RollerPaG a tool for the automatic path generation for roller hemming simulation using LS-DYNA

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1 Introduction

Compared to tool or table-top hemming, the roller hemming is unique by its specific kinematic. A robot guides a roller along the flange to perform the hemming, with more than one robot used for an assembly in order to speed up the process. Main advantages of the roller hemming are low investment for a new product and short lead time to design and manufacture product specific equipment. Application of roller hemming was up to now restricted to low and middle volume production, though new developments made it more suitable for higher production volumes as well.

Because of its special kinematic, the setup of the roller hemming simulation can be rather cumbersome and very time consuming. It is indeed necessary to describe the movement of the rollers along the flange in an accurate way. This paper describes a concept to set up simulation models of roller hemming processes with a high degree of automation. As an essential part of this concept, program *RollerPAG* is used for the automatic generation of the LS-DYNA input decks including Master Input Deck and the Load Curves which control the rollers motion and orientation during the simulation.

2 Basic Concept

The motivation for the development of program *RollerPAG* was to provide a tool for an easy as possible setup of an FE model for the simulation of roller hemming processes. While the output generated by program *RollerPAG* can be used for LS-DYNA simulations only, the approach for an almost automatic setup of roller hemming simulation models described here can be seen as a generic concept which means that it is not restricted to LS-DYNA.

The parts involved in roller hemming usually consist of an *inner* and *outer* part, a *hembed*, *blank holders* and, optionally, *guide pins*. The user has to provide a description of these parts in terms of an FE mesh and material and section data. What the user also has to provide are curves describing the path for the rollers to travel along. For each path, two parallel curves, used to control the motion and orientation of the roller and discretized by beam elements, have to be provided. Everything else is generated automatically by program *RollerPAG*.

RollerPAG is a standalone tool. This means that there are no restrictions concerning the tools used for the generation and discretization of the parts and curves. A usual approach is to create the FE mesh of all parts and curves with the user's preferred preprocessing tool which could be a CAD software. Almost no restrictions concerning the mesh quality have to be met for parts *hembed*, *blank holders* and, optionally, *guide pin*s since they are usually modelled as rigid parts. An alternative approach consists of generating the mesh for those parts by offsetting the mesh of parts *inner* and *outer.*

2.1 Discretized Path Curves Concept

The discretized path curves, used as input data for program *RollerPAG*, usually completely lie on part *outer.* Curve 1 lies at the interface of the flange and the main section while curve 2 lies some small distance away from curve 1 towards the center of part *outer*. Every simple 1D-mesher can be used for the discretization of the two curves. The length of the beam elements vary depending on the curvature. In straight sections of the curves or sections with big curvature radius, longer beam elements can be used compared to curve sections with small curvature radius. Not only the position and orientation of the rollers are controlled by the beam elements but also the velocity. To avoid

numerical issues, the roller velocity cannot be arbitrarily high and therefore the length of the beam elements cannot be arbitrarily long.

