Virtual Try Out and Process Optimization for an Innovative Conic Poles Production Concept

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Abstract

This paper describes how the production Process for conic poles has been reviewed in order to provide innovative solutions for the forming process which has been considered the most critical operation. Finite Element Analysis using an explicit code has provided a virtual way to investigate possible solutions evaluating advantages or disadvantages before that any prototype tool has been developed. More than one solution was possible, FEA has given the chance to evaluate the more promising one which was based on a different forming philosophy, that is the usage of profiling forming, which has an innovative aspect if it is applied on conic shapes like in this case. Tools shapes and process parameters were tuned through a massive usage of numerical simulations. The defined innovative solution allows to cut the production times of a considerable amount with an higher quality for the final product.

Introduction

Conic poles are normally and widely used for civil constructions applications like: lighting, telecommunication and voltage distribution. The most common way to produce them is to start from a shaped blank and to form it with traditional techniques using canonic dies tools. On this traditional workflow many possible different variations are used in order to obtain the final shape (Fig.1). As it is in any engineering application, the chance to explore Product and Process optimization has been promoted in order to obtain productivity improvement.

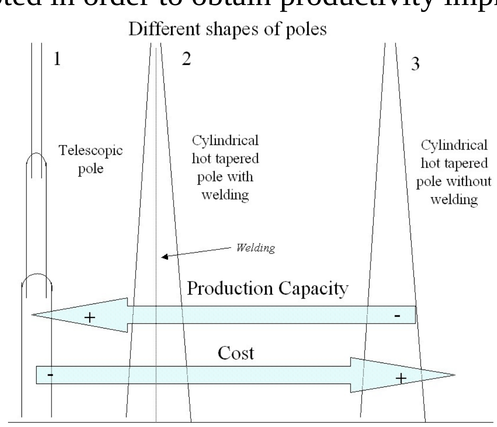

Fig. 1. Different shapes of poles

For this reason, an appropriate workflow was designed. Starting from this workflow all needed functionalities were developed in order to increase, as much as possible, the "Process Automation" for the virtual evaluation of possible innovative forming solutions for conic poles.

Production of poles: main characteristics of the traditional method

The traditional conic poles production procedure is composed by the following phases:

- Operation 1: Cutting Step in order to obtain a shaped blank from coils (Fig. 2)
- Operation 2: Forming Step in order to obtain the final shape of the conic pole
- Operation 3: Welding Step in order to connect the free edges of the conic pole using the MIG technology.

The poles investigated have the dimensions showed in table 1.

Table 1. Dimensions of the investigated pole

D_{min} (mm) Head section diameter	D_{max} (mm) Base section diameter	L (mm) Pole length	C Taper ratio	Material Type	s (mm) Sheet metal thickness
60	188	12800	1% C% = (D-d)/L×100	HSS Fe510	3

The cutting operation isn't very difficult, because it is a traditional sheet metal operation. This operation is necessary to create the blank for the forming operation. In figure 2 can be seen the steps from the coil to the shaped blank. In the last period many studies has been done to investigate the chance to automate the transition from the cutting phase to the forming one, without the help of an operator.

