# Automatic packaging machine design

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Automatic packaging machine construction
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*Application presented is a CAD/CAE based project of an automatic packaging machine.*
*The project has been developed with ADAMS, starting from a 3D model from Solid Designer and defined in SD/Adams, performing kinematics analysis in order to verify machine movements, and dynamic analysis for sizing actuators in a properly way.*
*The model created can be considered a virtual "test-bed" of the analysed machine, because, thanks to a complete parameterisation of the model, it's possible the evaluation of the best system configuration in order to improve production performances.*
*The "test-bed" developed is completed with a motion laws library, allowing to evaluate in a immediate way which is the type of motion that minimise the engine torque.*

## Introduction

High speed is one of the most important characteristics of packaging machines, and the upper limit for this feature is more linked with the properties of the objects to be wrapped then to the real limits of the mechanism.
This aspect is as more important as lighter and softer is the parts to handle, so design of automatic wrappers for bathroom tissue and house hold towel rolls implies a lot of problems that can be solved in a faster and better way using a mechanisms dynamic analyser such as *ADAMS*.
TMC machines reflect a new generation of advanced technology wrappers and bundlers which are far and away the industry bench marks for tissue wrapping and bundling now. The *Qualywrap* and *Qualyflex* machines have set new standards within the industry in terms of engineering design and technology, package and bundle quality, operating efficiency and flexibility.

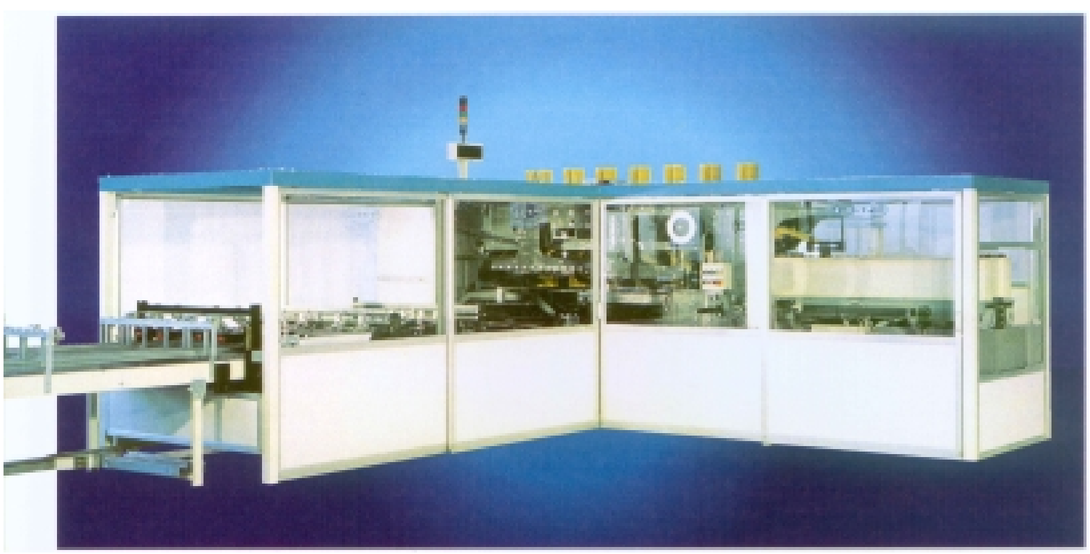

**Figure 1 : TMC *Qualywrap 1800* - Automatic wrapper machine**

TMC wrapping machines are the only machines designed, tested and proven today in the market which truly reflect a new generation of innovative technology and advanced mechanical design (*CAD* - *CAE*).
TMC automatic machines have been designed to be the best versatile machines available to the rolls tissue industry; virtual testing of machine in each configuration is an important tool to reach this goal, consequently the need to implement a complete *"test bed"* for this machine's topology, in order to verify main wrappers performances.

## Automatic wrapper machines

The structure of an automatic wrapper machine can be synthesised as simply crank mechanisms; but specific problems to solve are the synchronisation of the different cranks of the machine and the behaviour of the rolls to handle.
During all the movements of the machine, the rolls are never constrained but only supported by the moving parts. For this reason, the cranks must be driven in a properly way, avoiding irregular tissue rolls movements, detachments and jumps from the bearing surfaces.
The main requirement on the efficiency of wrapping machines is the huge acceleration of the controlled axis, generally seven axis moved by brushless motors. This requirement, normally, doesn't include high mechanical loads on the structures of the machine, also because all the parts have been designed in order to minimise inertial effects. The cranks have been modelled to keep the inertial centre as near as possible to the revolution axis, and all the links have been built up in light alloys instead of steel.
Moreover this requirement may cause problems to the rolls' stability during the first movement, the elevation of the roll from the store to the wrapping zone of the machine. To avoid, or reduce, this effect, the motion control must be very accurate, involving a jerk limitation. This means that the rate of change of the accelerations must be limited.