The discretized path curves are necessary for the generation of the load curves which control the rollers position and orientation. They are not needed in the simulation but can be included for visualizing the path.
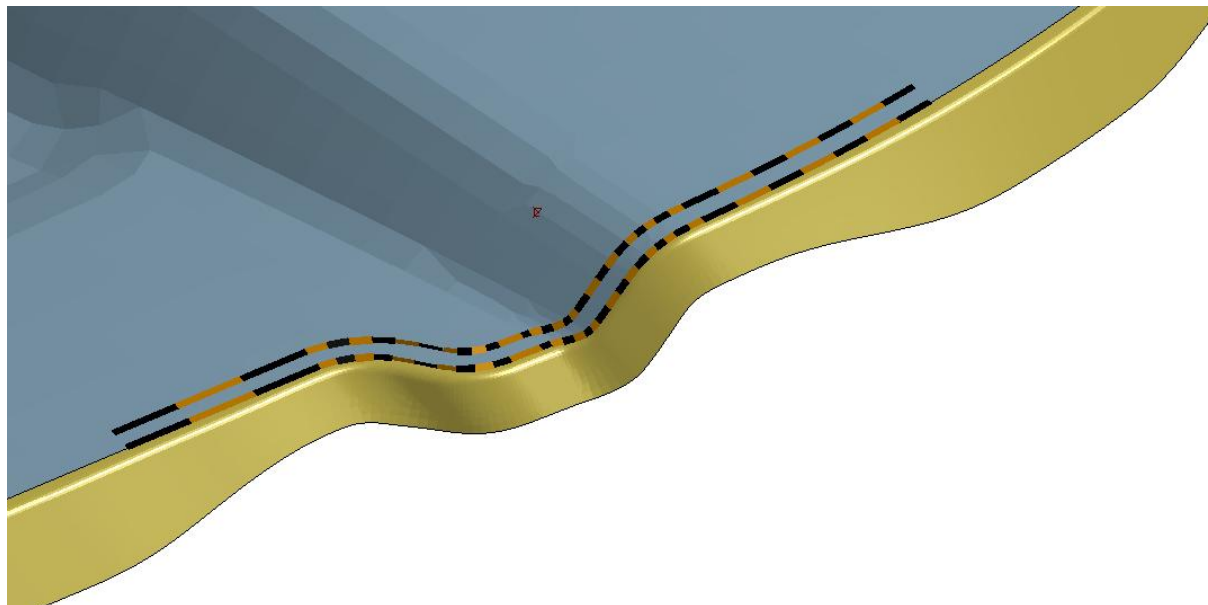

*Fig.1:   discretized path curves – curve 1 at the transition of **outer_main** (blue) and **outer_flange** (yellow) – curve 2 some small distance away towards the center of part **outer***

2.2   Roller Repository Concept

A repository of rollers of different sizes and shapes exists. Additional rollers can easily be added to this repository. Only few modelling conventions have to be followed before adding a new roller to the repository in order to be applicable by program *RollerPAG*.

In the Master Input Deck, which is generated automatically by program *RollerPAG*, the user declares which roller from the repository is used for a particular path. In general, the position and orientation of the rollers in the repository can be chosen arbitrarily. Program *RollerPAG* identifies the rollers position and orientation when generating the load curves. Within a particular project though, to have the possibility of an easy exchange of the various rollers, it is advised to use the same position and orientation for all rollers of the repository. In repository position, the roller can penetrate one or multiple parts since the contact is not activated before the initial positioning of the roller.

Since all of the rollers in the repository follow the same modelling conventions, the load curves used to define the rollers motion, orientation and velocity, do not depend on the roller. Therefore, if the user decides to use a different roller along a particular path, the current roller can easily be replaced by a different one in the ***INCLUDE** statement of the Master Input Deck without changing the corresponding load curves.

