THE SIMULATION OF A LABELLING BLOCK: THE PALLET CAM SYNTHESIS.

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ABSTRACT

The subject of this paper is to show how the Adams Solver (used as the I-Deas built-in Mechanism Design) and the Adams View/Flex features were used to determine the pallet groove cam for a cold glue labelling block.
All the pallet contact points were mathematically described in order to get the point by point motion of the cam follower allowing the pallet rotation. In the fully constrained cases, the kinematic laws were determined thanks to the suitable pallet motions applied to the joints; in the not fully determined problems, a combination of data coming from the experience and parameters optimization (also through requests related to dummy parts) was used.
The output function points were joined through splines on the labelling block layout; then, the different splines gained were joined using two basic constraints: the lowest follower acceleration and the pallet interpherence checks.
After a first approach with rigid bodies only, which gave very reliable results, ADAMS Flex was used as well in order to have a more realistic behaviour of the pallets in contact with some flexible labelling block parts.The two different behaviours were compared and the evidence is that at least for one aspect is worth to be studied with the flexibleapproach.
Then, after the cam synthesis, the labelling block was simulated and animated through I-Deas/Adams Mechanism Design Animation Controls and the cam follower diagrams were analyzed in order to have an overview of the main stress values and variations inside the cam path.
This system has been parametrized and it is now the Kosme's standard used to create new labelling blocks and improve the existing ones.

INTRODUCTION

The request of higher performances for the labelling machines is the every day challenge for all the designers involved. The time to market is getting shorter and shorter; the new projects schedulings have become too tight to perform tests and prototype modifications, we need "near net shape" prototypes. Moreover, the details about the technical aspects developed on the machines has become one of the preminent interests on the Customer's side.

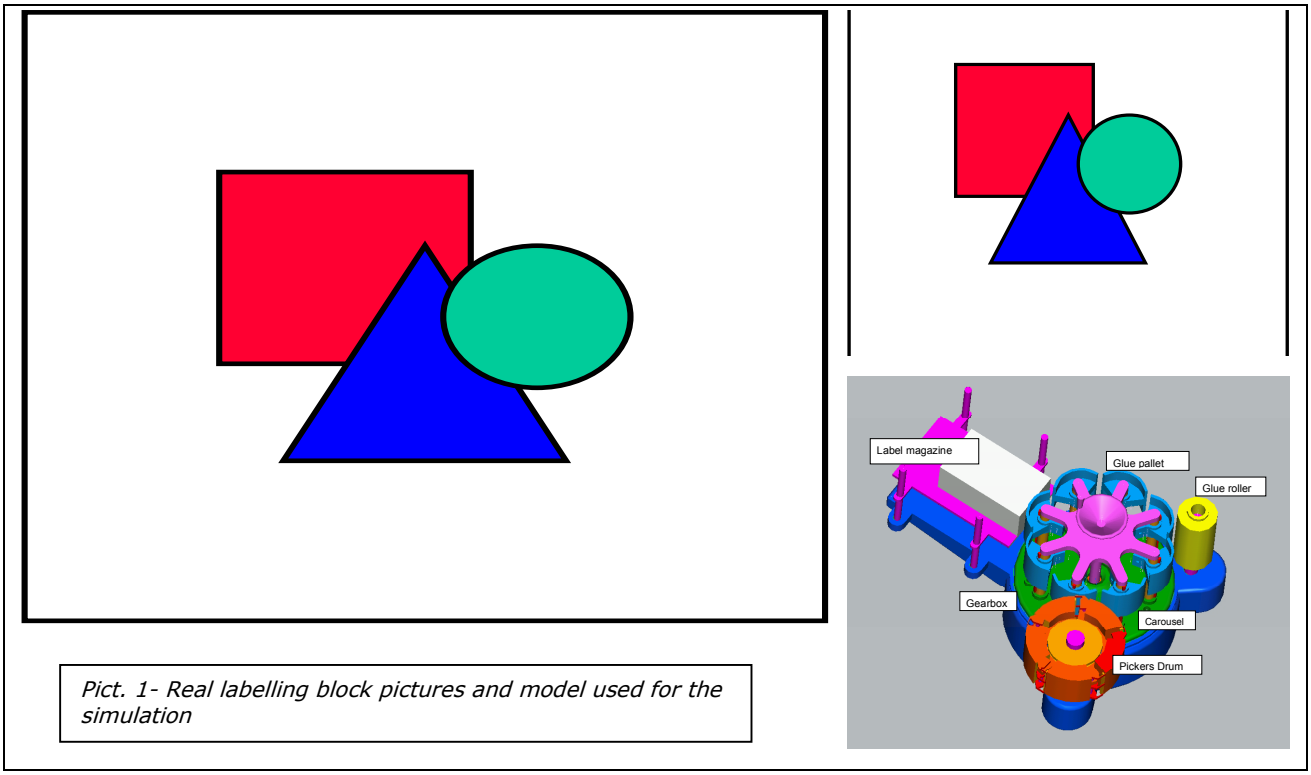
Kosme was asked to develop a new rotary labeller project for a very big customer particularly intrested in the technical aspects of the machine and in the fastest delivery.
The project was also involving a new labelling block and the schedule for the project was really tight. For this reason, it was decided to develop such block in order to obtain all the informations about the labelling block pallets motion, stresses and inertias in the shortest possible time, trying to get as closer as possible to the final prototype as well.
Moreover, since the labelling block cam shapes in the past were obtained through the hand grinding of a metal jig-plate which was welded and grinded until reaching the desired pallet motion, there were basically no filed toolpaths for the labelling block cams, but just jigs for cams copy milling (which couls get easlily damaged). Thus Kosme wanted to make the cam processing safer by creating a system through which it would have been possible to add objectivity to the pallet camtrack - CNC program generation -, give in advance the block performances at different speed, foresee the life of the different components through the stress analysis of the parts.

