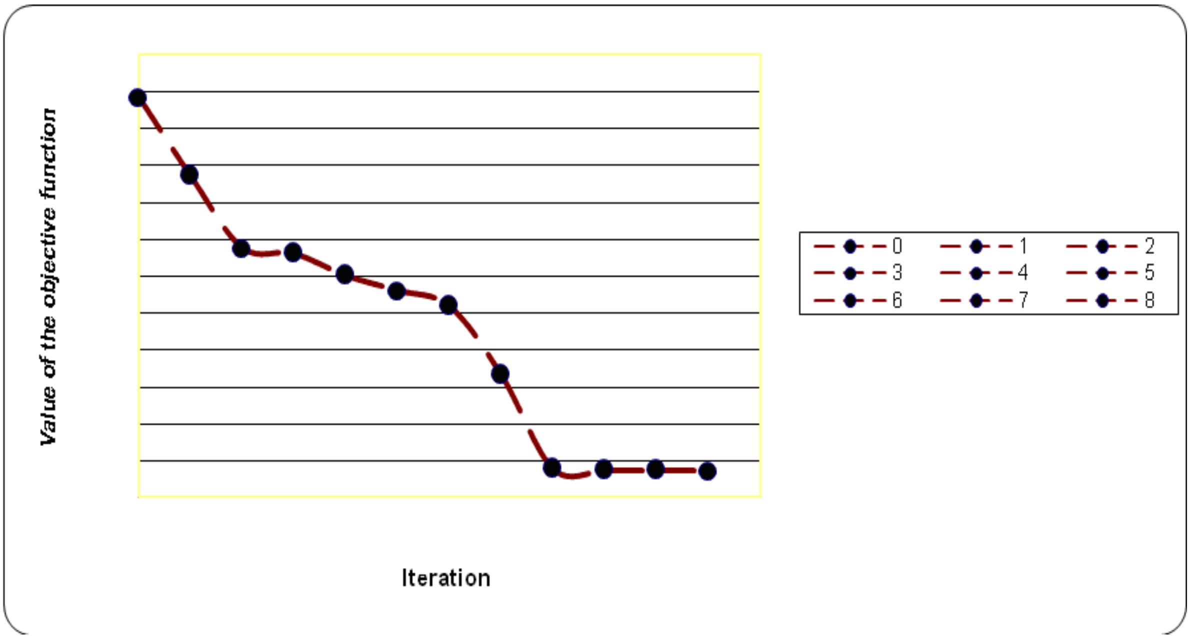

Figure 5: The value variation of the objective function

The chart above provides information on the original value of the objective function on the order of 4.55 to decrease in 11 iterations to the value 4.03. At this point, the convergence is realized accordingly geometric constraints after several iterations to the same value. We recognize a local minimum of the function with respect to the initial determined point by the design variables corresponding to the start of the descent of the algorithm.