2.3   Roller Approach Concept

The discretized path curves lie completely along the flange which has to be formed. It is not necessary to define the approach and detach of the roller. These process stages are controlled completely by the load curves generated by program *RollerPAG* and are calculated from the start points and end points of the two parallel path curves. The whole movement of a particular roller can be subdivided into the roller movement steps ***delay***, ***jump***, ***initial rotation***, ***approach***, ***hemming*** and ***detach.***
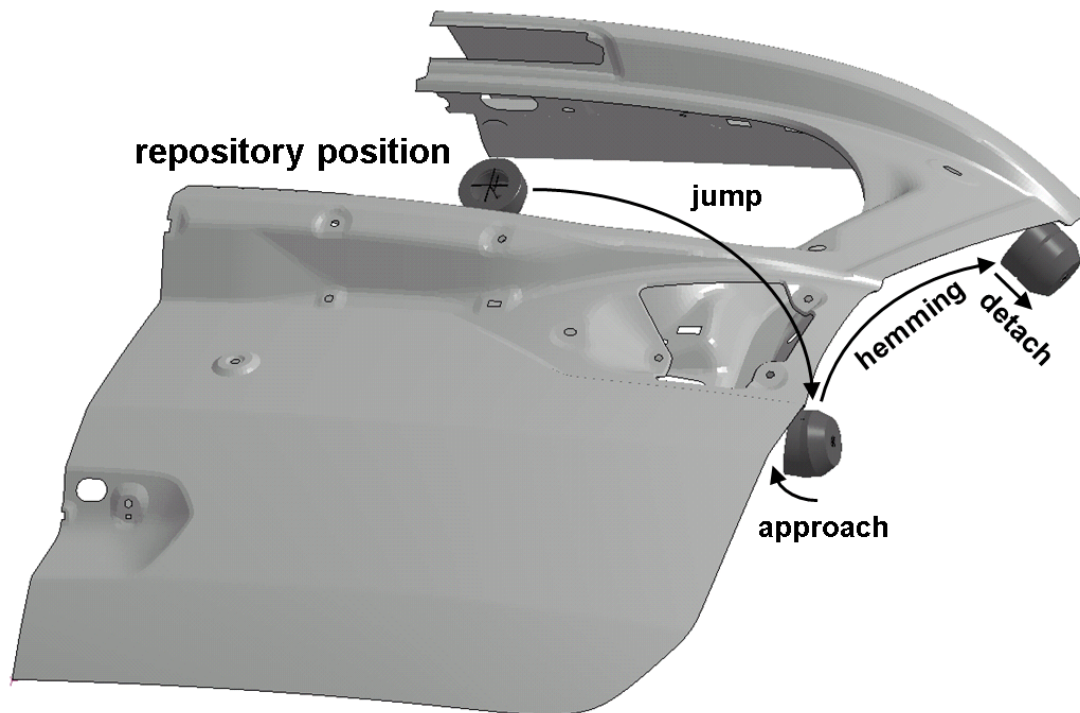
Fig.2:   Illustration of the roller movement steps

delay
The roller stays in the repository in the initial position and orientation.

jump
The roller is translated and rotated into the start position of the approach which entirely depends on the path curves. The jump is usually performed in one incremental step.

initial rotation
This step is usually part of step *jump* but may be defined as an independent roller movement step.

approach
The roller approaches the flange. During this step, the roller comes into contact with the flange. Therefore, the roller velocity is reduced in order to avoid numerical instabilities or non-physical deformations of the flange. The roller approach is a combination of translation and rotation. After approach, the roller has reached the start position for the hemming process and is positioned with the user defined pitch.

hemming
The roller moves along the path which is given by curve 1. The rollers position depends on the thickness of parts *inner* and *outer* while its orientation is controlled by curve 2, curve 1 and the user defined pitch for the current path and process step. The pitch can vary along the path.

detach
The roller is moved away from the flange so that the two parts are no longer in contact with each other.

3 Roller Hemming Process Setup

The images in this paper show an academic like process setup with three explicit roller hemming simulations step1/step2/step3, followed by one implicit springback simulation. For roller hemming simulations step2 and step3 and the springback simulation, the geometry and stress and strain distribution of the previous simulation is used by reading the corresponding dynain file.

The simulation model of this rear deck lid is set up with one half of the symmetric part using symmetry boundary conditions. The flange is divided into four segments. In each of the three roller hemming simulations, four rollers with diameter 60mm are running one time along one of these flange segments, using a different pitch angle in each of the three simulations. In addition, some sections of the flange with small curvature are formed by small rollers of different diameter. The small rollers are running along a particular flange section after the big rollers have passed this section.