LABELLING BLOCK PARTS and MECHANICS

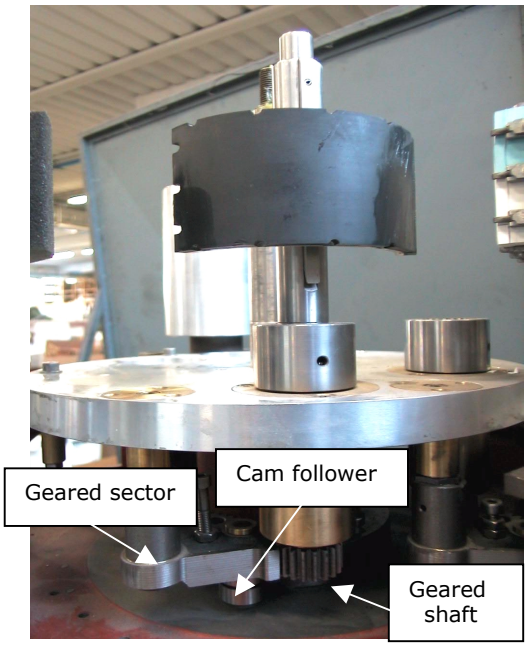
A labelling block is made of (see pict.1):
1. Carousel, holding the glue pallets shafts.
2. Shafts, holding the pallets, including a built in gear at their end

3. Glue pallets rubber coated
4. Geared sector holding the cam follower
5. Gear box (including gears)
6. Label magazine
7. Glue roller
8. Pickers drum

9.Glue pallet cam (to be determined)



Pict. 1- Real labelling block pictures and model used for the simulation



Pict. 2- Glue pallet shaft and geared sector assy.The cam follower moves the geared sector that rotate the pallet. The ratio between sector and pallet shaft is 4:1.

The pickers drum rotates with a fixed ratio towards the machine: every sector on the picker drum is corresponding to one of the machine carousel platform carriyng the bottles. The carousel is synchronized through a gear with the pickers drum. In pict.1 we can see 5 sectors on the picker drum and 8 pallets: this means that the carousel gear and the pickers drum gear are in a 8:5 ratio. The glue roller holds a fixed ratio with the carousel as well, but this ratio is one of the parameters to be optimized.