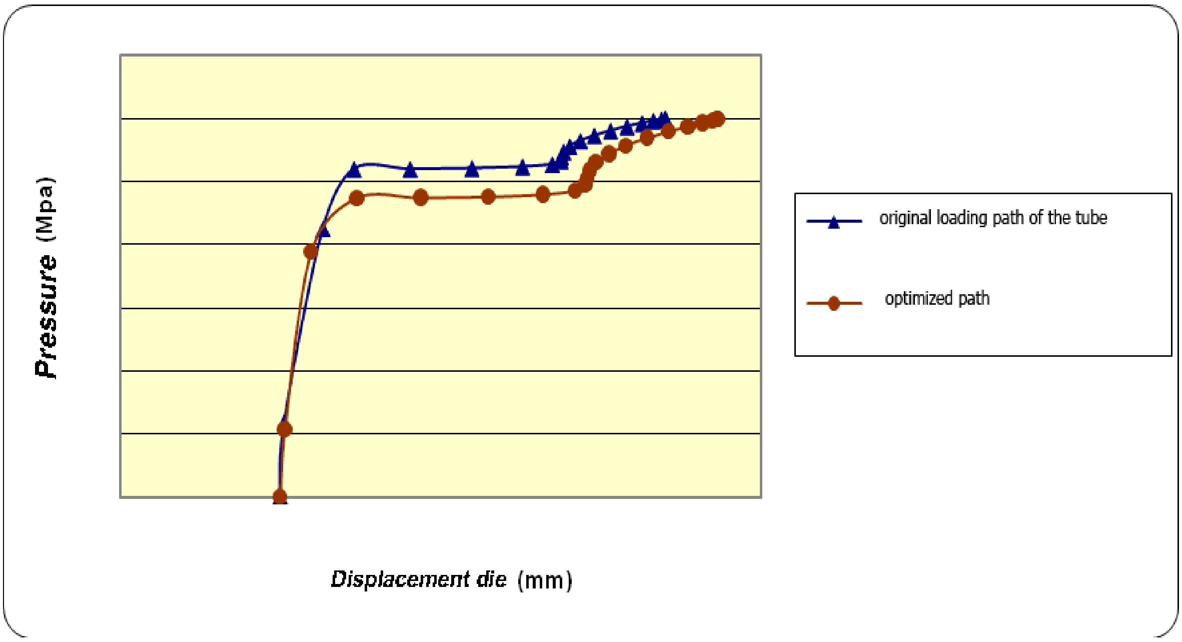

Figure 6: Representation of forming loading path of a simple tube

The latter works use the Quasi-Newton method in a linear search. At the end of the process, we can recover the optimized design variables and the results file under Abaqus (file.ODB). One draws the optimized feed path (see Figure 6) for a better distribution of the thickness from the initial configuration. On marks the increasing of the punch to the final state nearly 20% at the expense with a significant difference in the intermediate pressure by 10%. This fact also reduces the contact pressure and therefore potential friction efforts. In overview, the general shape of the curves looks pretty strong.

2.4. Application to methods of hydroforming the tube in T

We have highlighted the effects of different process parameters on the T-shape of the tube. This part in copper of 1.3mm very industrially widespread has significant variations all along the profile. A new, more appropriate objective function is proposed to be set to treat the two phenomena simultaneously as follows:

$$\min f(x) = \underbrace{\sqrt{\left(\sum_{i=1}^{M}\left|\frac{e_i - e_0}{e_0}\right|^2\right)}}_{A} + \underbrace{\sqrt{\left(\sum_{i=1}^{M}\left|\frac{e_0 - e_i}{e_0}\right|^2\right)}}_{B}$$

with e_i represents the instantaneous thickness in mm; e_0 represents the initial thickness in mm.

In the first term (A), this is to treat with thinning and in the second term (B) thickening of the tube thickness (e). This operation is repeated on each element (M) of the 3D model. (thin shell element with four nodes)

The first challenge beyond programming seems the appreciation of a stable representative model as close to the refined model of a mesh point. Therefore, the research provides a reference file on exactly 1224 elements for a cycle time set to over 20 minutes for an acceptable result. For an estimate of the overall length, we must multiply that number by the launching of the cost function, which can be very long depending on the desired precision of the model and calculation. It proposes to take the definition of the model below:

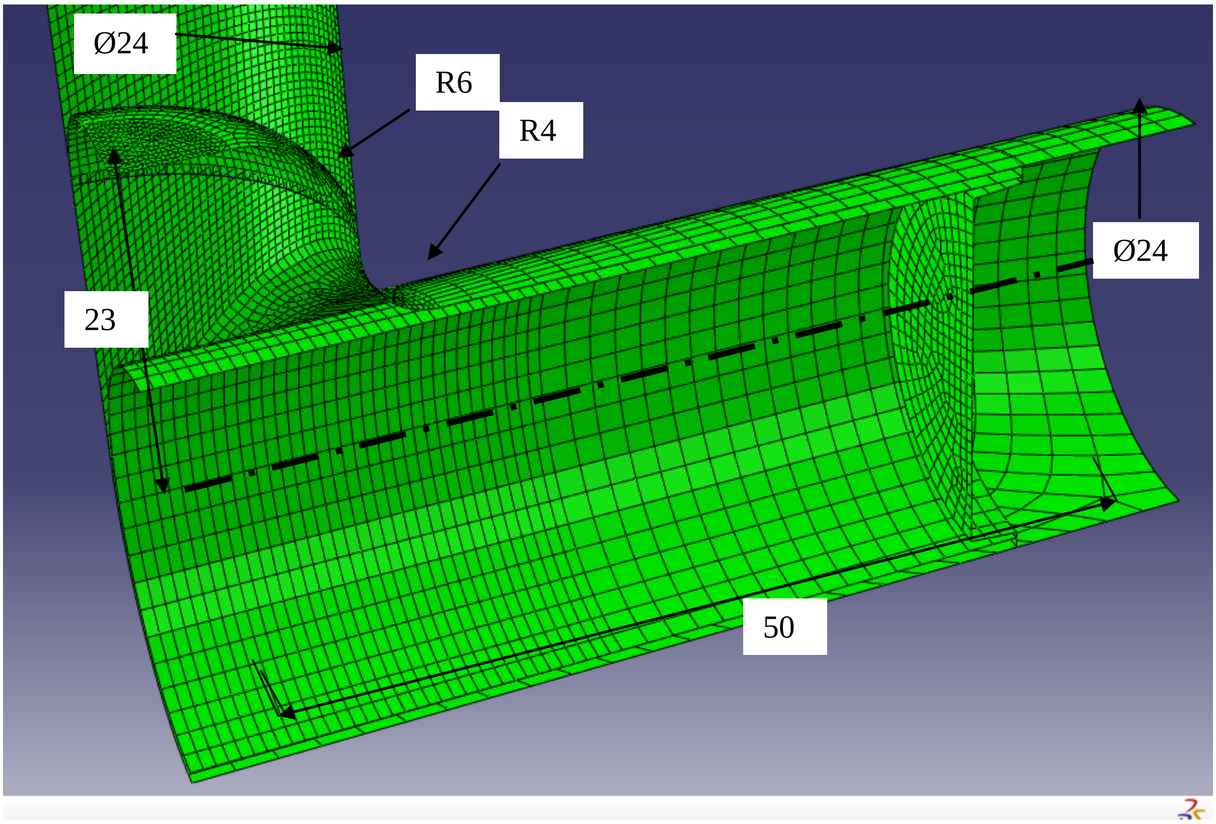

Figure 7: Dimensional of the T-shaped tube against form

The image above shows the main dimensions including those that differ with the model already studied previously. We notice the presence of a punch which acts against form to ensure formed part. There is a finer mesh in the part of the branch to form for reasons of convergence of results in terms of stress and strain.