This is a very simple and academic like process setup. Real world roller hemming processes follow a more complicated process scheme. On different stations, cylindrical and conical rollers of different size are running back and forth a particular section of the flange. RollerPAG is able to generate the LS-DYNA input files to simulate such real world roller hemming process shemes.
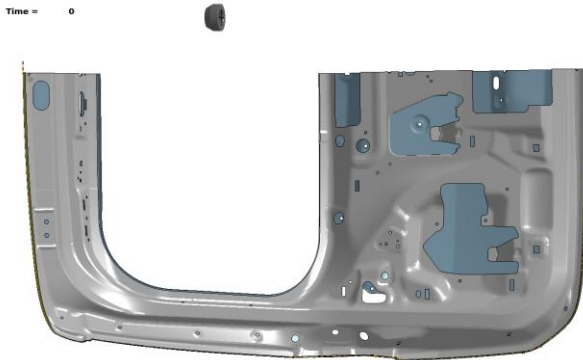
Fig.3: *Simulation step1 (pitch=80°) time t=0.000 All rollers in repository position – Initial geometry*
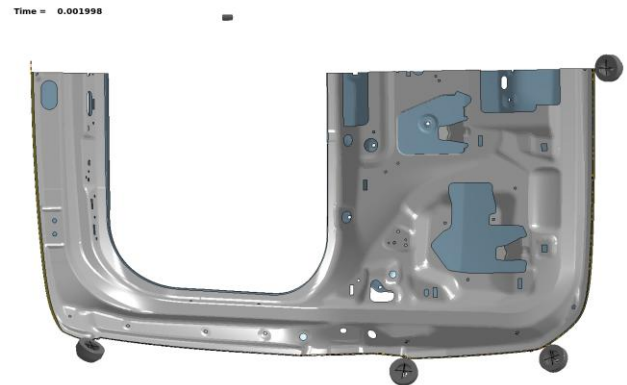
Fig.4: *Simulation step1 (pitch=80°) time t=0.002 Big rollers after jump and before approach Small rollers in repository position*
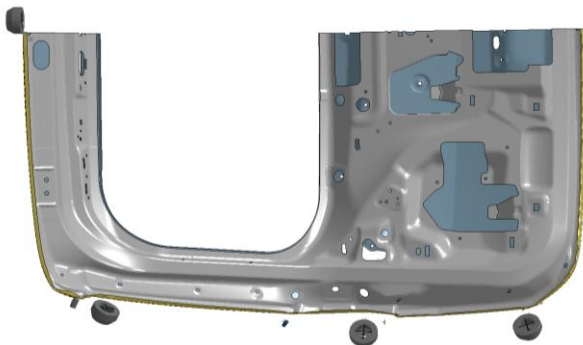
Fig.5: *Simulation step1 (pitch=80°) time t=0.270 After first hemming step and roller detach*
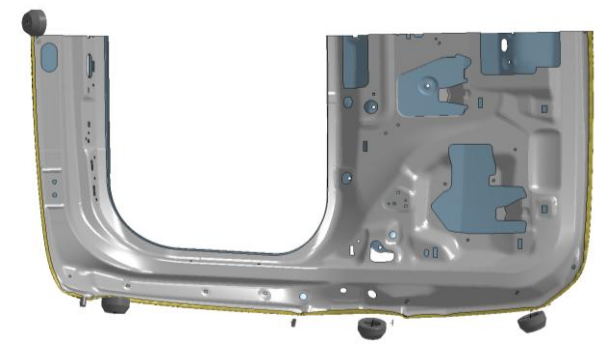

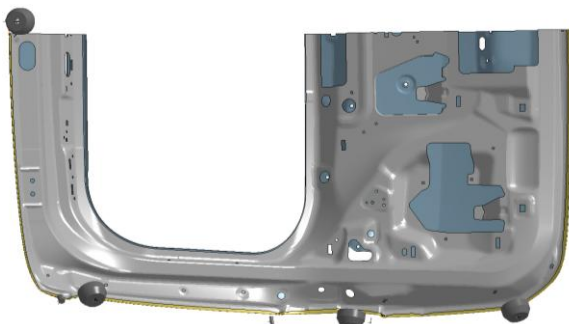*Fig.6:* *Simulation step2 (pitch=40°) time t=0.570 After second hemming step and roller detach*

Fig.7: *Simulation step3 (pitch=0°) time t=0.870 After final hemming step and roller detach*

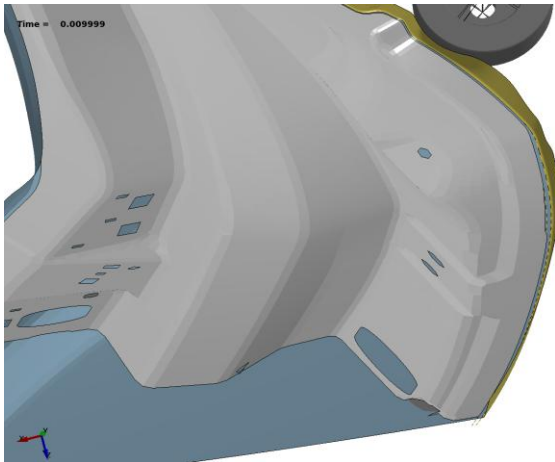*Fig.8: Flange4 step1 (pitch=80°) at t=0.010s (after jump and approach, before hemming)*