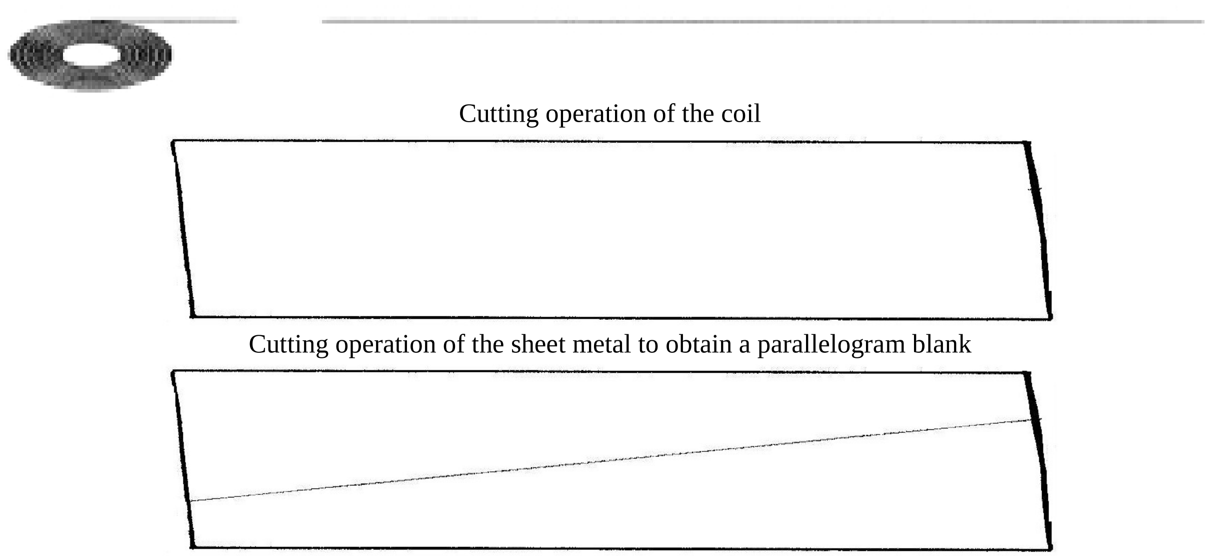

Fig. 2. Cutting operation of the parallelogram blank to obtain two trapezoidal blank, right for forming pole process

It is also very important to describe some problems related to the traditional forming technique, that is a "bend forming of a sheet metal" (Fig 3). The pole is obtained through a forming process made by multiple bending steps on the longitudinal direction of the sheet metal, which is the pole axis itself. The sheet metal is bended creating, in this way, the conic pole that it isn't still completely closed. This operation is followed by the welding phase to definitely size the pole.

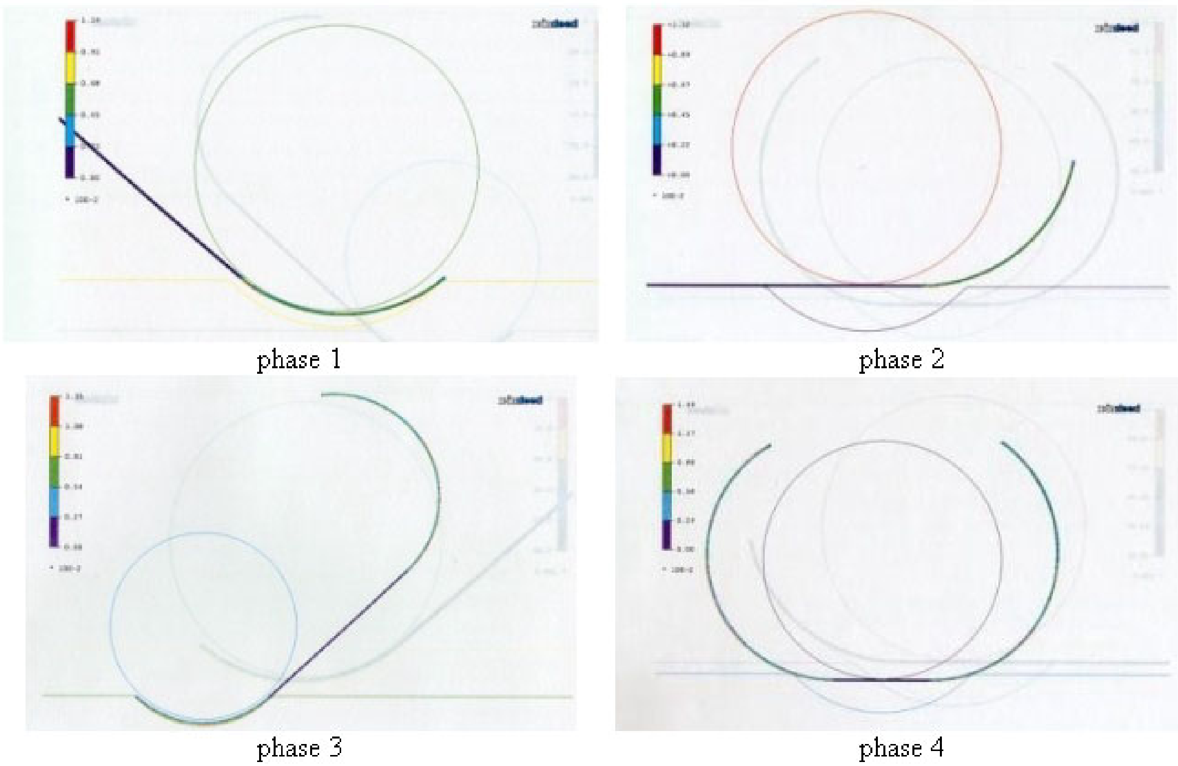

Fig. 3. Different phases of the bend forming operation

The previous bend forming of the blank is characterized by:

- Dimensions of the forming machine.
  Because the poles taken into consideration have a longitudinal length of 12800mm, two presses in sequence are necessary: so, there are plant layout problems which have to be considered.
- Design of the press in the forming zone.
  The blank must be moved from one side to the other during the forming operation (Fig. 3) and this causes the necessity to have enough "forming spaces" and, at the same time, high resistance of the "forming machine". Besides it is also possible that not all poles in market could be realized, due to this difficult handling of the sheet metal during forming operation which may cause possible collision against the machine.
- Pole handling from the pressing machine to the welding one.
  Although the welding phase is the most time-expensive, also the handling of the pole from the forming machine to the welding ones is a critical phase, due to its dimensions.
- Set up of optimal working process parameters: forming force, velocity and so on.

Taking into consideration the previous sentences, it is possible to understand that the Process Optimization, due to product dimensions, it has to be considered the Plant Layout Optimization.

In the recent past the welding phase was considered the most "time consuming" phase in the traditional poles production process. In fact:

$$\frac{n^o_{formed\_poles}}{n^o_{welded\_poles}} = 3$$

because:

- Forming time under the press machine≈ 2(min/pole)
- MIG time (welding phase)≈ 6(min/pole)

Many studies have been done to reduce the welding time and to improve, in this way, the velocity of the whole production process. The most efficiently welding procedure is related to the "High Frequency Welding" process. In fact with this technique it has been possible:

- To improve mechanical properties of the welded area, because the new welding process is able to weld the 100% of the joining section while, the MIG process has the upper limit of about 75%.
- To drastically reduce welding time, moving the "bottleneck" of the pole production process from the welding phase to the plastic deformation ones.

So, this new solution for the welding phase, which applies a different welding technique, has dramatically reduced the time frame requested for this operation and, in order to optimize all the production cycle, new procedures were investigated for the forming phase which now has became the most time consuming one.

A new forming philosophy for conic poles production

The only way to speed up the forming phase was, as it has been made for the welding operation, to fully redesign it approaching a new technology to reach the final result instead to use the traditional metal forming option. In fact this last one seems to have reached his limits related to performance in terms of time needed. Many alternatives have been evaluated and the one with the highest performances in terms of time saving and quality of the final product it has seemed that one related in some way to the rolling technologies.

Rolling technology is applied to obtain constant sections profiles along the axis development of truss elements. Any time the producer wants to obtain new profiles, new rolling tools have to be used. There are already industrial applications (like Nakata Industries) which allow producing more than one type of profile using the same rolling tools. This is possible due to the fact that the rolling tools which are made by shaped cylinders, have the chance to pivot on their axis and, in this way, they offer different profiles to the blank on which they work.

The new type of metal working idea takes the first step from this consideration: any portion of the conic poles has to be considered like a portion of a rolled bar having that section. It is clear that, if any section of the conic pole is different from the section which stay before and after it, the conic pole production may be considered like a: "rolling process where sections continuously change from the first to the last section of the pole". Starting from this definition as the possible solution in order to find innovative procedures, many possible solutions were available. The idea on which the working team has concentrated its attention is basically based on a forming tool made by two cylinders (Fig. 4) with an appropriate: profile and kinematics in which the shaped blank is fed in order to form it having as product the final shape for the conic pole.

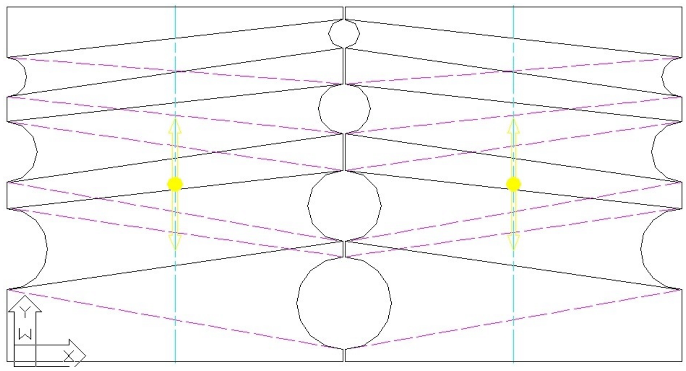

Fig. 4. Schematic representation of a new forming philosophy based on "profiling forming"

Analyzing the front view of the forming area of the machine (Fig. 4), in which there are two different cylinders rotating around their respective axis at the same velocity (cylinders axis are in y direction in Fig. 4) in opposite direction and also translating along y. Due to the cylinders rotation, the shaped blank is taken between them and, thanks to the fact that they are also translating along their axis, it meets always different sections, which are the ones of the conic pole.