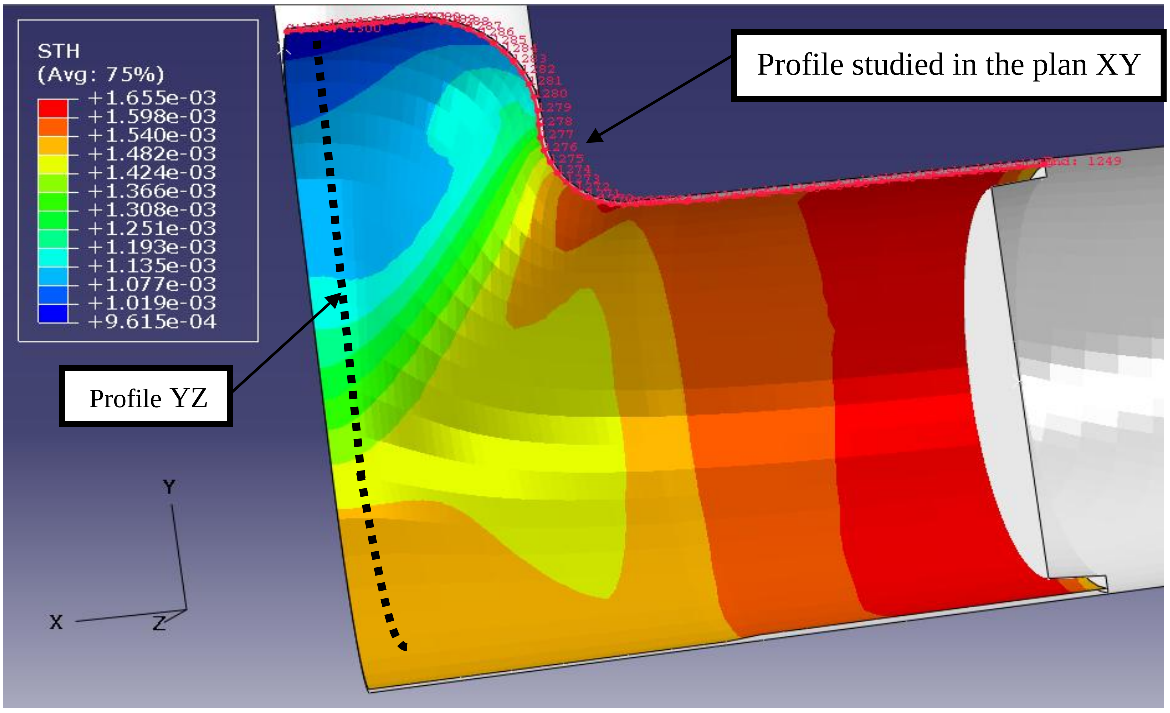

Figure 8: Distribution of optimization before thicknesses

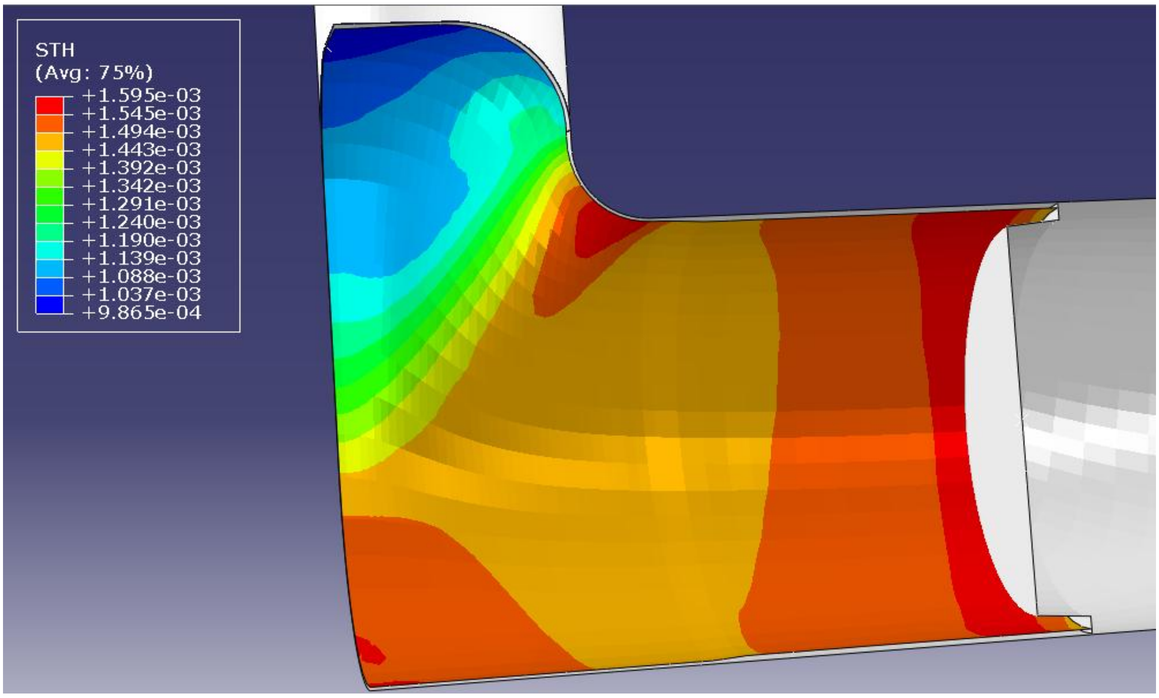

Figure 9: Thickness distribution after optimization

The imposition of constraints draws heavily on achieving optimization of previous single tube. It proposes to study by direct comparison between the original state (Figure 8) with the one corresponding to a 1.12 result after