The shafts have a geared ending portion that works with a geared sector holding a cam follower (see pict.2):

The goal of this application is to determine the grooved cam path in order to have the geared sector motion for the suitable pallets rotation in every basic operations:

1. **Glue picking**
2. **Label picking**
3. **Label releasing**

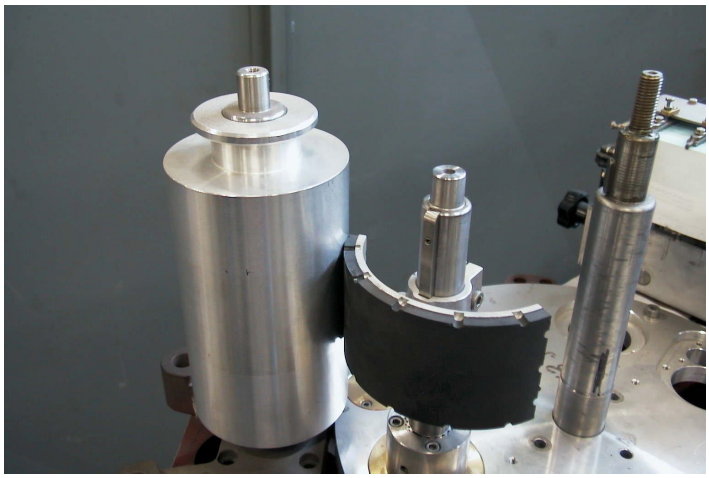
CAM ANALYSIS - Reverse kinematics process

1. *Glue picking*

The glue pallet has to wet its rubber surface by rolling on the glue roller that is running at a fixed ratio towards the carousel.
In this case the kinematic relation between gluen pallet and glue roller is

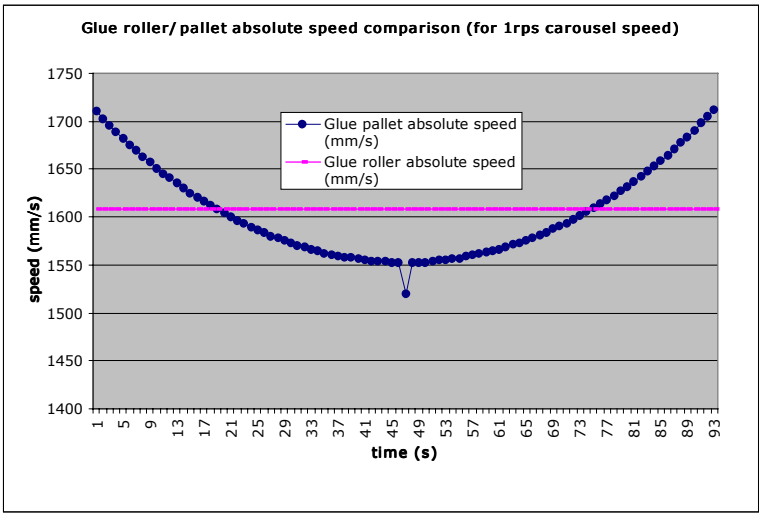
$$\mathbf{V}\text{abs.pallet} = \\ = \mathbf{V}\text{pallet} + \mathbf{V}\text{carousel} = \\ = \mathbf{V}\text{glue roller},$$

intending all the velocities as vectors.
Due to the shape of the pallets (off center arcs) and to the motion, from the experience it is mathematically not possible to have the same two bodies in contact at the same speed at any time (see pict.4)



Pict. 3- The glue pallet starts wetting of glue rolling on the glue roller. Glue feed ing system is not shown in the picture

The normal method to work out this problem is to make the pallet rotation is in such away to "print" on the glue roller exactly the pallet length, i.e. to minimize the total sliding between glue roller and the glue pallet.
The coupler joint ratio between the carousel and the glue roller gear was set as variable, a cam-cam constraint between the pallet and glue roller revolute joints was created and a measure of the roller arc between the beginning and ending contact points was determined.
Thanks to the ADAMS Optimizer, we got the best ratio for the two gears imposing the measure equal to the pallet length. Obviously, after we have to modify the ratio in order to meet the teeth modulus of the gears.
Finally, trough the revolute joint motion of the geared sector and the coupler joint 4:1 between sector and pallet revolute joints, we got the



Pict.4 – Glue roller / pallet absolute speed comparison. The out-of trend mid point is absorbed by the elastic deformation of the pallet rubber coating

coordinates of the sector rotation through a specific request previously created.

