TYRES MANIPULATOR DESIGN FOR MECHANICAL BOOMS

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Manitou telescopic handlers cover an enormous field of employment taking advantage of their compactness and great versatility. Company policy, focussed on satisfaction of the productive world requirements, and the equipment's interchangeability on the mechanical telescopic boom, offer the insertion possibility in new niches of market with the invention and the design of new accessories.
So the use of tecnologically advanced instruments as ADAMS can advantage in an important way since the beginning of a new plan, with consequent time reduction in satisfying the customers requirements and for a fundamental improvement of the qualitative standard.

Figure 1-Some examples of telescopic handlers Manitou in building construction and agricoltural field.

INTRODUCTION

Movement and stoking of different materials cover a fundamental role in the productive world; an interesting approach for these application is performing some operations with only one instrument, also reducing operating costs.
Manitou telescopic handlers are characterised by a functional range of lift height and load capacity, and a complete offer of equipment that can be easily charged and replaced on a boom with a universal interface.
Because of these features, Manitou telescopic handlers can solve al lot of problems involved in manifold tasks, such as general building, waste treatment, farming, civil engineering, poultry farming, etc.
With four-wheel drive and excellent ground clearance, these machines are suitable either for on-road or off-road tasks and can achieve the most difficult ground conditions. Compact dimension, noteworthy stability and four-wheel steer capability ensure Manitou telescopic handlers to be easy to manoeuvre, even in the most restricted spaces.
These elements induce a continuous and fast evolution in planning and production of accessories involved in new applications, consequently an enhanced research is essential to speed up design and prototyping process with worthless error margins.
Kinematic and dynamic simulation of virtual models contribute to preview mechanism behaviour before its realisation, or to evaluate dynamic stresses in applications difficult to forecast.

CLAMP OPERATION FOR TIRES 27.00 R49

A tires clamp has been designed in order to satisfy a customer specific request. Such clamp must manipulate wheels, with relative tyres, for off-highway trucks. The specific clamp task is assembly and disassembly of wheels of the off-highway quarry trucks, directly in working place.
Wheels to handle are 2000 kg mass, external diameter between 2700 mm and 2900 mm, and 770 mm maximum width.
Main clamp features, in order to execute requested operations, are robustness, to resist in such working place, and capability to seize and handle wheels within a well defined spatial range.
Actually, wheels must be taken from ground or a transport truck bucket, lifted to 1200 mm height and centred on the off-highway truck hub. To perform this sequence, clamp structure is composed by two synchronised arms, restraining wheels, a side-shift and a spin mechanism for positioning wheels next to the assembly bolts.
Therefore a new accessory has been designed and realised: a clamp integrated on a model of the already existing Manitou telescopic handlers series: chosen model is MVT 675T Confort.

Wheel characteristics:

- *Weight (Kg): 2000*
- *Diameter (mm): 2700 or 2900*
- *Width (mm): 770*
- *Wheel employee on Off Highway Trucks:*
  - *Related Industries: Heavy Construction, Mining, Quarry / Aggregate*
  - *Operating Weight – Loaded: 161028 Kg.*

Figure 2 – Off hightway trucks.

MVT 675T "Comfort", Maniscopic 6m, Heavy duty

- *4 wheel drive and 4 wheel steer*
- *Hydrostatic transmission*
- *Diesel Engine: Perkins 1004.40 Turbo (106 hp)*
- *Nominal capacity (kg): 7500*
- *Standard lift height (m): 6,00*
- *Max. forward reach (m): 3,70*
- *Overall height (m): 2,51*
- *Overall width (m): 2,4*
- *Overall length (m): 4,67*

Figure 3 –MVT 675T

Manipulator characteristics:

- *Capacity 27:00x49 29:00x49*
- *Lift capacity 2200 Kg*
- *Body rotation 300°*
- *Greatest clamping force 10000 Kg*
- *Mass 1900 Kg*
- *Least gap 2130 mm*
- *Greatest gap 3100 mm*
- *Sideshift race 300 mm*

MODEL CREATION

First model has been built starting from existing SolidDesigner 3D model, using SD/Adams cad-embedded environment. Obtained results are involved with mechanism kinematic behaviour, allowing to correctly evaluate sliders bearing lateral arms and cylinders length.
This design approach allows to validate previous designs and models, developed without kinematic and dynamic analysers.

Figure 4 –Wheel clamp.