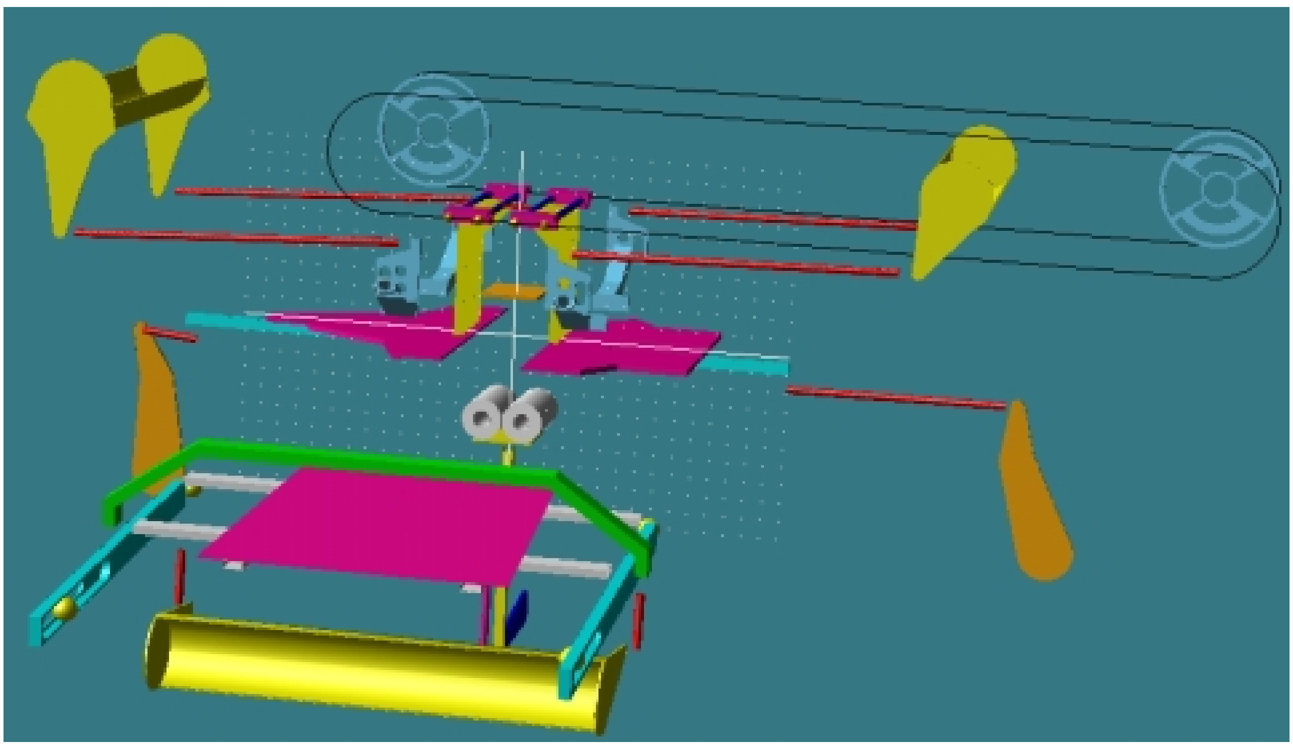

**Figure 2 : Simplified model of an automatic wrapper machine**

The virtual model of the machine has been used to check the behaviour of the tissue roll during the movement. Thanks to the machine "*test bed*", different types of motions can be compared in a fast way, finding the movement that allows a good compromise between production efficiency, roll stability and mechanisms synchronisation.
Another important result from this analysis phase is the correct sizing of the brushless motors, evaluating the maximal requirement of torque and velocity during the crank motion.
The verification of this feature is very important, also considering machine versatility. Actually presented machine can handle up to 43 different pack formats, and for all of them must be set the proper motion condition in order to minimise the problems over discussed.
In this context can be easily understood the importance of virtual prototyping in order to chose the correct size of the brushless motors and to validate the correct working of the wrapper in each configuration, before the physical programming of the brushless controls.

## Wrapper machine virtual model

The virtual model of *Qualiwrap* automatic wrapping machine has been developed starting from an existing 3D model in CoCreate SolidDesigner.
The model has been set using *ADAMS* CAD embedded version (*SD/ADAMS*), obtaining first important results on the machine performances with geometric and shape characteristics previously designed, without specific dynamic analysis.
This approach allowed us to validate the size of electric drives installed on the machine.
Another important result has been the improvement of general wrapping process efficiency, studying complex motion for reducing torque absorption by brushless motors and tissue rolls troubles during movements.
In order to evaluate the sensitivity of geometric characteristics on global machine performances, a completely parametric model has been developed in *ADAMS*.