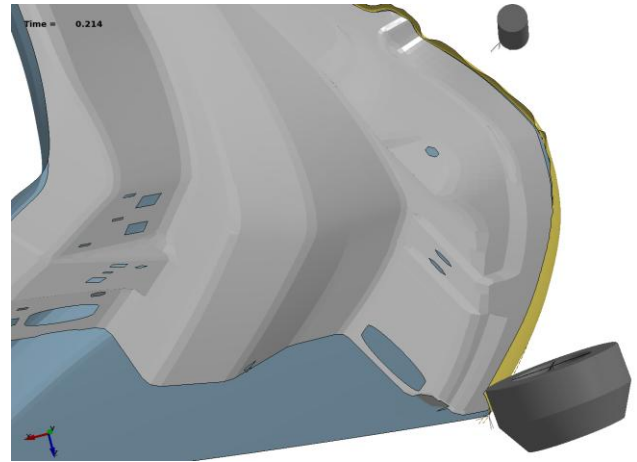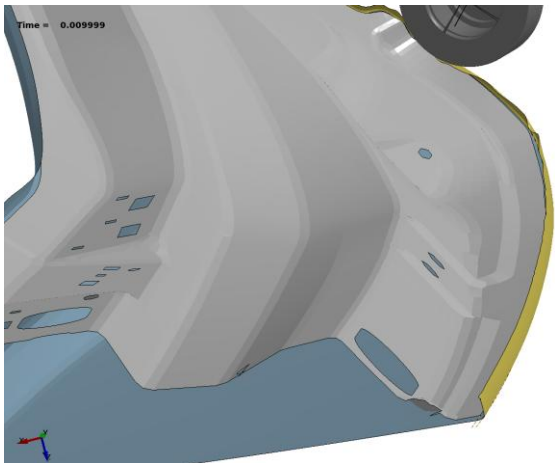*Fig.9: Flange4 step1 (pitch=80°) at t=0.214s (after hemming, before detach)*

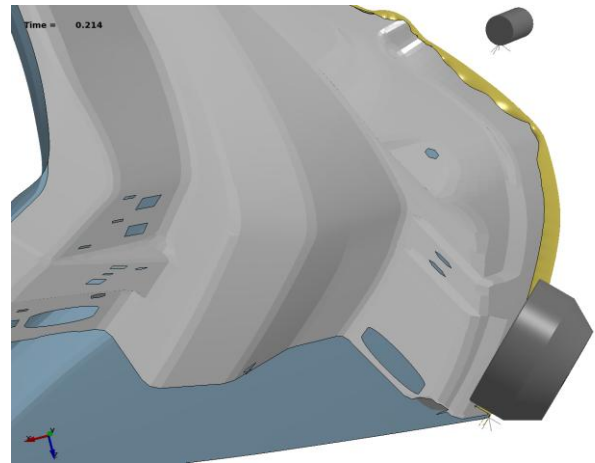*Fig.10: Flange4 step2 (pitch=40°) at t=0.310s (after jump and approach, before hemming)*

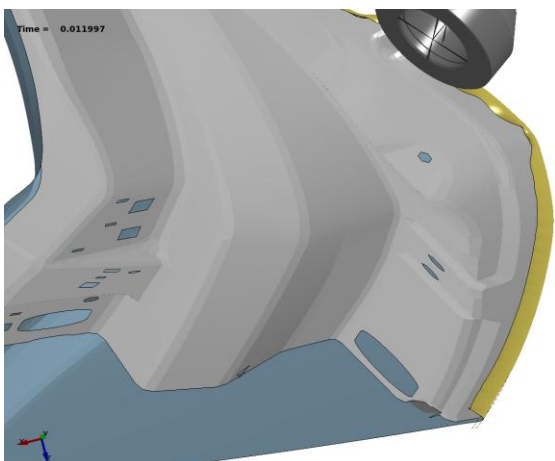*Fig.11: Flange4 step2 (pitch=40°) at t=0.514s (after hemming, before detach)*