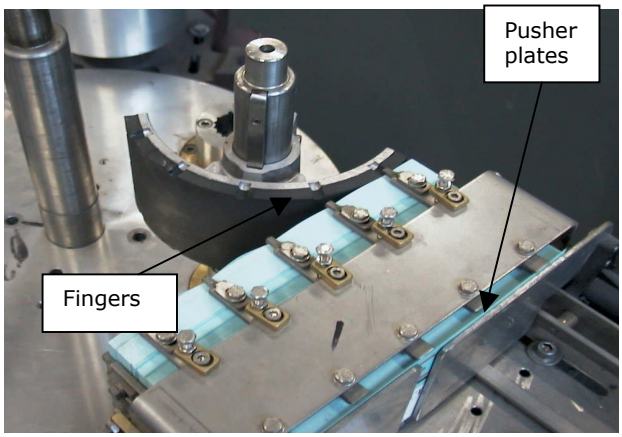
2. *Label Picking.*
The label picking is operated through the glue wet pallet rolling on the label magazine. The kinematic relation in this operation is:

$$\mathbf{V}\text{abs.pallet} + \mathbf{V}\text{abs lab.mag.} = \mathbf{V}\text{pallet} + \mathbf{V}\text{carousel} + \mathbf{V}\text{abs lab.mag.} = \mathbf{0},$$

but since $\mathbf{V}$abs lab.mag = $\mathbf{0}$, we get the final relation

$$\mathbf{V}\text{pallet} = -\,\mathbf{V}\text{carousel},$$

at any time.
Once again the geometry of the labelling block does not make the pallet rolling without having a variable pressure on the label magazine. This variable pressure on the paper is allowed by the plate pusher springs of the label magazine (see pict.5).

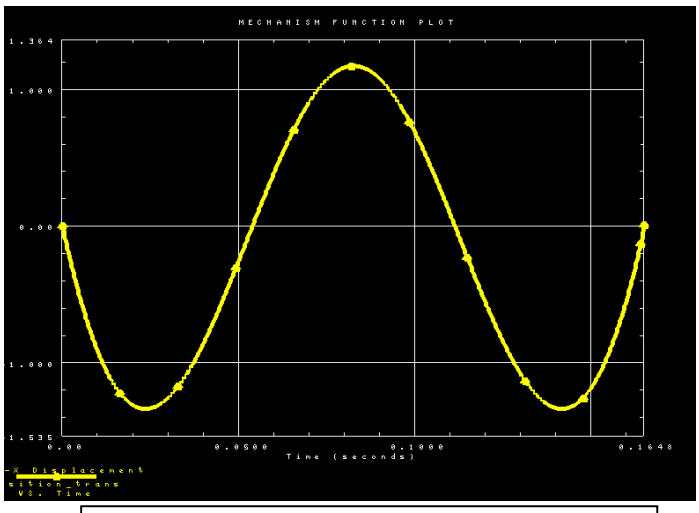


Pict. 5- Glue pallet starts rolling on the label magazine. The label magazine is kept against the pallet thanks to the pushers. The labels pack is kept by the fingers.

Through ADAMS-IDEAS Mechanism Design, the system was simulated as follows:

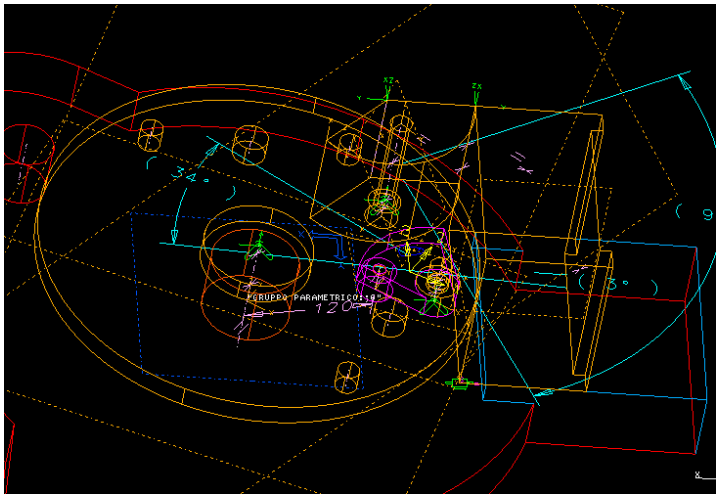
- A cam-cam joint was set between the pallet surface and the label magazine surface. At first the label magazine is considered a rigid body.
- The label magazine is sliding on the carousel support (translate joint). It stays in contact with the pallet for all the picking time thanks to the cam-cam joint.
- There is always the 4:1 ratio coupler between the geared sector and the pallet revolute joints.
- In order to impose a pure rolling contact with the label magazine (the cam-cam joint does not guarantee this), a rack-pin joint was applied between the label magazine surface and the geometrical pallet axis (different from the spin axis).

The pressure on the label magazine should have a so called "seagull wings" shape (as mentioned in the labelling machines handbooks) and the variation of theis pressure should result in a label magazines displacement range of max. 3 mm; bigger values can result in paper jamming, expecially on long labels (see pict.6). The riesult of this simulation was used to adjust the pallet shape umtil the label magazine dsiplacement fell into the 3 mm range.



Pict. 6 – The label magazine pressure from the beginning to the end of the picking.

The consequent pallet motion pulls the geared sector and, thanks to a proper request previously operated, it is possible to get the coordinates of the cam follower or and its rotation during the simulation (see pict. 7).



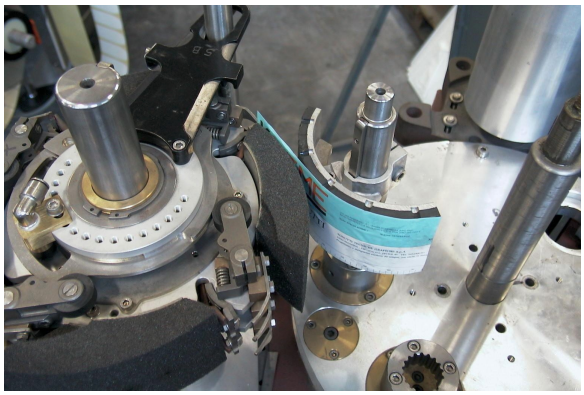
Pict. 7 – The label magazine simulation mechanism (I-DEAS model)

3. Label releasing

The label releasing is the more important operation because a good label release should avoid label breaking or tearing or rimpling (see pict.8).
The kinematic law describing this movement is:

$$\mathbf{V}\text{abs.pallet} = \\ = \mathbf{V}\text{pallet} + \mathbf{V}\text{carousel} = \\ = \mathbf{V}\text{picker drum},$$

where the picker drum speed changes on behalf of its diameter which is related to the label length. A good label releasing should also result in a small drum diameter range for a wide label length range. Thus, the simulation system was provided with two dummy spheres that had to stay on the picker drum and on the pallet respectively. Making a request for the distance between the spheres center marker, it was possible to keep under control the label detachement. A second trial was done driving the pallet through the spheres marker distance at any point.

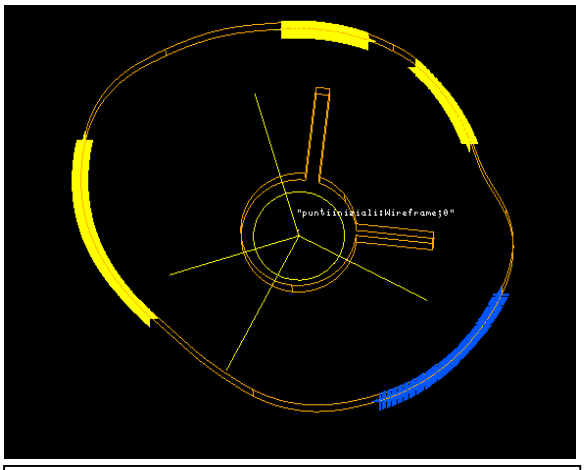


Pict. 8 – The label releasing to the picker drum

The pallet and the sector are usually in a 4:1 coupler ratio between the revolute joints and the picker drum is in a 5:8 coupler ratio with the carousel revolute joint. The calculated law (1st trial) and the spheres center markers distance optimization (2nd trial) gave quite similar results. The 1st trial was used because the pallet was running faster; this avoids the label tearing.
After having found the configuration, it was possible to get the cam follower coordinates, the interpherence between the drum sponges and the pallet, the picking diameter for the different label lengths.