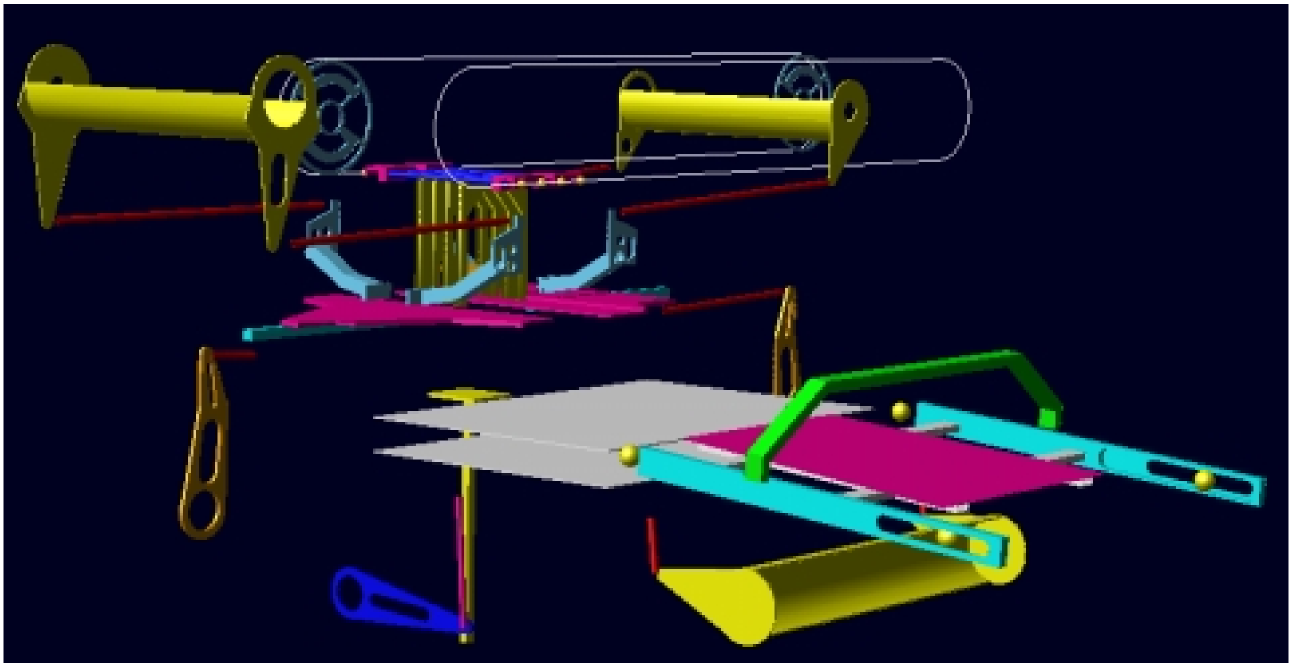

**Figure 3 : Parametric model of automatic wrapper machine – iso view**

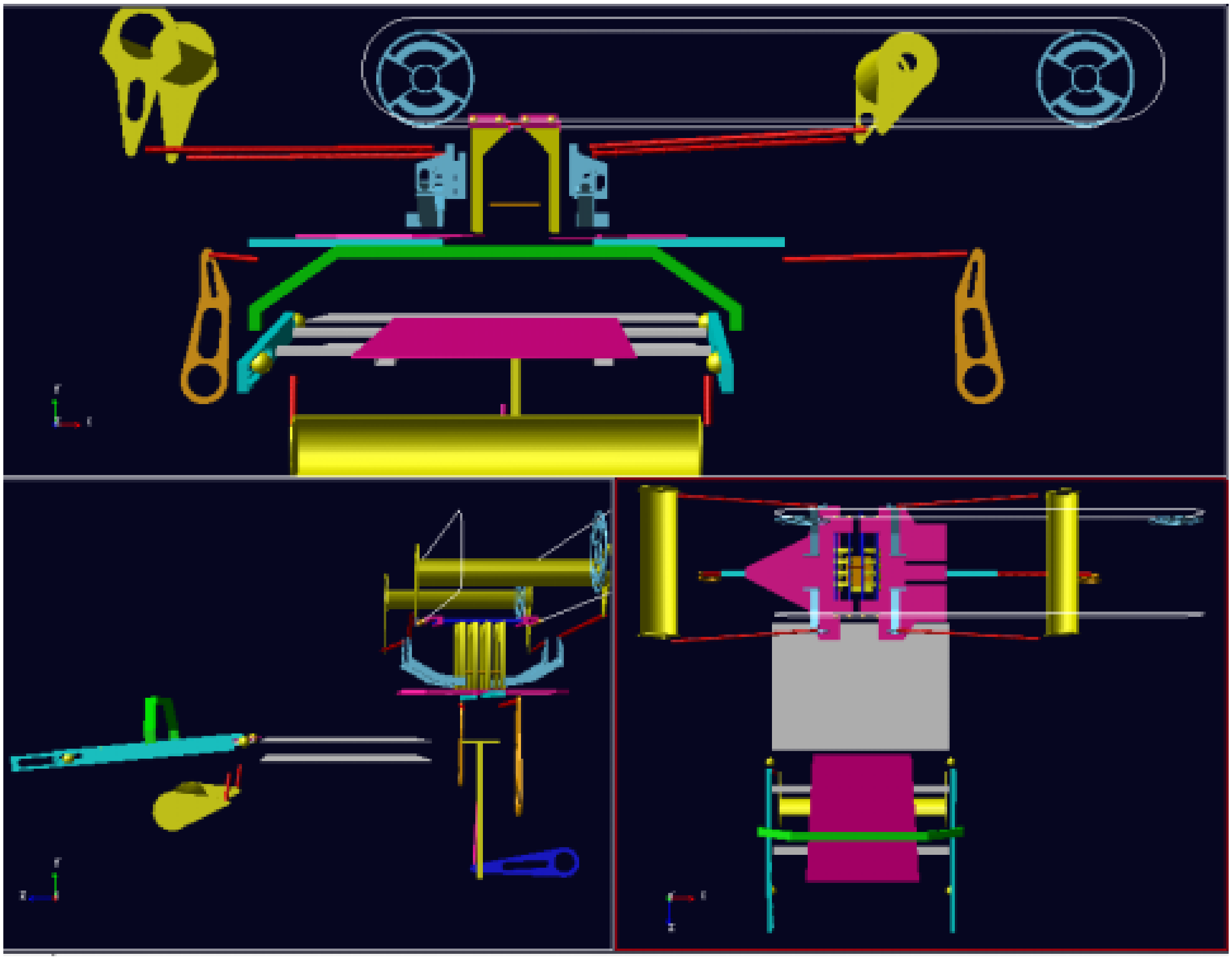

**Figure 4 : Parametric model of automatic wrapper machine**

Parameterisation of the developed model allows to validate in a very short time different setting up configurations for this machine topology, related to the various tissue rolls formats to be packed and to all the components dimensions.
This model, with an elevated parameters number, gives important results considering both the synchronisation and the performance optimisation problems. Approaching the machine design in this way, in order to solve the problems over discussed, a non symmetric model has been tested, with interesting results. Actually, cranks and links of different lengths, and with non symmetric revolution axis, driving the movements of the wrapper allow to reduce the torque requirement respecting the synchronisation needed for a good wrapping process.
Sub-models have been analysed to finally solve problems of specific mechanisms or operations, such as the elevator and the chain hooks used to drive packs out of the wrapping area.

