Design and virtual analysis of a cam system for an automatic machine

C.Antonioli
Research & Development Department of P.E. S.r.l.
Labelling Machine Construction
Via A.Grandi,1 Marmirolo 46045 Mantova ITALY

The increase of production speed and efficiency, the development of new ideas, and the optimisation of performance of our production lines, is the aim of this research and development department. These results can be achieved with long tests and expensive trials on prototypes as well or even better with virtual prototyping.
In this study we would like to show the developing process of a special mechanism on an automatic machine, which applies labels on containers, based on the integration of CAD/CAM/CAE application.
Especially using the cad-embedded version of **Adams** and Solid Designer as CAD we were able to design and test a cam profile and moreover to generate the output path for final machining of the cam.

Introduction

What is a labelling machine?

A labelling machine is classified as an automatic machine, which applies one or more labels on a container. Typical speed of this kind of machine is approximately 24'000 bph (bottles per hour) but they can achieve also on a bigger model approximately 50'000 bph. The labels are stored in reels and there is a unit that, at this speed, cuts the labels to the right dimension in the right position before their application on the container. The machine has to be able to handle the containers at the proper speed during the transfer of the labels.

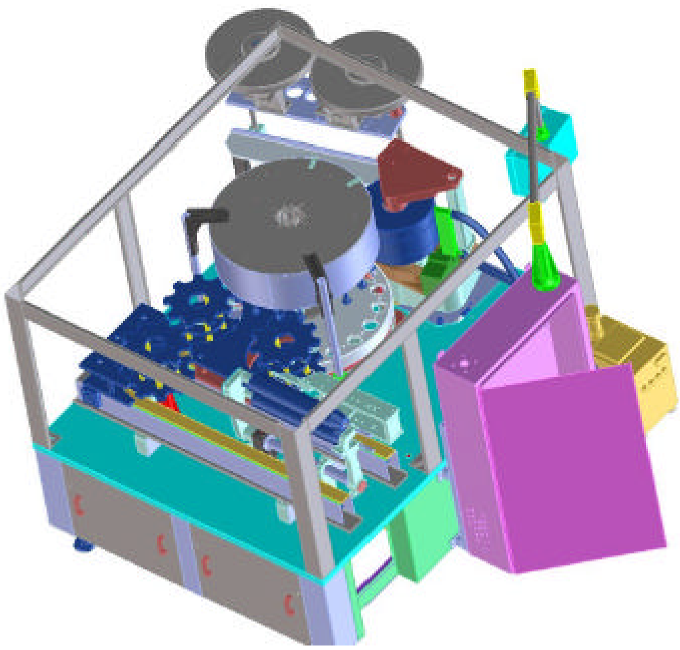

Figure 1: view of the whole labelling machine

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

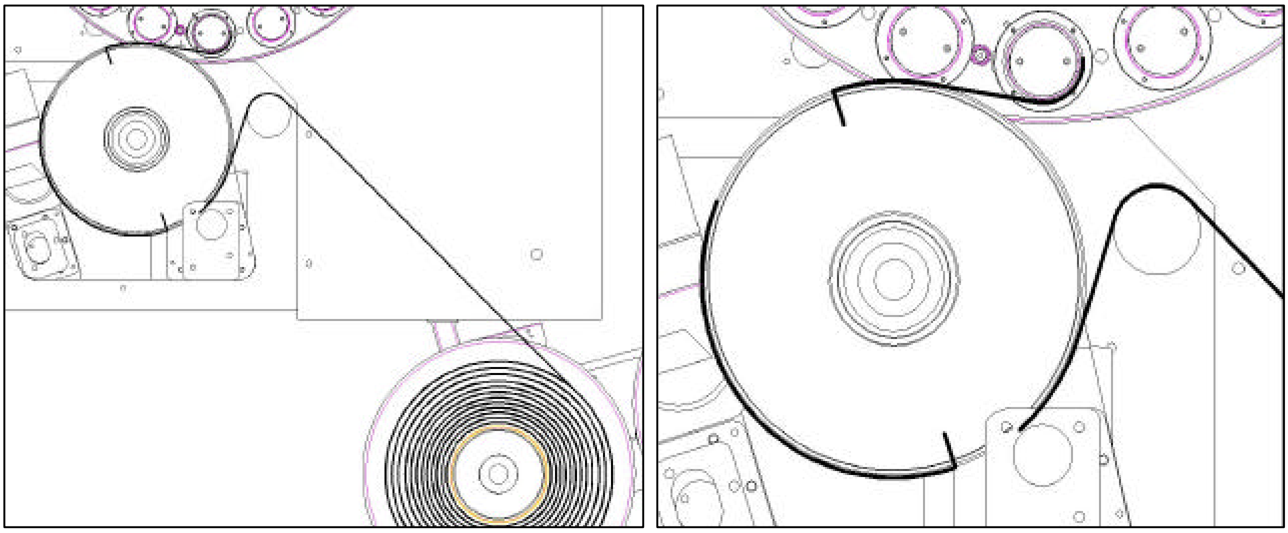

Figure 2: Cutting and transfer of the label on a container

Our study is on the mechanism, which drives the container. In our case, the container has a square shape and for this reason we need a more accurate control on the position of the container (for us the container is a PET bottle).
In any case, the machine has to manage bottles of different sizes. For these reasons, we have chosen a special conjugated positive cam that works as a single closed track cam.
We don't need springs and we can control exactly the position and the speed of the bottles and furthermore, one portion of the cam is designed as an interchangeable sector in order to run different bottles without having to replace the whole cam.