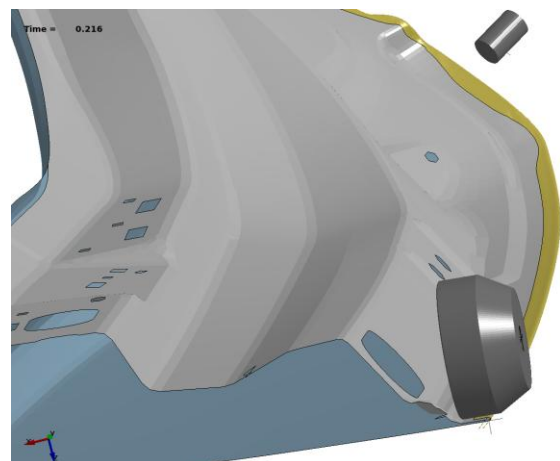*Fig.12: Flange4 step3 (pitch=0°) at t=0.612s (after jump and approach, before hemming)*

Fig.13: Flange4 step3 (pitch=0°) at t=0.816s (after hemming, before detach)
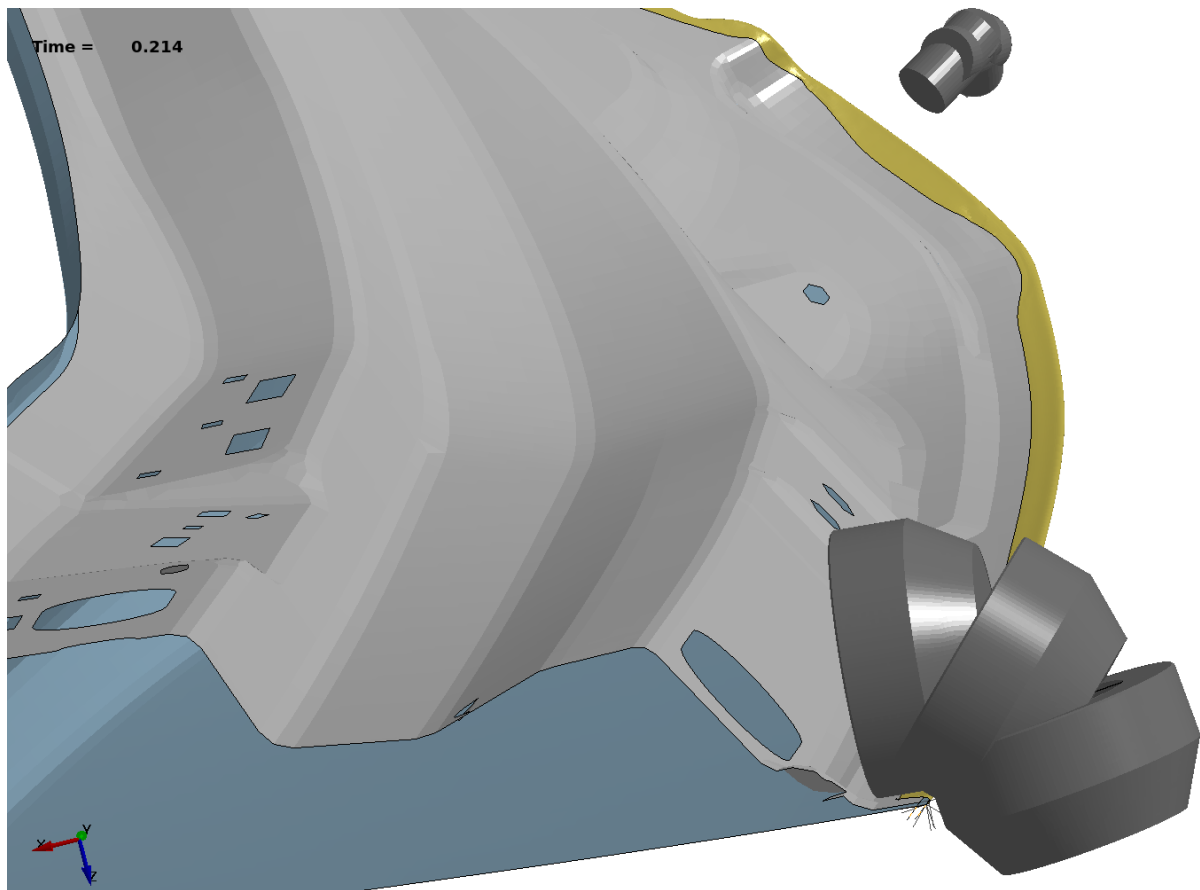
Time =   0.214