CAM SYNTHESIS – Direct kinematics process

After having fixed a common coordinate system, all the points were displaced on plane with I-DEAS Master Modeler, the points were joined with splines (see pict.9a) and the solid cam was generated.
The splines generation in the undetermined zones was done with I-DEAS Master Series Shape Design which allowed us to draw minimum pressure angle and acceleration curves.
At this point, all the parts were assembled and the whole mechanism was simulated with direct kinematics applying a 100 rpm carousel speed. The test gave the following results:

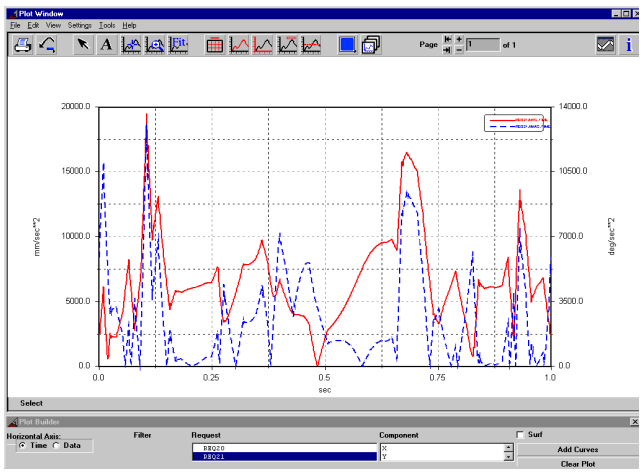


Pict. 9 – The cam generation from the points gained from the trheee basic pallet operation

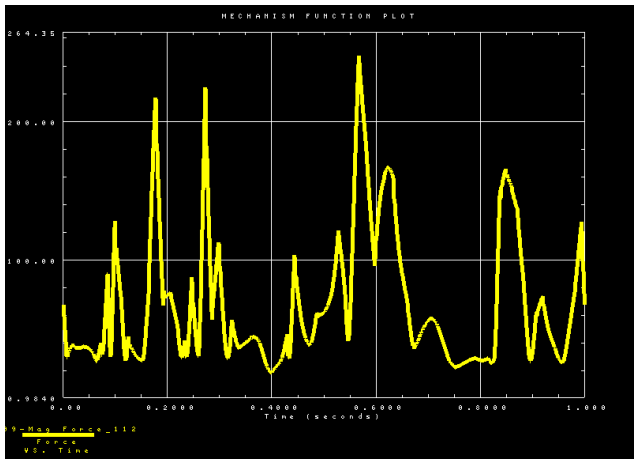
1. The inertial force coming from the the cam

follower acceleration showed values that did not seem to affect the cam follower pin shear stress (pict.10a/10b). By the way, in order to avoid any problem, a FEM test was done on the cam follower (pict.11).

2. The pallet outfeed from the label releasing operation had to be driven through a specific law since two following pallet were interphering. So a specific motion was developed in order to avoid interpherence and excessive speed at outfeed. After some trials, the two problems were finally solved (pict.12)
3. It was decided to work with a no friction system, although the glue could have some effects