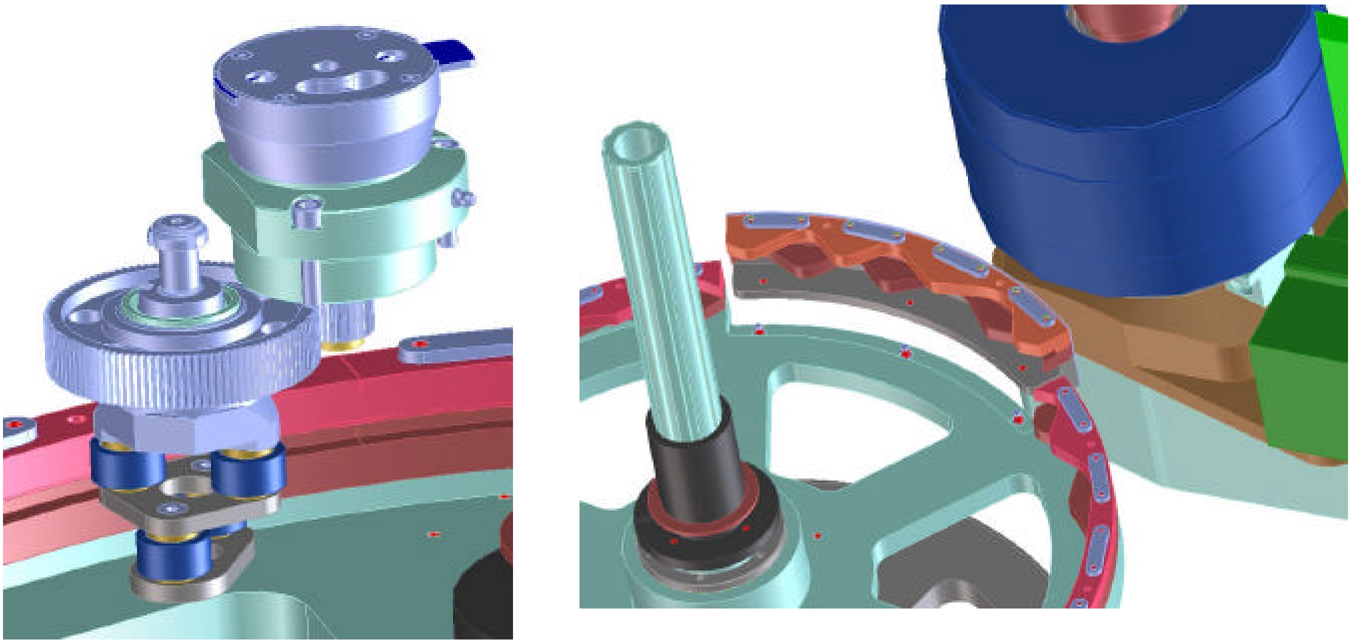

Figure 3: drive of the bottleplate and interchangeable sector.