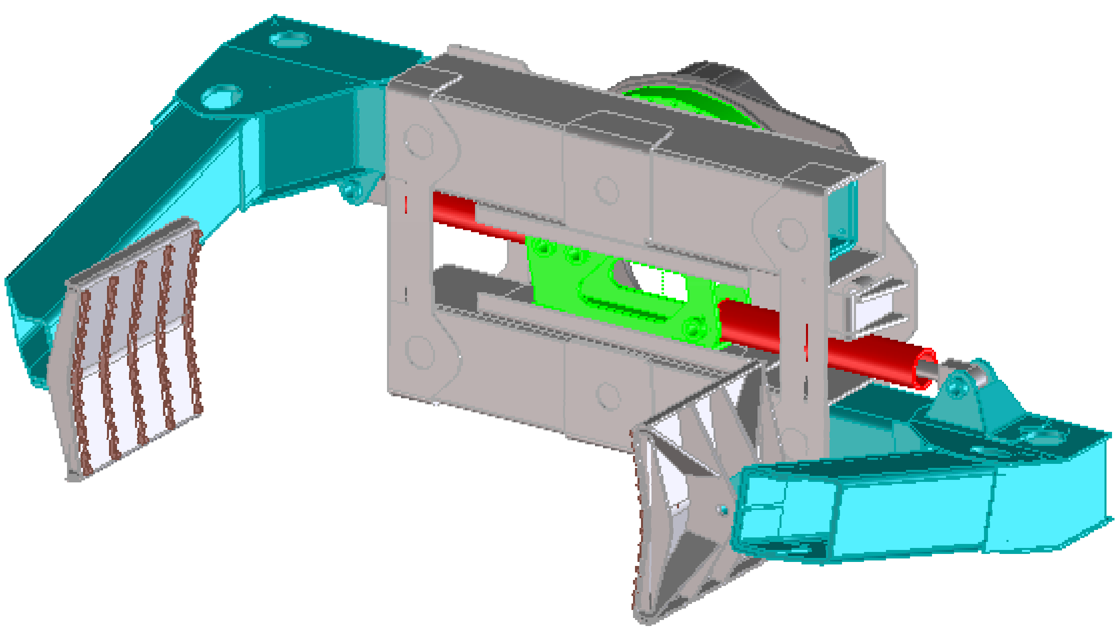

Figure 5 : Clamp 3d CAD model - iso view

In order to consider geometry optimisation and real clearance in arms sliders, a model has been built in ADAMS View environment respecting geometric and physical dimensions of the real wheel clamp.
Moreover, to obtain the same mass distribution of the physical clamp, some fictitious masses have been introduced in accord of non modelled ribbings and reinforcements positions, approximating the working conditions of the manipulator for the mechanical boom.

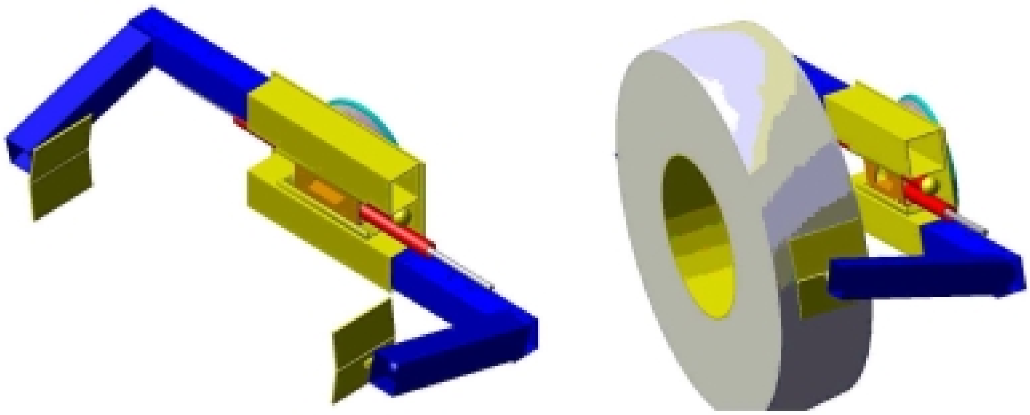

Figure 6 –Wheel clamp model (isometric view)

Real physical characteristics of the materials have been introduced, either of steel parts or other material parts. Starting from tires catalogue, a reaction force/deformation curve has been extrapolated for current application. So we have been able to characterise behaviour of the wheel closed between clamp jaws.
All the connections between the various clamp members, in relative transitional motion between them, have been approximate with contacts of sphere/plan type, introducing friction, damping forces and physical clearance.
Also the wheel contacts with taken the clamp booms and with ground has been managed as *ADAMS* contact force between spheres and plan, starting from tyre characterisation previously explained.
So we have developed a virtual model of a clamp and a virtual model of a wheel in real scale and exactly identical to the realty.
Other parts of the machine (the telescopic handlers) haven't been considered in the model development, because not interesting for the our study aim.
Therefore we have considered the manipulator directly connected to ground through a prismatic joint, to which a motion curves have been applied to approximate elevation and eventual effects of land convolutions during the wheel transport.