Pict. 10a – Cam follower acceleration trend in one carousel revolution



Pict. 10b – Cam follower force trend in one carousel revolution

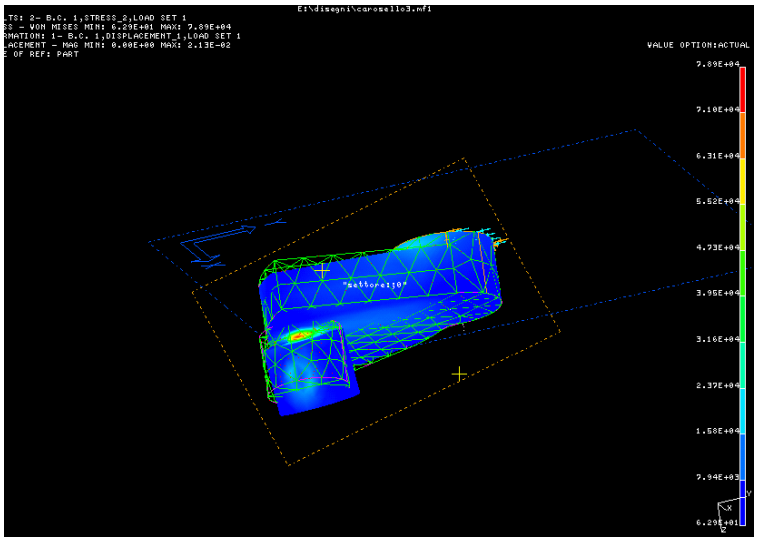
on the model; at first, the glue sticking power was considered neglectable in order to see the possible difference with the real prototype after the final testing.

PROTOTYPE TESTING

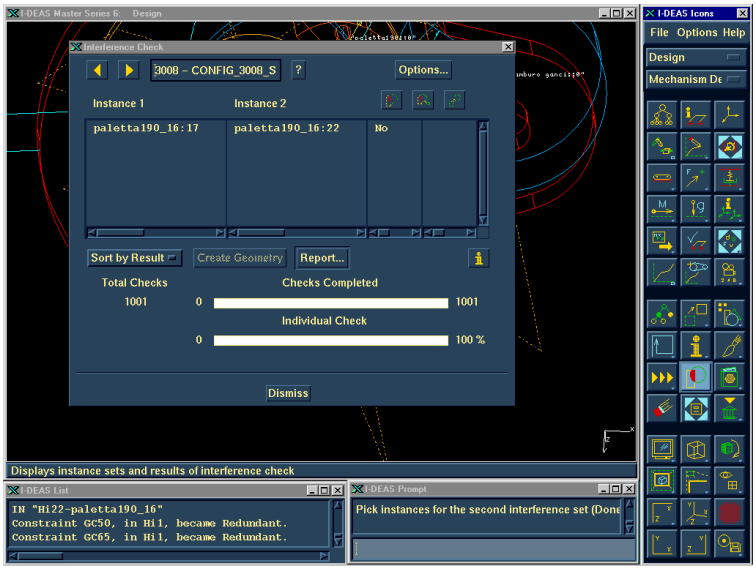
A prototype was built to test the determined cam. The cam path was passed to a CNC machine and machined through a CAM direct process.

The following aspects were pointed out:

1. The motions during the glue picking and label releasing gave the desired result.
2. Acording to the motion during the label picking, the pallet needed to be faster in the second label magazine half; in fact, it was found that this speed increase was necessary because of the label magazine paper flexibility; in order to avoid "waves" on the glue pallet after the picking, the pallet had to recover some speed.
3. The pallet outfeed during the label release operation was satisfactory for straight labels; it resulted too high for shaped labels due to their built-in weakness to the tearing in the sharp angles.
4. For practical reasons, it was not possible to test the prototype effective working at the maximum labelling block speed (a big and fast test machine should have been set up) and the cam vibrations (a very important aspect) could not be practically investigated on the real prototype. Thus, it was decided to check the possible cam vibrations using ADAMS Flex to perform a modal analysis on the FEM model of the sector gear, to point out the possible elastic effects.
5. The glue sticking seemed to be significant just during the label release operation and for the very big labels, which normally mean slow labelling block speed (low productions).



Pict. 11 – Shear stress FEM analysis on the cam follower pin



Pict. 12 – Pallet interpherence analysis with I-Deas Master Series Interpherence Check

Although the protptype coming from the model was satisfactory at the 90% of the expectations after a total time 0f 15 days including designing, test parts production and testing (a very good result if compared with the 2 months total time to perform the same thing in the past), it was anyway decided to feedback on the model.