In this way, it is possible to obtain the following results:
- The production speed is higher than the one obtained with the traditional method
- The forming tools have a very compact layout

The "state of the art" of the traditional pole process method can be easily compared with the proposed method in terms of process advantages like the ones mentioned above (Fig 5).

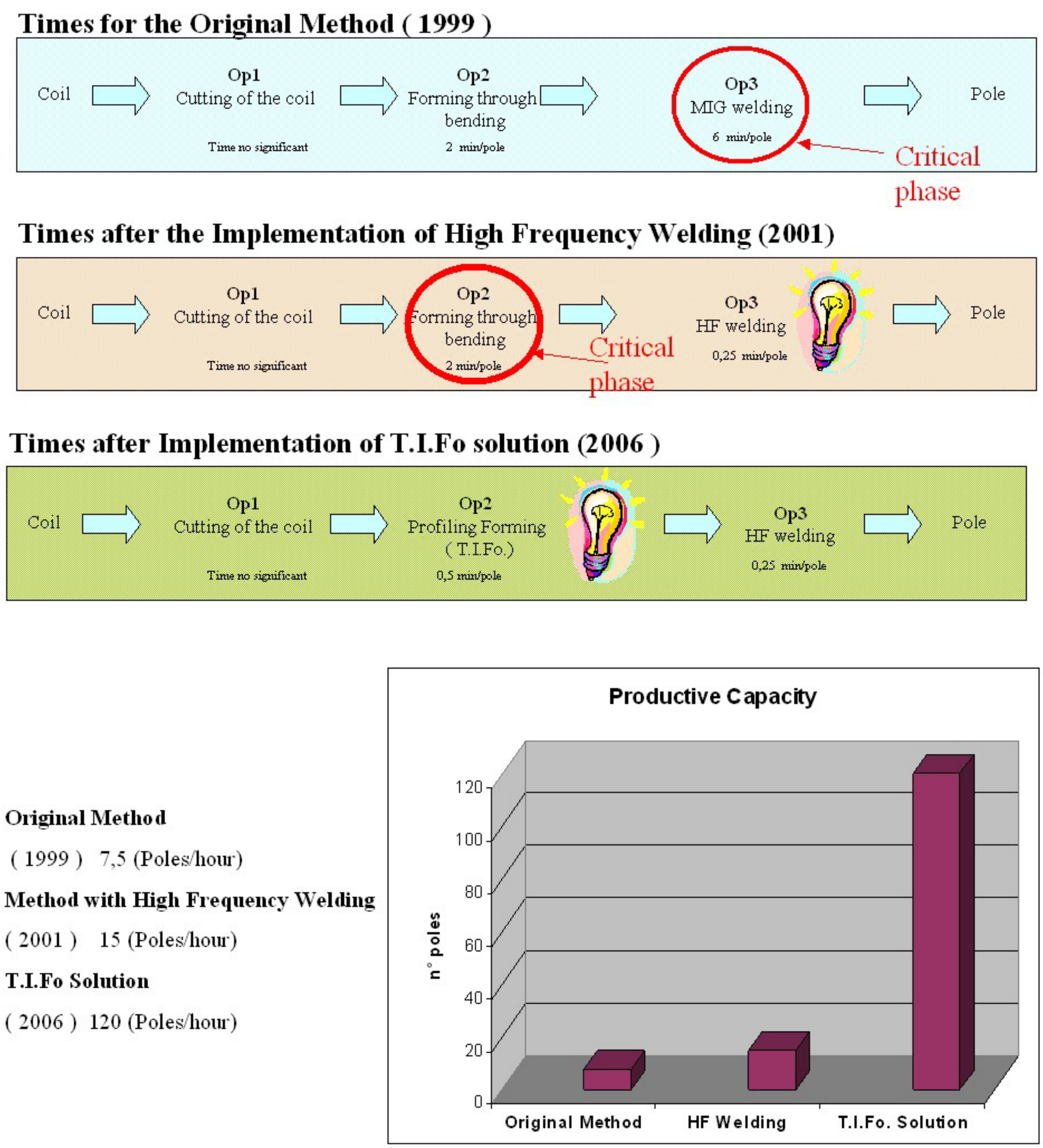

Fig. 5. Overview of the possible advantages obtained with the proposed method.