## Sub-models: Elevator

The main problem of the pack elevation from the store to the wrapping area is the behaviour of the tissue roll during the deceleration of the bearing plate.
Cause of high productivity required, the elevation must be completed in a very short time, also depending form the dimensions of pack to handle. Plate deceleration is so important to cause the detachment of the rolls from the plane itself. The pack is stopped by a stroke end plate, and after reached by the elevator plate.

Considering different pack dimensions and wrapping rates, the detachment must be avoided, or at least limited. For this reason, a model considering unilateral contact between the tissue rolls and two different plates has been developed and analysed.

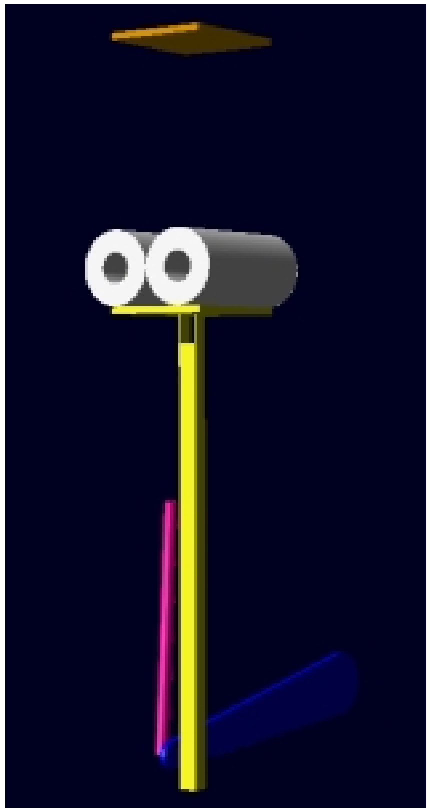

**Figure 5 : Elevator model**

Following examples show of two different motions imposed to the crank and their effects on the pack. In case 1, tissue roll is subjected to a double impact, the first one with the stroke end plate and the second one with the moving plate.
In case 2, because of a refined motion imposed to the crank, the tissue roll doesn't collide against the stroke end plate, but after a shorter period of detachment is hit by the elevator plate.