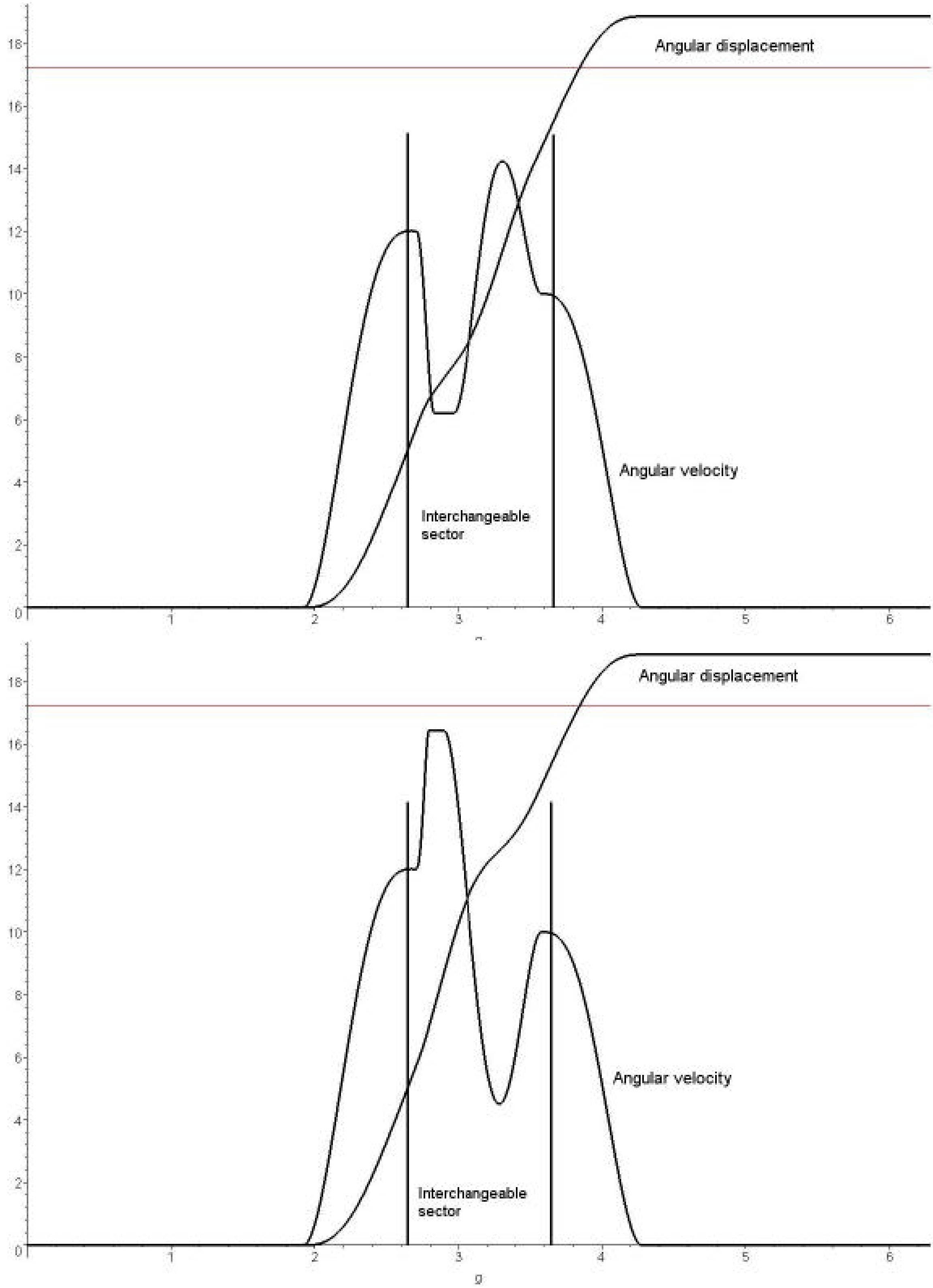

Figure 4: Different velocity profile for different bottles

(130 mm diameter above; 50 mm diameter below)

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

Design and analysis of the cam

The main requirement for developing this cam is the precise control of the bottle, independently from the machine speed, and the possibility to run different bottles through without having to change the whole cam.
Furthermore, another goal was to develop the most automatic process possible to design this cam, to test virtually its validity and finally to have the output ready in order to machine the cam.
The first step is to design and optimise the profile of the speed for the different bottles using a mathematical software ("Symbolic Computation Systems").
The second step is the implementation of the movement laws in a simplified model of the mechanism in ADAMS FSP to generate the profile of the cams.