From the increased production capacity point of view, with new production method is possible to have a theoretical value of 120 (poles/hour) instead of the 7,5 (poles/hour) of the original method and, finally, to make comparable the forming and the welding needed times on the production process.

Steps of the R&D phase

The project had many aspects which were not known and for this reason a deep investigation of their influence on the problem sensitivity was needed. The usage of CAD/CAE techniques was a forced way in order to have feasible results useful to develop the new tool. Even the chance to implement process automation tools it was something needed in order to explore all the possible chances in the design space for the tools geometry and kinematics in a reasonable time frame. The developed workflow was made up by the following steps:

- Geometry definition in the Solid Works® environment through a Macro which allows the user to define the geometric variables for the tools shape. The usage of this macro allows the user to do not use the CAD tool in order to directly obtain the wanted shape in iges format ready to be read in the pre-processor module HyperWorks® HyperMesh®.
- Model Set Up : properties definition, boundary conditions assignments and LS_DYNA input file write out. Also in this phase a customized automation was implemented in order obtain the wanted data with: the right quality in the minimum time frame.
- LS_DYNA run execution and a post processing with automatic reporting of the interesting output via the post-processor HyperWorks® HyperView®.
- Results analysis comparing different solution in order to develop the optimized process solution.

Tools definition: The final shape has been obtained using two profiled cylinders. Their relative motion offers to the fed blank time by time the right section profile to form the decreasing or increasing sections. For the given complete geometry: initial and final diameter and total length, the CAD macro has been developed in order to drag the half conic profile on each cylinder. It is a matter of fact that, the way how to position the half profile is function of the profiled cylinders geometry: total height and diameter. Depending upon these parameters also the number of steps are chosen in order to wind the half profile.

Automation in CAD generation

A couple of profiled cylinders has been designed to produce poles of 12800mm length, 188mm as initial diameter and 60mm as final diameter. The used process philosophy is mainly based on the idea to start from a cylinder and to wind the axis of the pole around the cylinder itself. The final geometry of the cylinders can be obtained trimming the surface of the cylinder with that one of the helicoidal profile. Winding the previous axis around the cylinder, a helix is obtained, for which the main characteristics are: diameter, pitch and revolutions. The helix goes from 188mm of diameter at the bottom to 60mm of diameter at the top of the cylinder. The relations between the previous variables are:

$$s(\varphi) = \sqrt{r^2 + h^2}\,\varphi$$

$$\varphi = 2\pi n\,,\ \ p = 2\pi h$$

so it is possible to write:

$$D = \sqrt{\left(\frac{s}{2\pi n}\right)^2 - \left(\frac{p}{2\pi}\right)^2}$$

where:

s= helix length, that is also the pole axis length (12800mm)

φ= angle described by the helix, that is a multiple of 2π

r= helix radius, that is also the radius of the cylinders (calculated by the macro)

D= (r/2) helix diameter, that is also the diameter of the cylinders (calculated by the macro)

n= number of revolutions pitch (introduced by the operator in the macro)
$p = 2\pi h$ helix pitch (introduced by the operator in the macro).

It is very simple to understand that the length and the initial and the final diameters of the pole are constant quantity while diameter, pitch and revolutions of the helix are variables quantity. It is also necessary to produce many different CAD of the profiled cylinders in order to test them and to find the best solution (Fig. 6).

It has been created a MACRO which generates the CAD of the profiled cylinders after the introduction of the pitch and the revolutions of the helix. The diameter of the cylinder is calculated as a consequence because the previous diameter, the pitch and the revolutions of the helix are related to the length of the helix itself, which must be 12800 mm.
Calculations are made in Microsoft Excel®. With Visual Basic® is possible to create a macro which connects SolidWorks® and the primary excel file, in order to create the CAD of the solid element and to export it in iges format (Fig. 7).