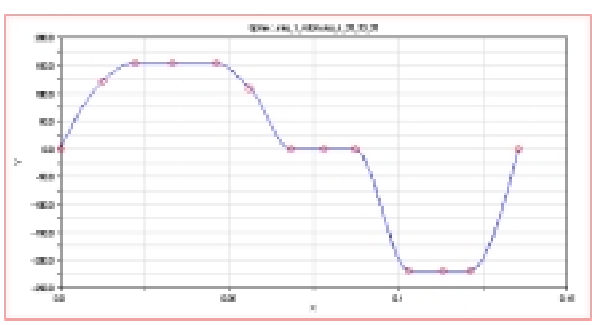

**Figure 6 : case 1 - Crank contolled angular acc.**

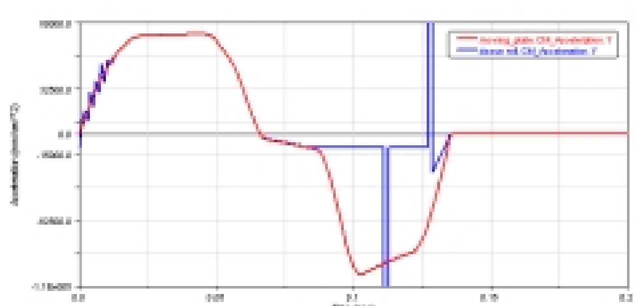

**Figure 7 : case 1 - Moving plate and pack acc.**

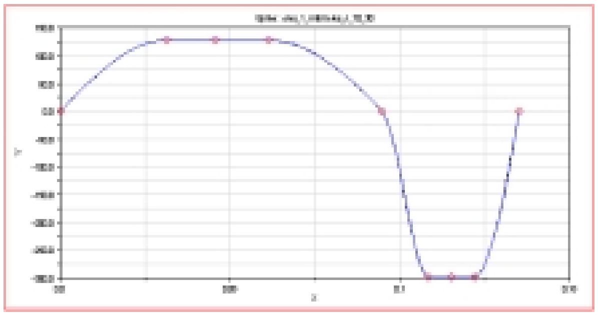

**Figure 8 : case 2 - Crank contolled angular acc.**

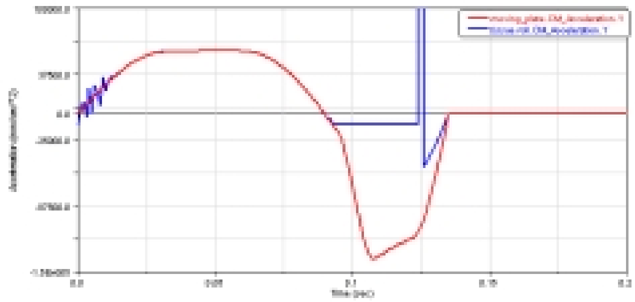

**Figure 9 : case 2 - Moving plate and pack acc.**

## Sub-models: Chain hooks

A chain-like mechanism has been chosen to drive the packed products out of the wrapping area. This structure allows to manage some packs with only one brushless control. Main problem to solve is the proper motor sizing, considering different number of hooks on traction chain and dynamic effects of all the moving bodies flexibly linked between themselves.