optimization. The situation is much more obvious than the simple tube. Indeed, a thinning effect a gain of more than 2.1% and nearly 4% over the thickening is observed on extreme values, all with a total geometric tolerance 0.15 max. Color effects highlight the comparable dispersions in the model.

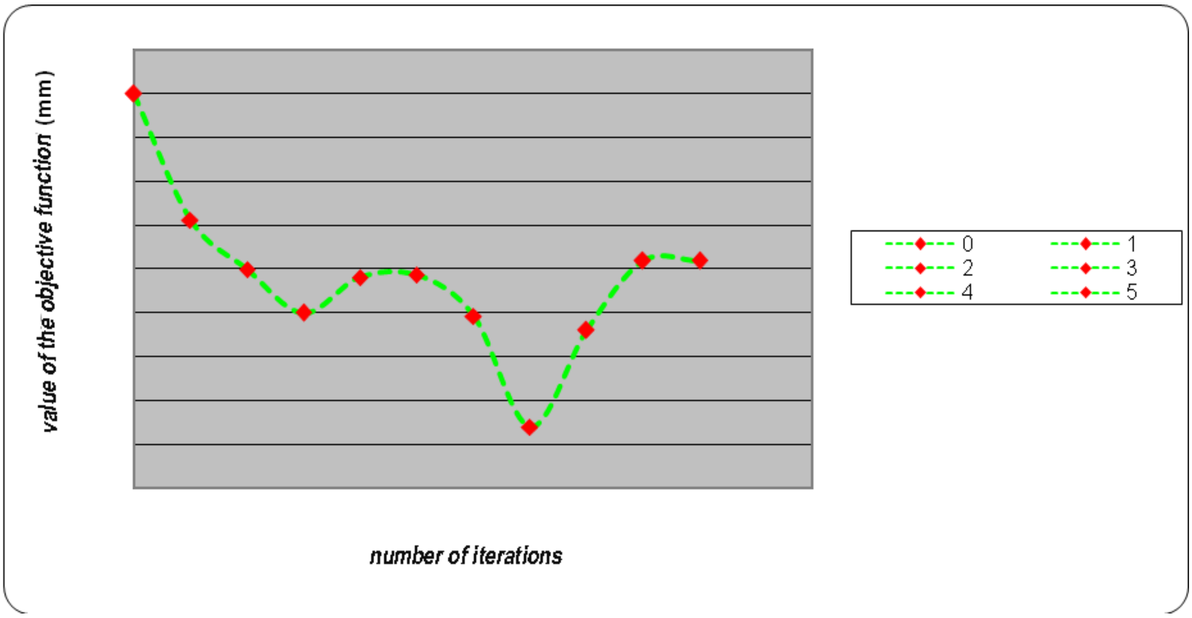

Figure 10: Viewing the number of iterations to convergence on an optimum.