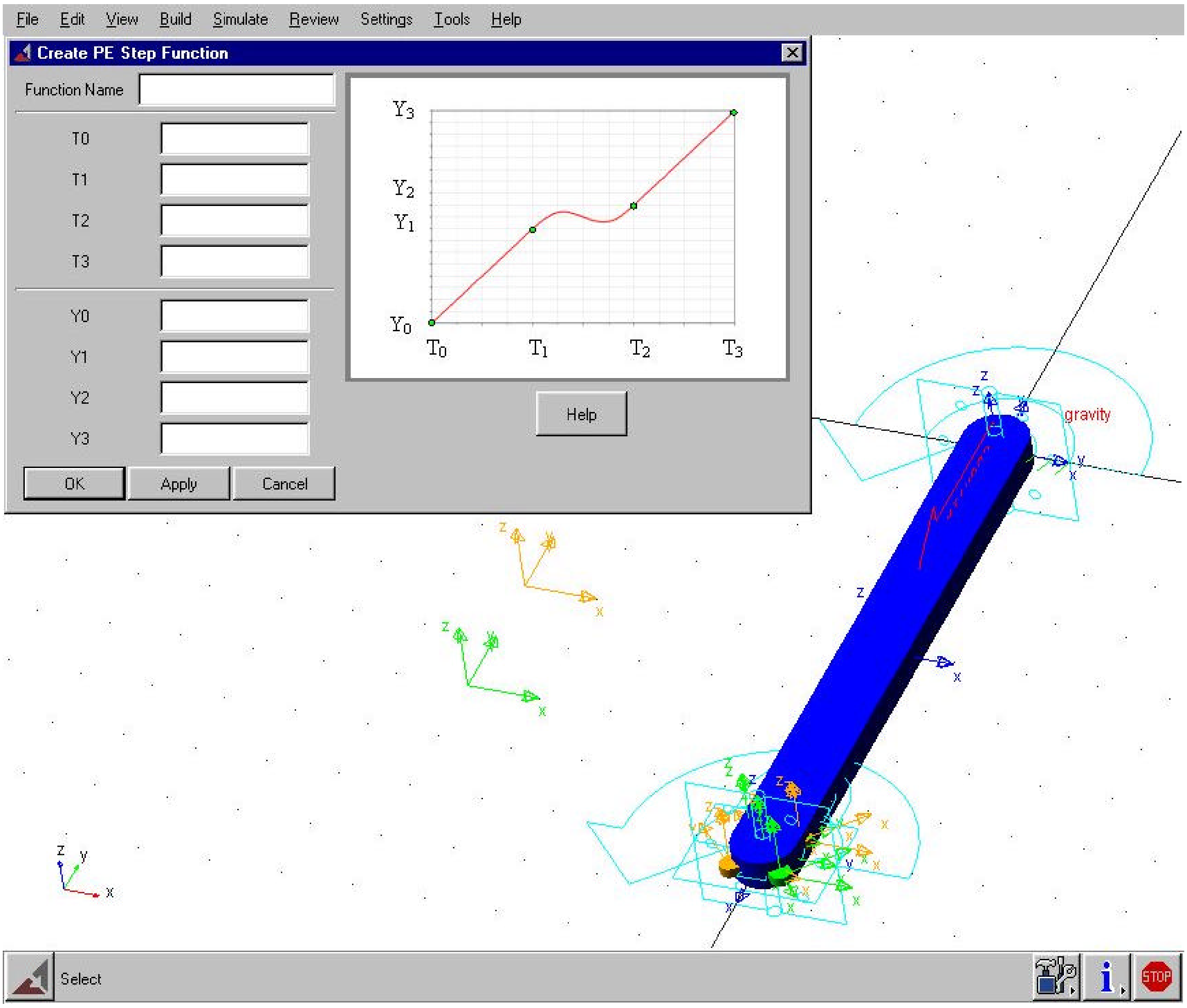

Figure 5 : Simplified model and interface of the personalised STEP 5 function

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

To handle these movement laws we needed a polynomial function of the fifth order with the control of the speed at the beginning and at the end of the curve. This type of function is not implemented in the standard version of ADAMS, so we required the development of this special function (it is a modified STEP 5 function). The whole movement is defined by a combination of four of these personalised functions.
We applied the obtained curve to the joint spider in order to trace the correct profile of the center of the rollers.
Because the joint spider is made up of two arms (upper and lower), each bearing two rollers, the profile of the rollers on the first arm is conjugated with the profile of the rollers on the second arm.

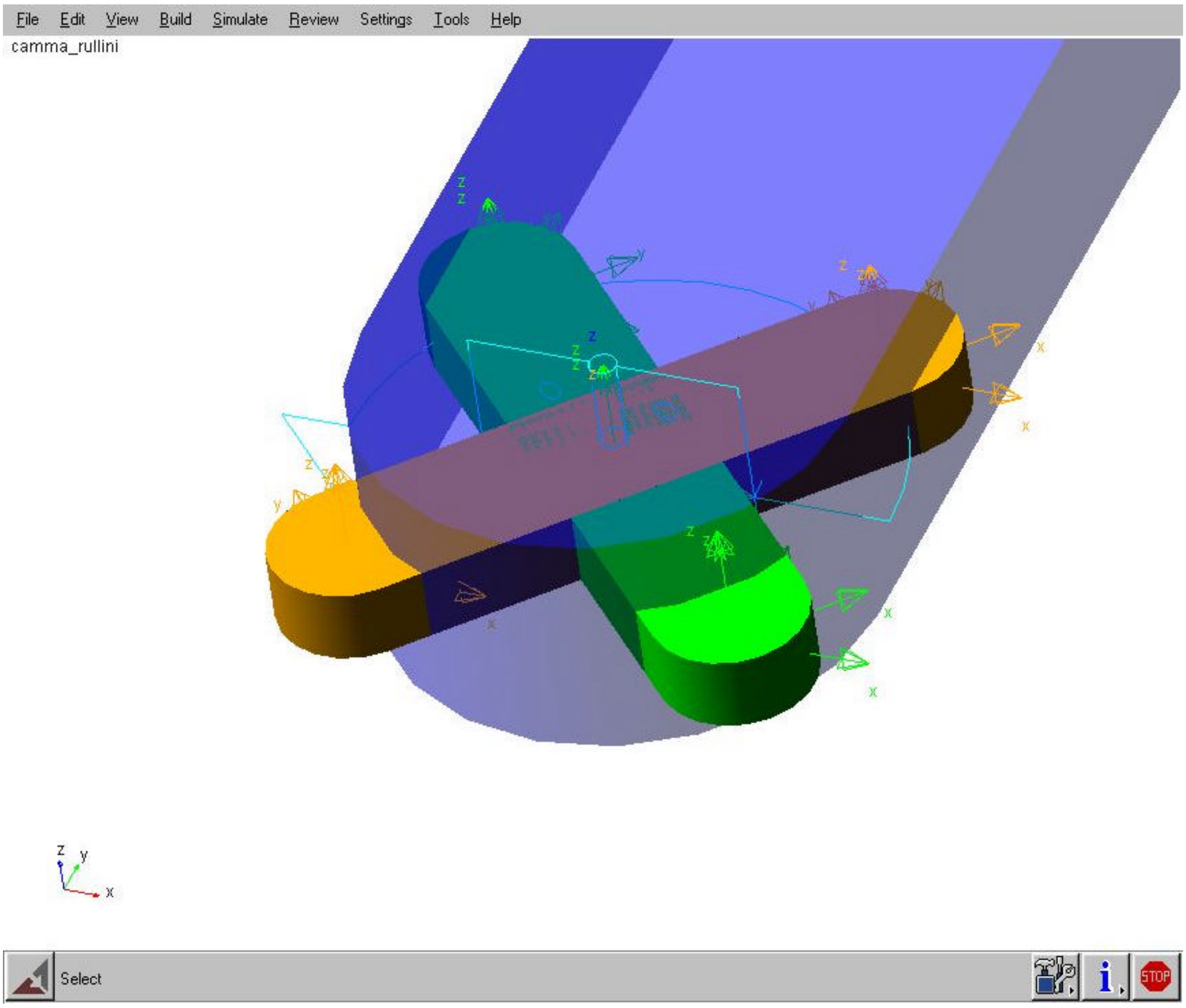

Figure 6: Joint spider simplification

The traced profiles are the paths of the single rollers but the profile to be designed must generate an intermittent contact. During the movement, at least one roller is in contact with the upper profile and one roller is in contact with the lower one (see figure 3).