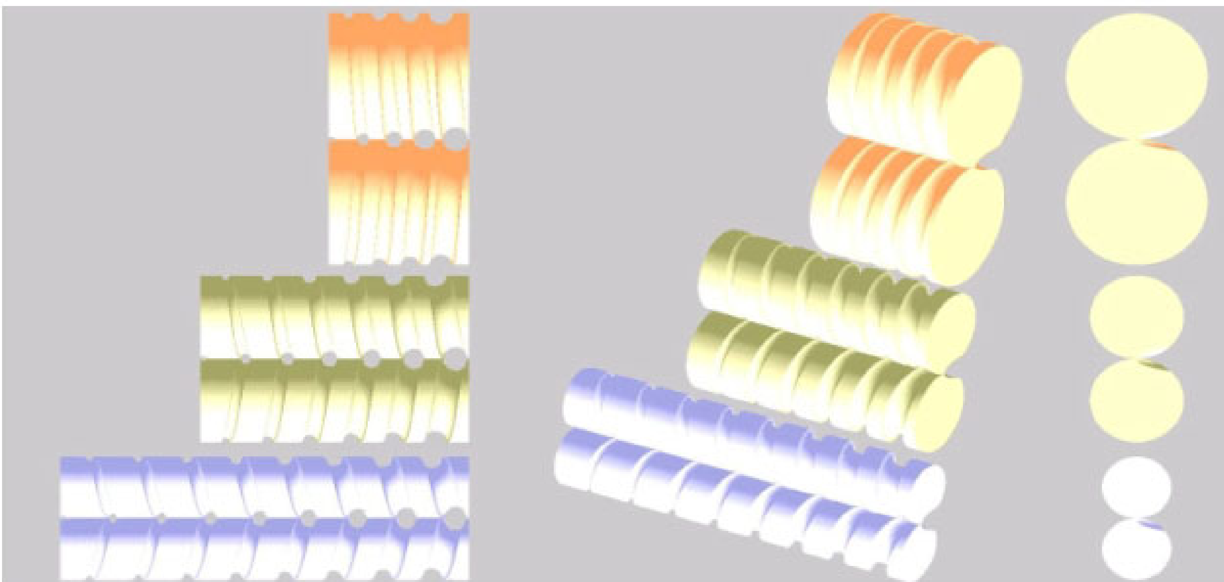

Fig. 6. Possible solutions evaluated

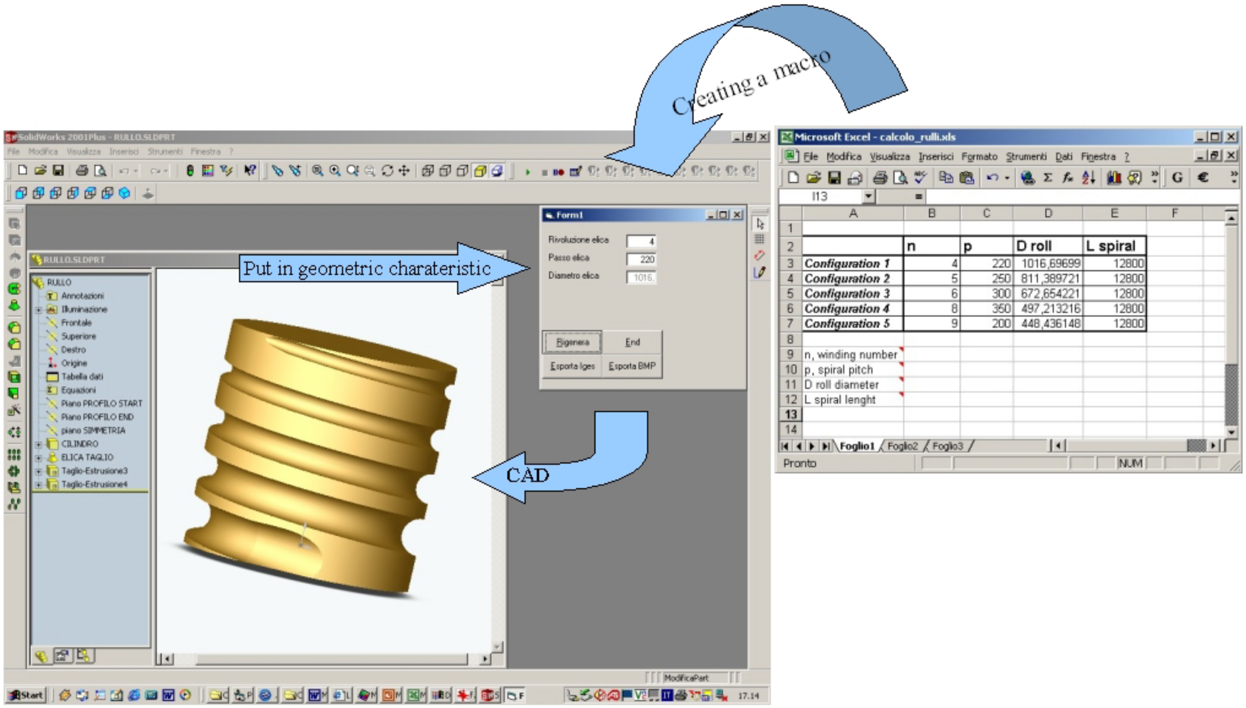

Fig. 7. Automatic CAD generation

CAE activity: simulation and results

The workflow for the CAE activity set up was implemented in an automatic procedure through the Altair HyperWorks Process Studio® and Process Manager® tools which allow the user to create, deploy, and run automated processes within HyperWorks®. This solution had allowed to cut out all the requested time for normal set up reducing dramatically the amount of time needed due to the high number of runs.

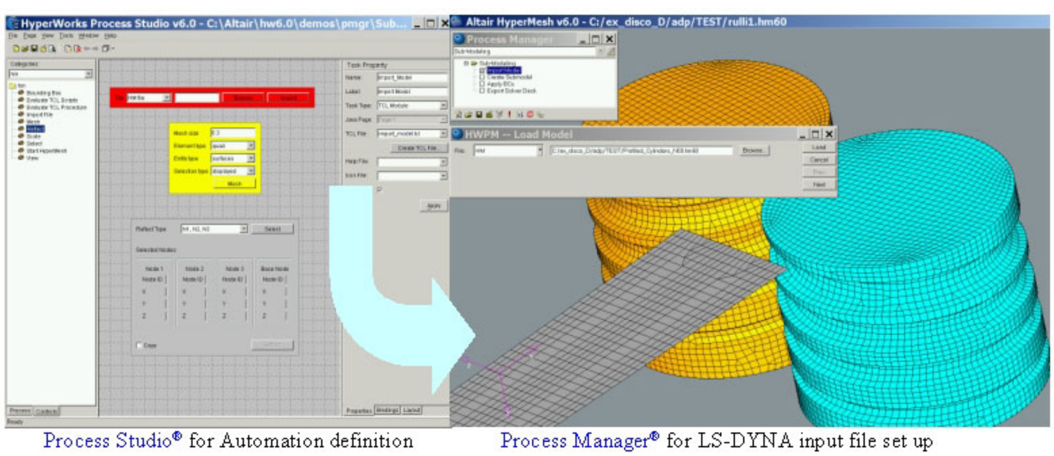

Fig. 8. Process Automation for input set up

The specific options available in LS-DYNA in order to control rigid body kinematics were successfully implemented. The used option were the kinematic constraints assigned using the available cards for the rigid materials assigned to the tools (MAT_RIGID OPTIONS CON1 and CON2) and the cinematic rules assigned to the tools (*BOUNDARY PRESCRIBED MOTION RIGID). Many configurations were tested thanks to the fast set up and solver options chosen (Fig.9). Useful information to the designer was delivered in order to define the prototype tools needed for the testing phase of the new forming process.

Fig. 9. Forming simulation results for one of the tested solutions

Conclusions

The virtual development for innovative forming solutions through LS-DYNA explicit module has allowed one to find a feasible configuration for tools geometry and process variables set up giving a feedback on the quality of the final product. Even if the final solution has to be validated through an experimental verification, LS-DYNA has given a strategic contribution in terms of time and cost savings for the process development of the conic poles forming technology. The reached stage has to be considered not as an arrival point for this kind of application. On the contrary, it has to be considered as a starting point from which it will be possible to investigate new forming solutions in the case of conic poles with different shapes and dimensions for example in the case of conic poles which have to be produced with different lengths and different conic ratios or/and different section shapes.

Further developments

The dimensions of the pole are strictly connected to the dimensions of the designed profiled cylinders. So, with a couple of cylinders is possible to produce only one type of pole, with fixed length, fixed initial and final diameters. From this point of view, the most interesting and successful future development will be about the possibility to produce more than one type of pole with the same tool. Moreover, further steps for CAE usage are considered like for example, the application of Optimization software tools in order to investigate optimal solution from both points of view: product and process.

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