The figure above provides information on the variation in the objective function over an interval of 10 iterations. The latter takes a starting value of 12.5 to stabilize on an optimum value of 10.5 a relative variation of 16%.This value shows the potential for improving the desired objectivity. Therefore, we should propose an analysis of two distinct profiles for correct representation as a whole (see Figure 8)

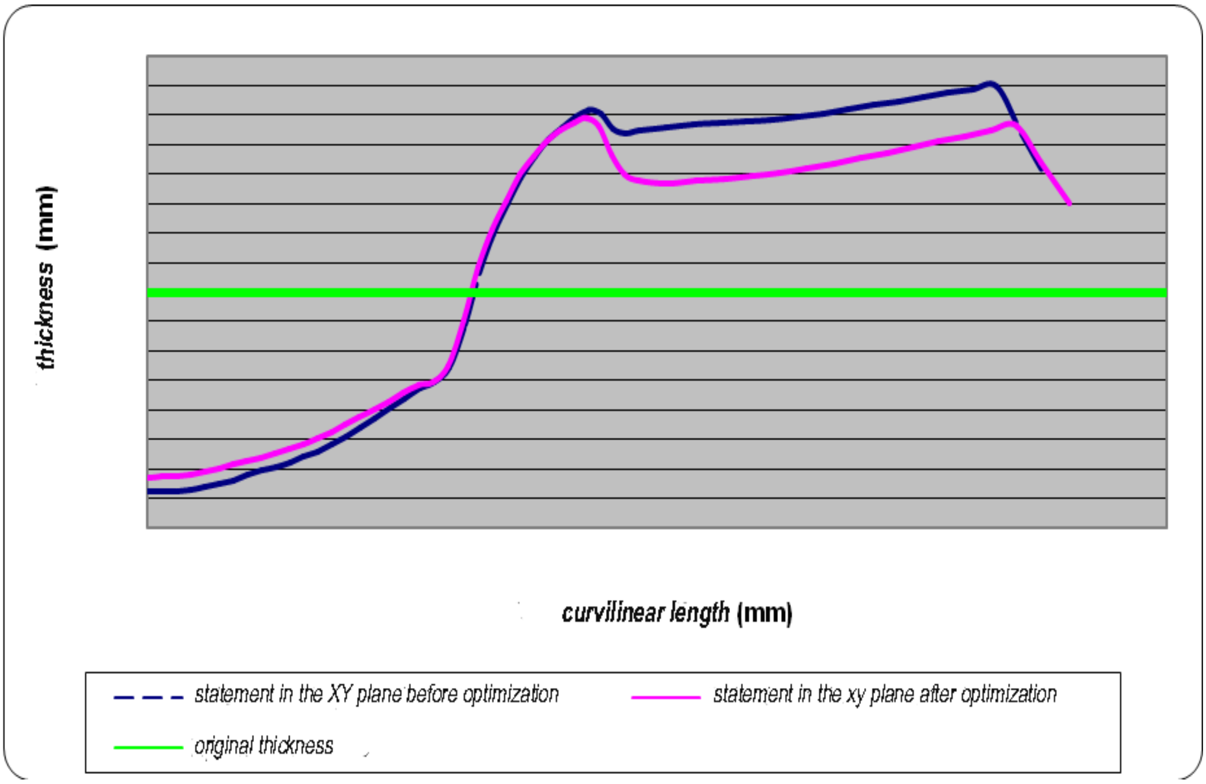

Figure 11: The thickness variation in the profile passing through the XY plane

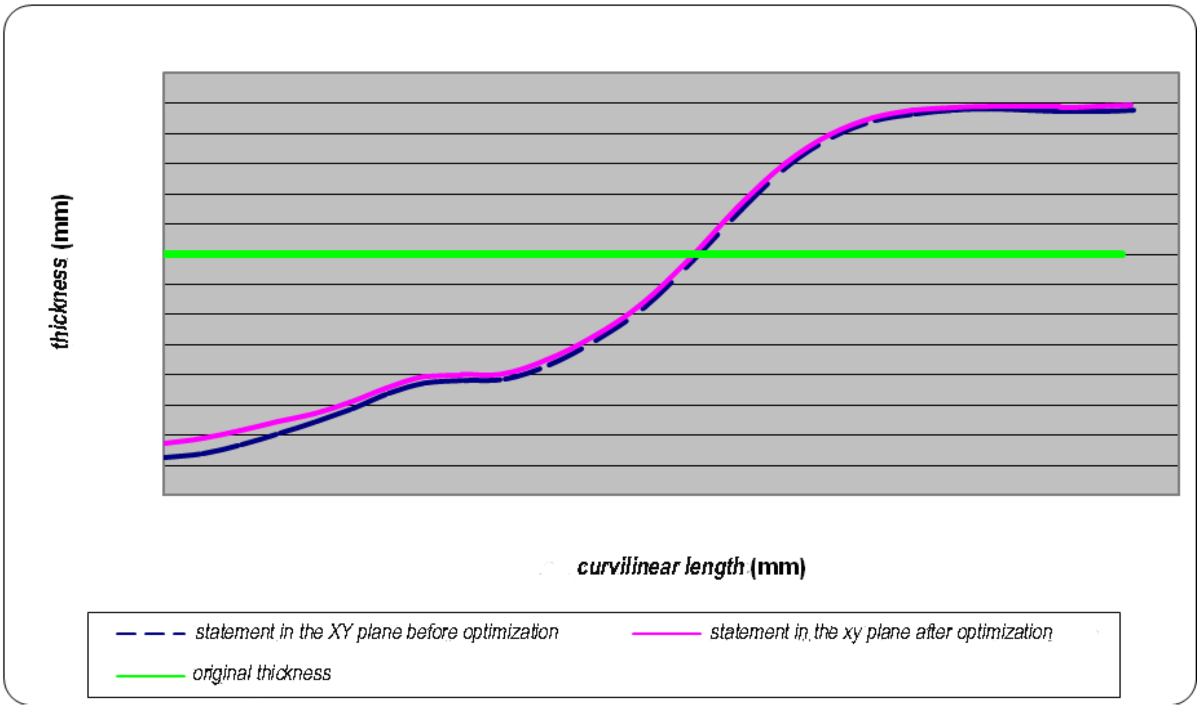

Figure 12: The thickness variation in the profile passing through the YZ plane

It is interesting to notice more precisely the total potential on the two profiles contained in the respective plan. Since (Figure 12) 2/3 tube at the bottom of the branch T undergoes little variation. However, the other third where the risk of cracking may occur to an improvement of nearly 0.03mm thick gain. In the direction of the XY profile, improvement appeared more evident (see Figure 11) as observing in the branch a gain at least equivalent to that of the other profile. However, the entire localized portion after 4mm radius which represents the thickening, the gain is confirmed on almost all (22 to 43mm) to medium almost 4%. It is noted that the objective function defined deal well with two aspects of deformation of the material in the tube wall.