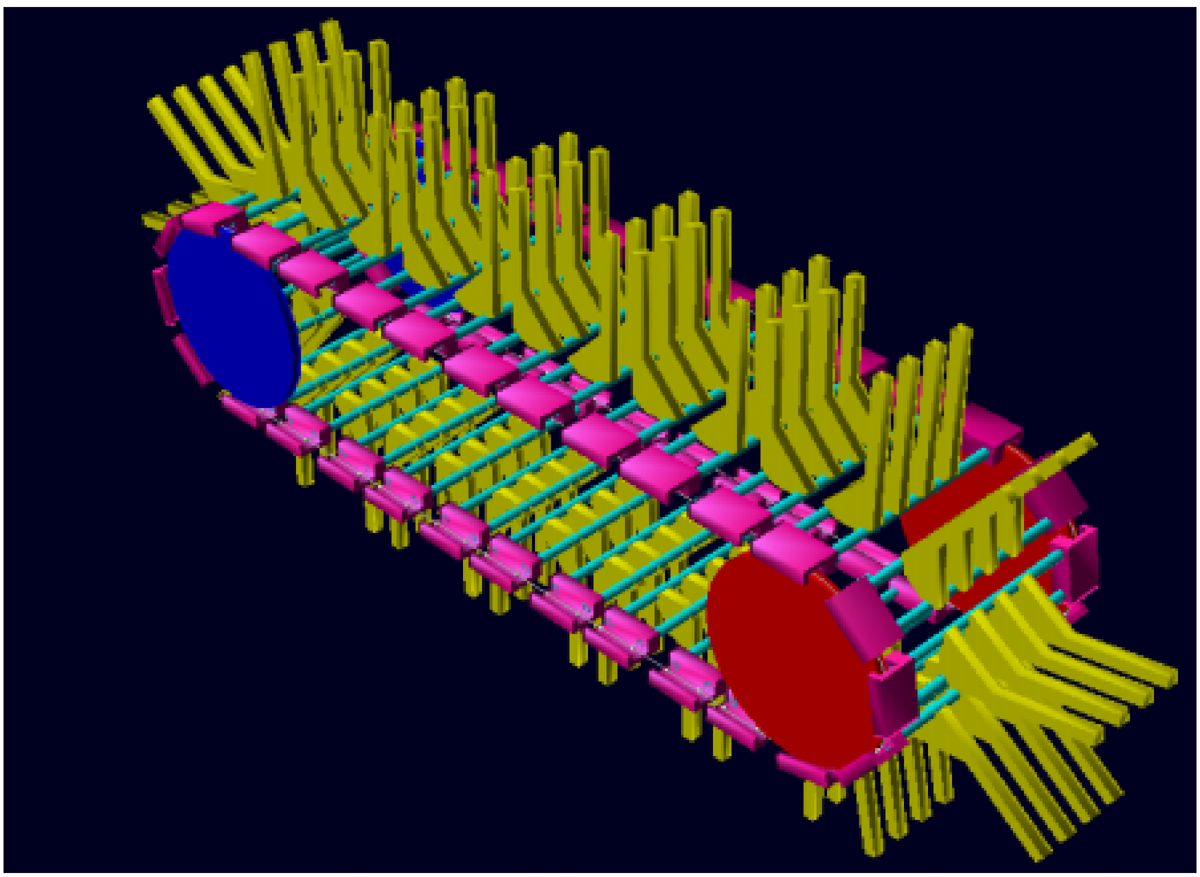

**Figure 10 : Chain hooks model**

Virtual machine *"test bed"* can build up this chain mechanism, starting from a simply model in which wheels only are defined. The accurate use of this tool allows to evaluate the best chain configuration, considering all main geometric parameters, such as wheels diameter, revolution axis distance or number of hooks, toward motor performance.

Following example shows the results of an analysis on model represented in Figure 10, chain mechanism supporting 14 hooks, driving wheel controlled as in Figure 11.

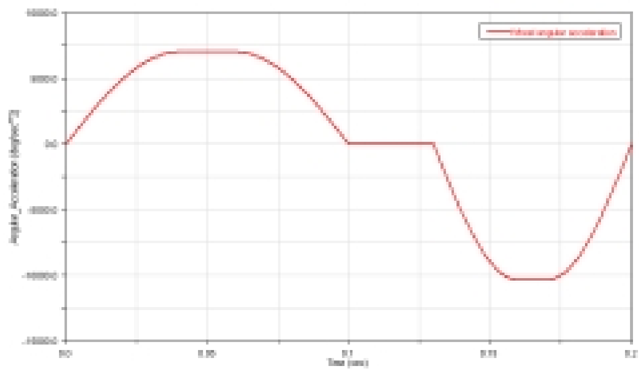

**Figure 11 : Controlled wheel angular acceleration**

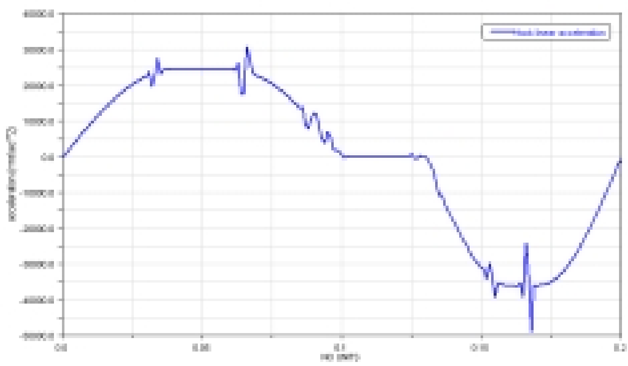

**Figure 12 : Hook resultant acceleration**

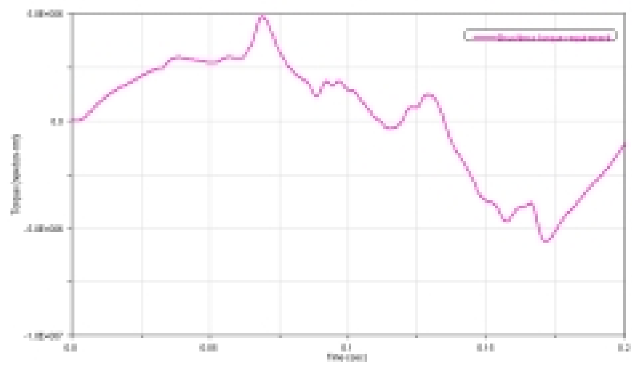

**Figure 13 : Brushless torque requirement**

As shown in Figure 12, hooks resultant acceleration present some ripple due to flexible connections between hooks and chain elements, representing chain flexibility.
Resultant torque requirement is evaluated considering all the hooks carried by the chain.