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

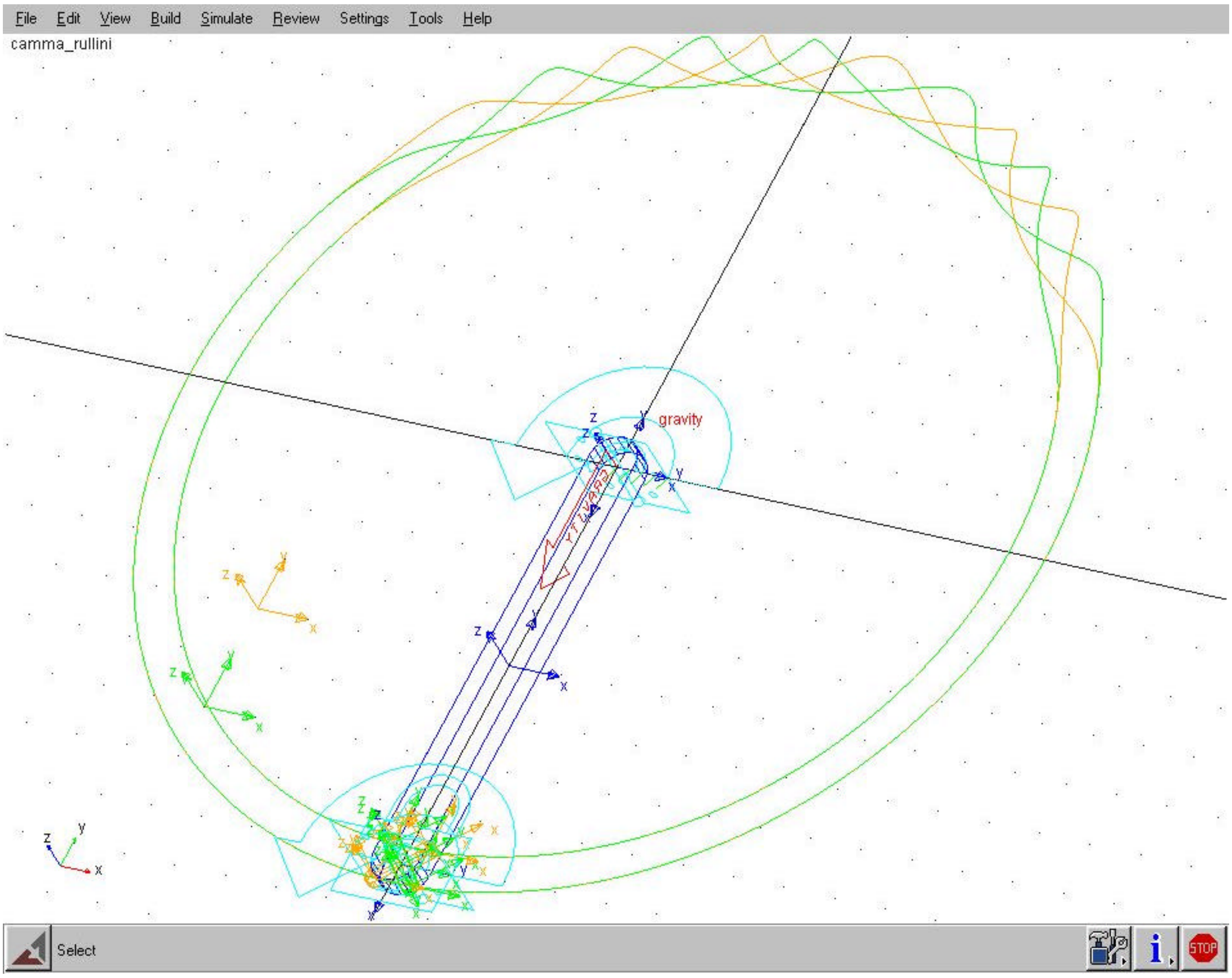

Figure 7: Envelope of the rollers' path

The correct cam profile for each pair of rollers (on the same arm) is obtained from the intersection of the two traced curves.
The data value exported from ADAMS (third step) must be processed with a Spreadsheet to obtain two different types of data. The first one is imported in to CAM application to machine the cam, the second one imported into SolidDesigner so to extrude the model of the cam.
The fourth step was within the cad-embedded version of ADAMS, SD/Adams. In it, by working on the same assembly utilised for the project of the machine (with the obvious reduction), we imported the model of the cam. Still in SD/Adams, we prepared the assembly with the definition of the rigid body, joints, couplers, motions, contacts circle-curve, so to be ready to export all within ADAMS FSP.
In Adams we performed both the cinematic and dynamic type of analysis, paying special attention in to the dynamic behaviour of the contact between the rollers and the cam. We checked the acceleration imposed on the rollers and the load on the roller itself, possibly to carry out the necessary correction of the motion laws.