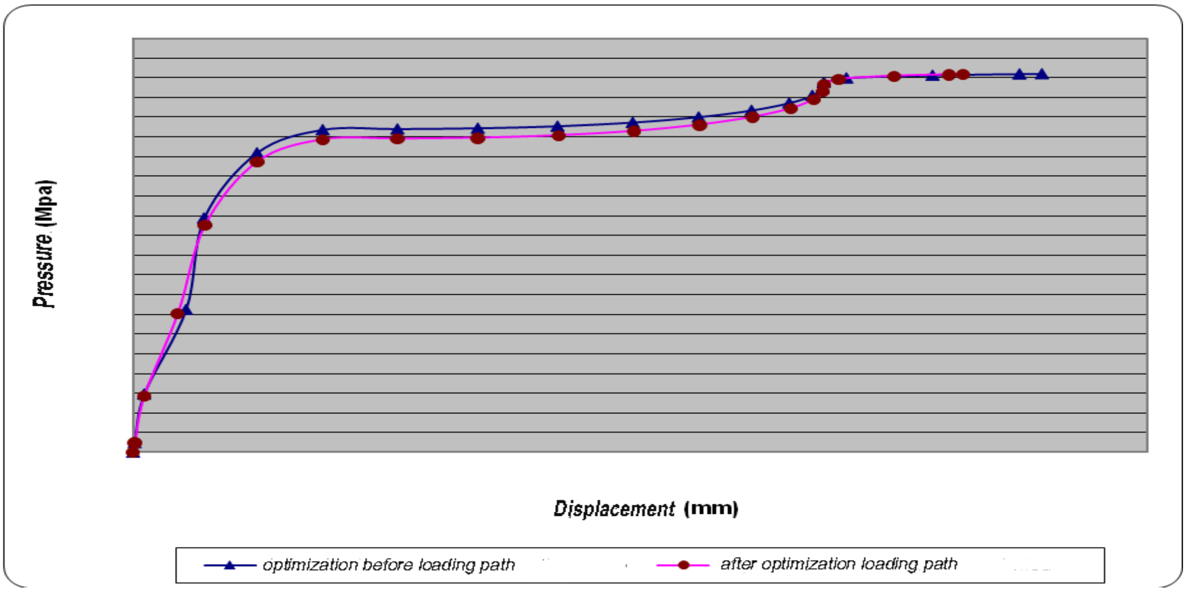

Figure 13: Representation of the shaping of the feed path of the tube T

Figure 13 shows the effect of the correction made by the SQP algorithm (sequential quadratic programming) deemed suitable for this problem. [2] Again, we see a slightly optimized pressure loading path and especially the move where we mean nearly 10% over an initial distance of 12.5mm. From an industrial point of view it is interesting to reduce the lead to its bare minimum in order to reduce the cycle time, so we get a substantial saving of unit cost. However, the general shape respects that of originally defined.

We deduce that the driver loading path quite significantly the forming condition and one of its parameters can lead in this case to unwanted variations.

III. CONCLUSION

This section dedicated to the optimization of tube hydroforming process highlights the need to know the limits of feasibility domain. These analytics can be order, geometrical and numerical. The objective must be clearly defined in order to limit the search algorithm complexity chosen. The required method is based on the compatibility of the physical problem of the optimal state. Here, that used (SQP) is part of the gradient so research methods calculating the first derivatives and partial seconds are necessary to convergence. Thus, small changes of the parameters are obtained by finite difference where the disturbance function is adjustable according to the desired precision. When the value of the objective function stabilizes after a more or less rapid descent, very small variations are observed which represent a position corresponding to an optimum (see Figure 1.1). From a numerical point of view, the selected mesh must be sensitive enough to return modified values in line with the physical constraints. When the feasibility of field is highly non-linear, there is a risk of saturation of the stresses present, which sometimes the need to try to simplify and reduce the number of constraints. This can be seen when selecting control points geometric optimization of previous single tube.

A preparation work and organization to minimize the area of research is still needed. The processing time required in the model is multiplied by the number of function launch costs necessary for the functioning of the algorithm. Thus, an optimization problem of this type is still very expensive in time calculation according precision and size of the proposed model.

REFERENCES

[1]. J.F. Barthelemy, « Function approximation, Structural optimization: Status and promise », Ed. Kamat M.P, 1993.

[2]. N. Boudeau, A. Lejeune and J. C. Gelin, "Influence of material and process parameters on the development of necking and bursting in flange and tube hydroforming", Journal of Materials Processing Technology, Vols. 125-126, 2002, p 849-855.

[3]. M.Koç et O.N.Cora ''Hydroforming for Advanced Manufacturing'' Elsevier, 25 avr. 2008 - 412 pages

[4]. Labergère C.,Contributions à la modélisation, à l'optimisation et au contrôle des procèdes d'hydroformage de tubes et flans, PhD Thesis, Université de Franche-Comté, 2003.

[5]. Gelin, J. C.; Labergère, C. (2001), Modelling, optimization and optimal control for hydro forming process, Proceedings of the 4th international ESAFORM Conference on Material Forming- Volume 1, Liège, Belgium (2001) pp. 377-380.

[6]. Kang, B. S.; Son, B. M.; Kim, J. (2004), A comparative study of stamping and hydro forming processes for automobile fuel tank using FEM. International Journal of Machine Tools & Manufacture 44 (2004), pp. 87-94.

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