## Virtual "*test bed*"

Automatic wrapper machine "*test bed*" has been developed in order to improve *ADAMS* performances in design capabilities of mechanisms involved in this kind of automatic machines.
Actually the tool can be shared in two different tasks:

- Chain hooks mechanism generator;
- Complex motion generator.

As previously explained, first task allows to build up, starting from few and simple data, a complex mechanism, involving flexibility effects between driving wheel and hooks moving with chain.
Second task is a complete library, containing types of motion generally used in automatic machine applications.
From a specific interface, complete motion curves can be easily defined, choosing profile type, total displacement to impose and execution time. Also multiple curves can be implemented, choosing single run or double run with return. Following figure represents the motion generator interface.

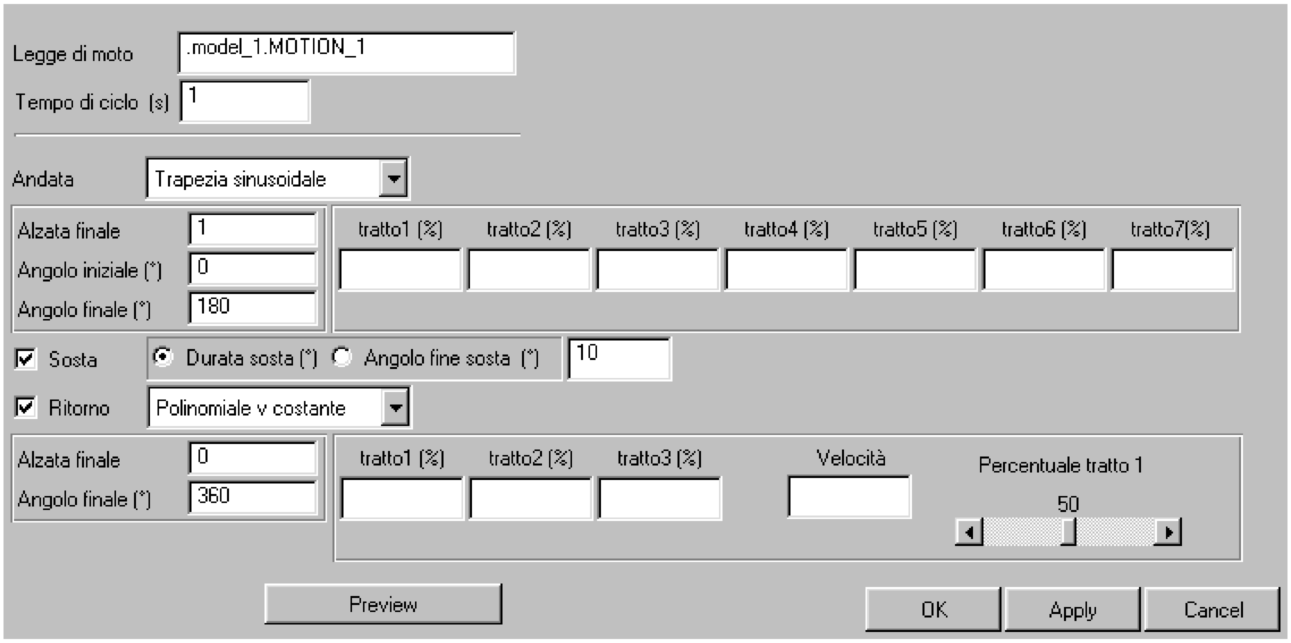


**Figure 14 : Complex motion generator interface**

Four different curve type are implemented in library:

- Displacement along 3° order polynomial function;
- Displacement along 5° order polynomial function;
- Trapezoidal acceleration profile (with sinusoidal fillets);
- Constant velocity (with polynomial transition).

Follow examples of third and fourth profiles type, single run.