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

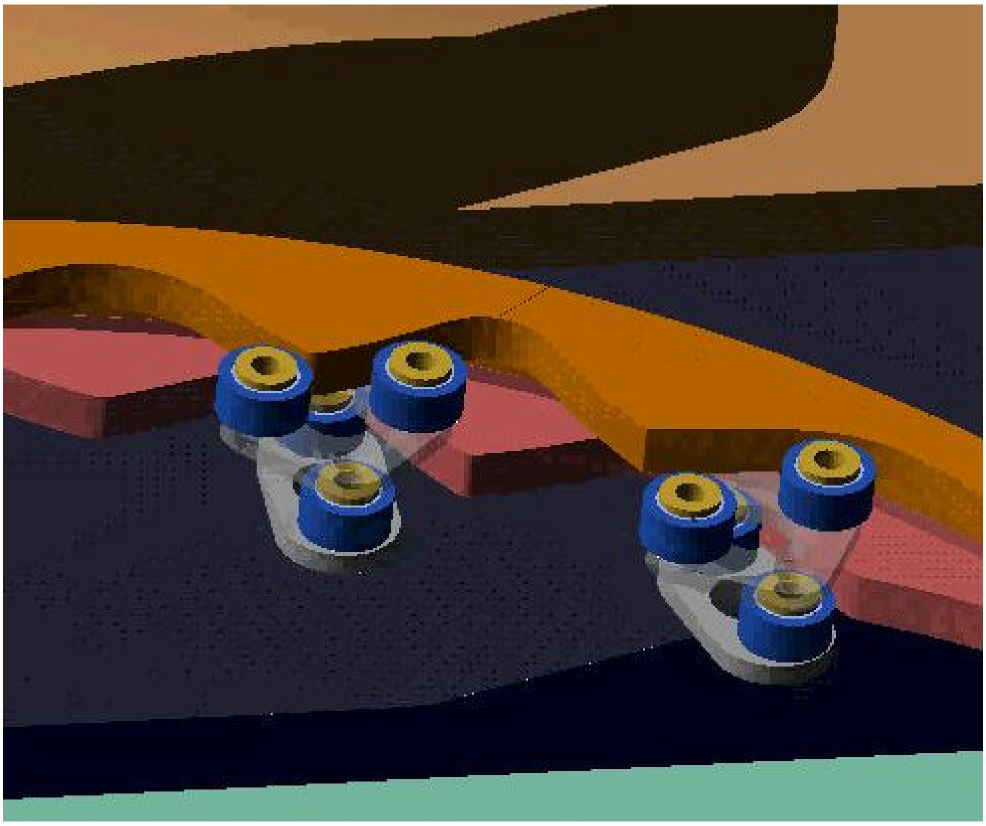

Figure 8: Detail of the intermittent contact rollers-cam

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

Results

The first result is the process itself, which allows us to obtain the cam profile in a shorter time. We have very high confidence level for cams of this complexity.

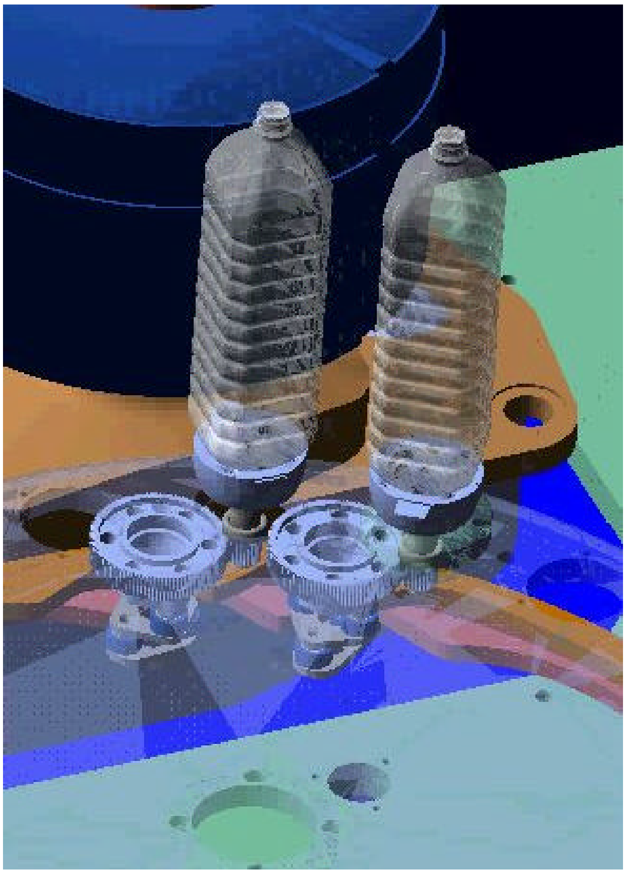

Figure 9: Image of the simulation

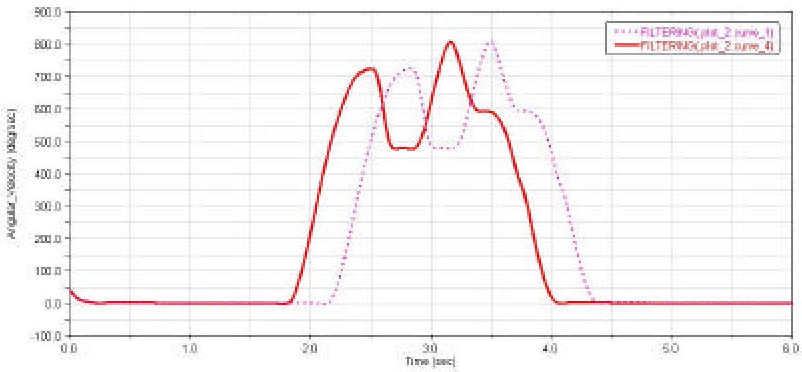

Figure 10: Velocity of the two joint spiders

We checked the speed of the rollers, the speed of the bottle and the contact force between the roller and the cam.