MODEL FEEDBACK AND REFINING

In order to try to comply at 100% with the real model, Kosme's technical staff decided to feedback all the informations coming from the prototype on the virtual model. Some aspects could be implemented immediately, others are still running:

1. The pallet speed to be recovered at the label magazine side was equally distributed on the pallet motion starting from the half contact point on the label magazine; then, the cam was updated.
2. For the running project it was decided to leave the model as it was because there were not shaped labels. In order to meet a shaped labels acceptable releasing, a new model starting from the previous one was generated; the glue roller gearbox support was moved of 20° in order to have a smooth release outfeed and to avoid interpherence. The gearbox was modified, the cam updated and the model was succesfully re-simulated.
3. The modal analysis on the cam follower /sector system showed significant modal effects just at very high frequecies the real case does not deal with. So, the rigid approach in the cam simulation can be assumed as reliable (see pict.13).

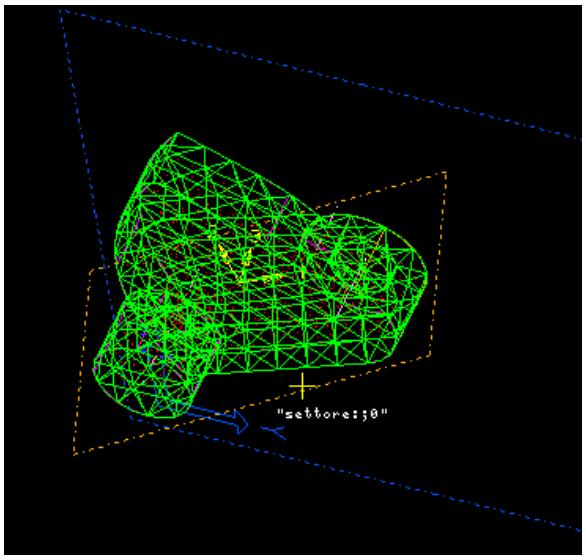
RUNNING MODEL DEVELOPMENTS

As a consequence of the first experience, it was decided to make further model investigations to deal with paper flexibility and glue sticking force and friction. Obviously, this is just something which will allow us to have a model closer to the reality, but, as a matter of fact, the results obtained from the rigid body simulation were more than satisfactory:

1. It was planned to make the label magazine flexible using a FEM model and ADAMS Flex, in order to take in consideration the label paper flexibility. This implementation is still running

because of the difficulty of finding a good flexible model for the paper since also slight differences on the paper composition, presence of printings, presence of thin metal layers on the labels cause very big differences in the elastic behaviour.

2. It is planned to adopt a flexible model of one label simulating the label release to the picker drum (including the glue sticking force) in order to investigate the paper stress coming from the pallet speed and the glue sticking power.



Pict. 13 – Cam follower/sector FEM model for modal analysis through ADAMS Flex

CONCLUSION

1. The approach used gave the desired results, because the virtual prototype fitted at 90% the pallet rotation cam to be obtained.
2. The system allow the designer to understand how much is objective and how much is arbitrary in the initial premises and to have feedback in every moment to shapes, links, joints and masses in order to avoid unacceptable behaviours during simulations carrying out.
3. The system makes possible to work out not analitically definible coditions thanks to the definition and optimization of fictitious forces or torques, dummy parts, markers measures which have to take care of contacts, speed regulation, interpherence checks.
4. The need of having flexible parts is under study and Kosme is looking forward to end this model improvement by end of the year, in order to implement the next projects with this system. Neverthe less the rigid bodies approach was more than satisfactory.
5. The total time of the labelling block cam design was reduced of 70%.
6. The goal of the major knowledge and objectivity was fully reached: stress, acceleration, displacement diagrams are now available together with the resulting CNC part program which ensures the highest machining quality f the cam, expecially if compared to the past used pallet cam jig copy-milling.
7. The future development of the system includes the possibility of applying frictions to the joints, to the body wet by the glue and to optimize the sizes of the acting bodies (pallet radius, picker drum diameter, carousel diameter) on behalf of the machine pitch and of the different application required.