Fig.14: Overlay simulations step1/2/3: Rollers in same position, same orientation, different pitch angle
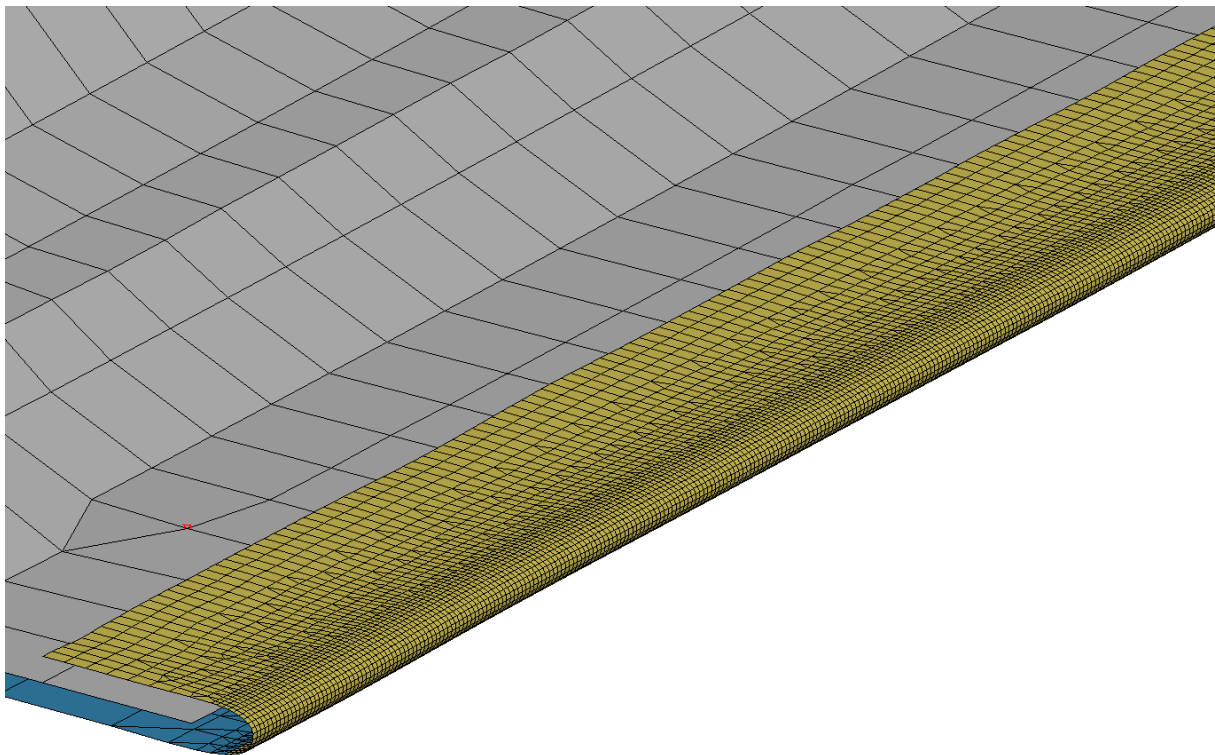*Step1: pitch=80° (10°) – Step2: pitch=40° (50°) – Step3: pitch=0° (90°)*

Fig.15: Flange4 after final hemming step (mesh display mode)