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

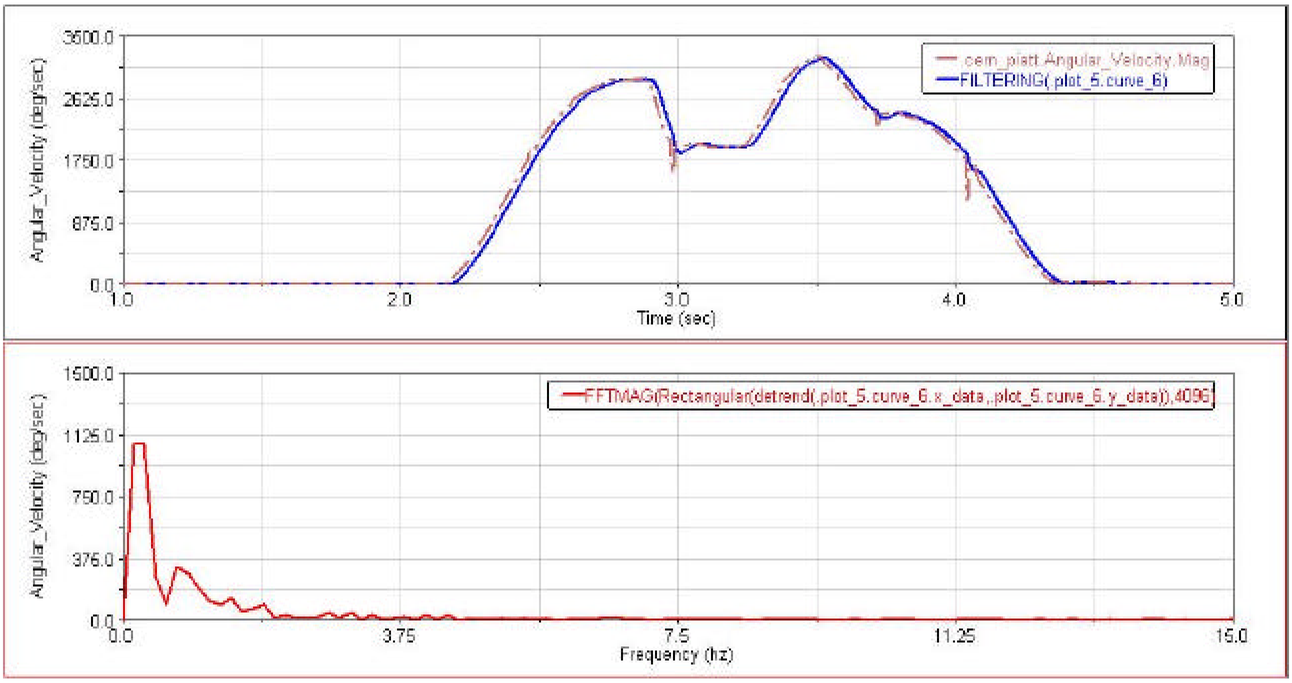

Figure 11: Velocity of the bottle and frequency response

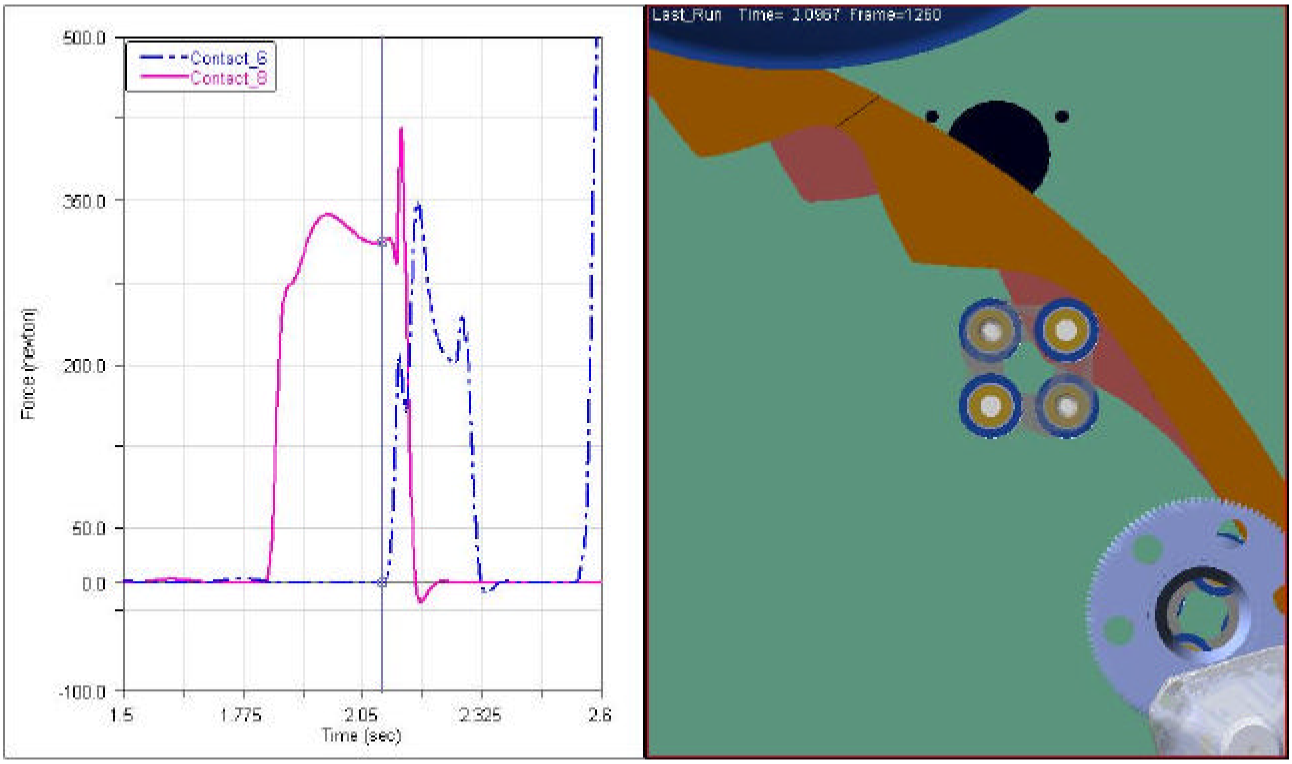

Figure 12: Contact force of the two first rollers in the acceleration sector

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it

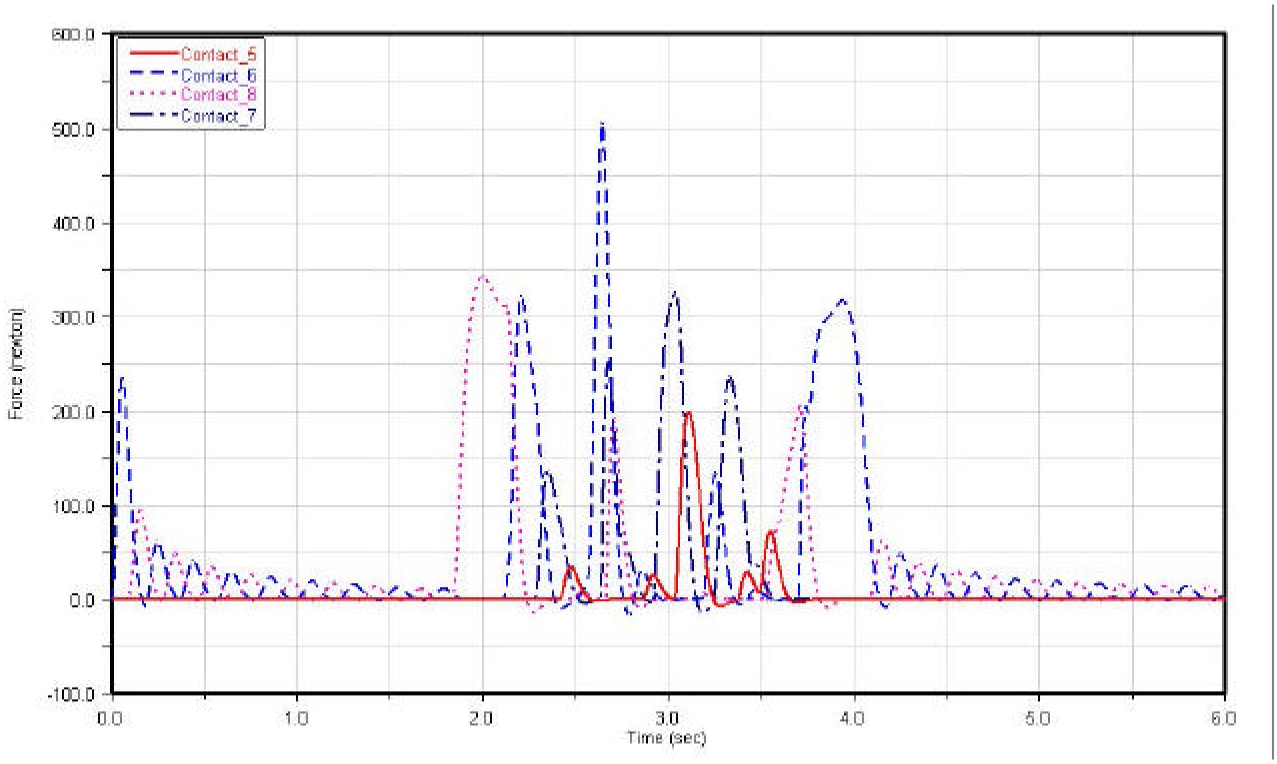

Figure 13: Intermittent contact forces on the four rollers

Conclusion

Based on this model we checked the advantages using an integrated system CAE, able, with an iterative process, to generate a mechanism movement driven by the complex cam profile.
But first of all, we can validate the design itself, before expensive tests and produce, at the same time, the output for the machine tool.
Furthermore, we have information about the limit of this mechanism in order to always achieve higher performance, and accuracy in the labelling process, without compromise the reliability of the machine.

P.E. S.r.l.
Via A.Grandi, 1
46045 Marmirolo (MN) – ITALY
TEL: +39-0376-298116
FAX: +39-0376-298112
e-mail: sviluppo@pelabellers.it