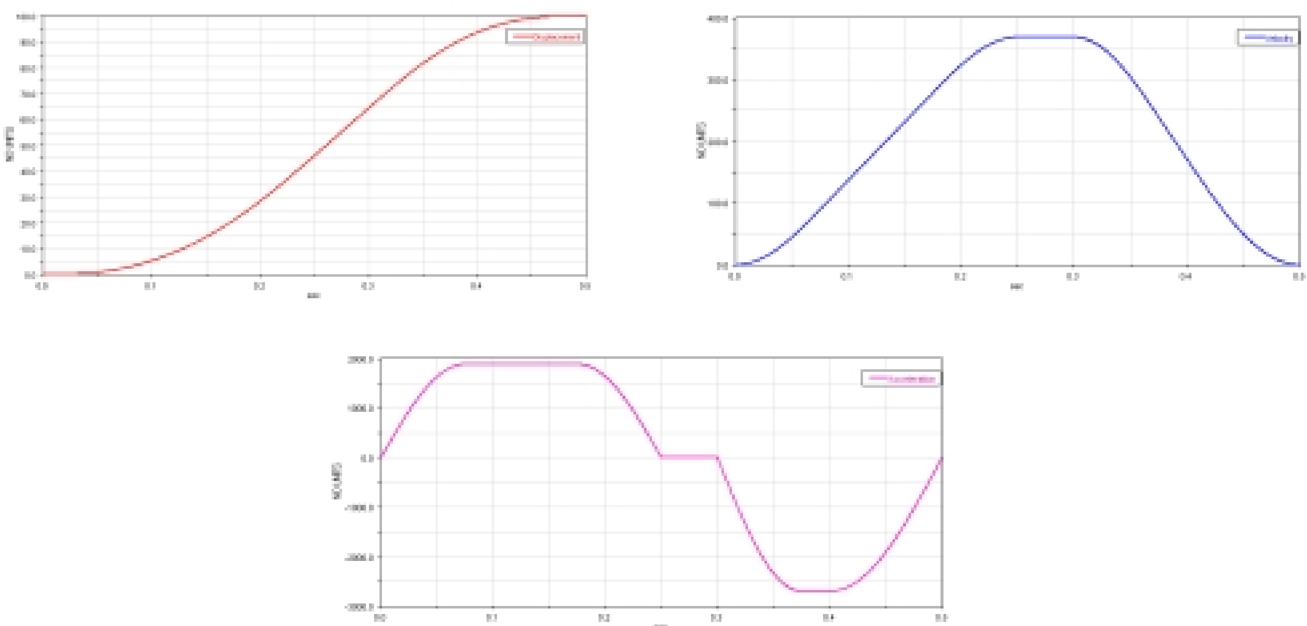

**Figure 15 : Displacement, velocity and acceleration of trapezoidal profile**

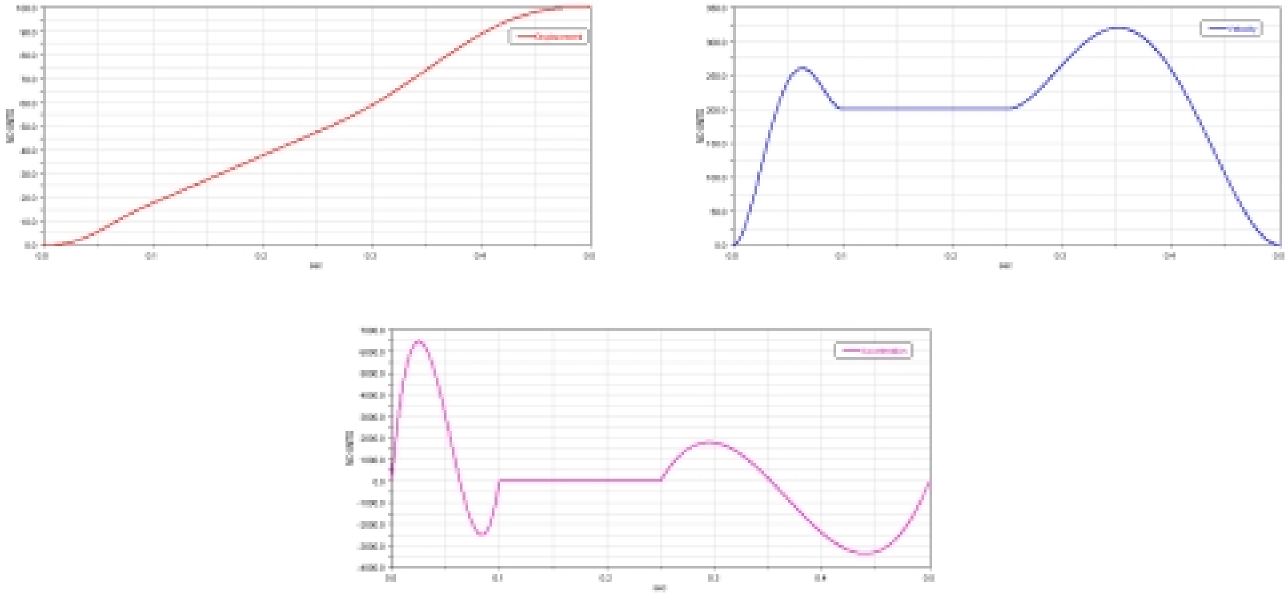

**Figure 16 : Displacement, velocity and acceleration of  constant velocity profile**

## Conclusions

Virtual prototyping technology can be completely integrated in automatic machine design. Different approaches allows to obtain important results either starting form existing CAD models and validate previous designs using *SD/Adams*, or creating completely parameterised models for evaluating feasibility of new designs, using *ADAMS*.

Added tools can be used in order to improve *ADAMS* performances for specific application; in presented examples two important goals have been reached with great time saving. First of all, crank motions have been optimised, allowing a proper motor choice. Second results are a great volume of data used to synchronise all the mechanisms involved in wrapper machine.