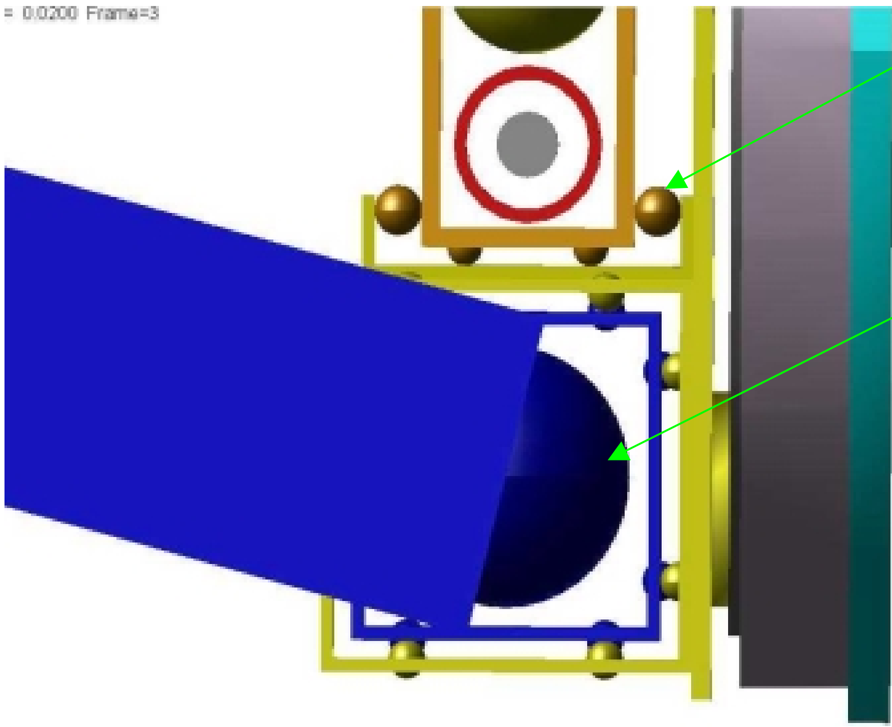

Figure 7 –Contacts management.

SIMULATION

Performed simulations can be distinguished in two different phases:

- A first phase in which laws of motion and forces have imposed, evaluating kinematic and dynamic behaviour either of wheel or of clamp, using either cad-embedded model or *ADAMS* stand-alone model. For example, imagining that the telescopic handler moves on a difficult ground, we have simulated the lifting of tyre and clamp with a step function, then we imposed some sudden alternative movements: so we have found the lowest closing force necessary to keep fix the wheel.
- In a second phase the clamp hydraulic circuit has been introduced, in ADAMS Hydraulics environment, estimating the correct elements dimensions, considering the real parameters and the real characteristics of the hydraulic members.

SIMULATION RESULTS

First and the most important result obtained is a correct evaluation of the clamp closing force.

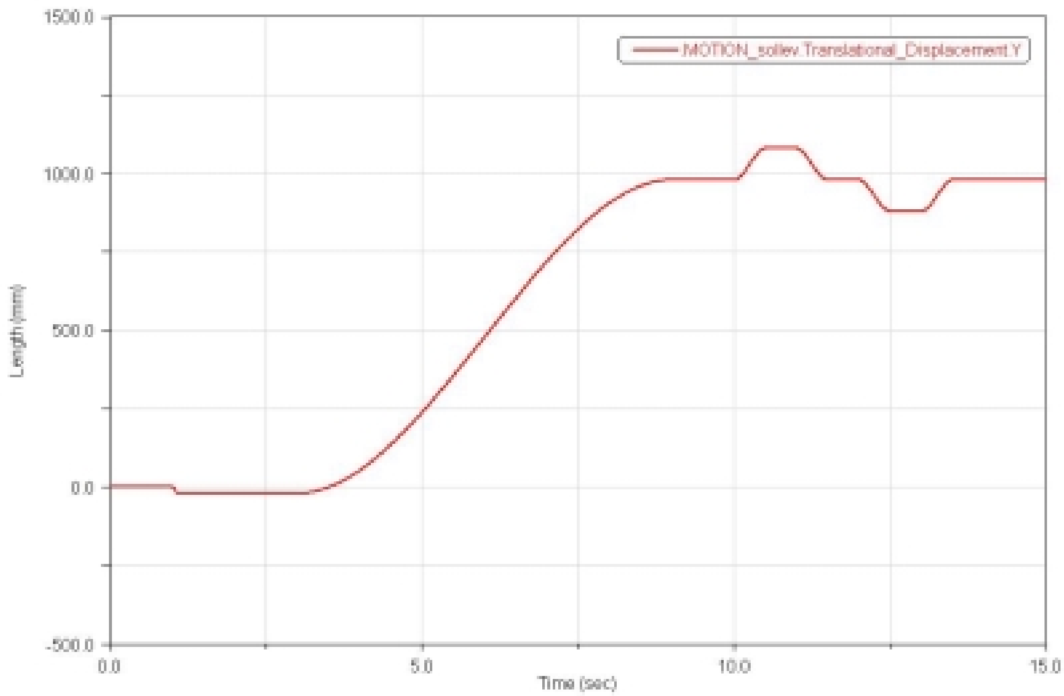

Figure 8 – Motion curve applied to evaluate lowest clamp closing force.

In previous evaluations, lowest closing force as been estimated approximately 100000 N, the simulation has instead revealed that 80000 N would be enough. This would involve a reduction of the structure weight (arms and guides) from 1900 kg to approximately 1600 kg (beyond 15%).
According to results obtained with the simulation in ADAMS Hydraulics, a slight under-dimensioning of translation cylinder has revealed.
In a particular configuration of this mechanism, performance

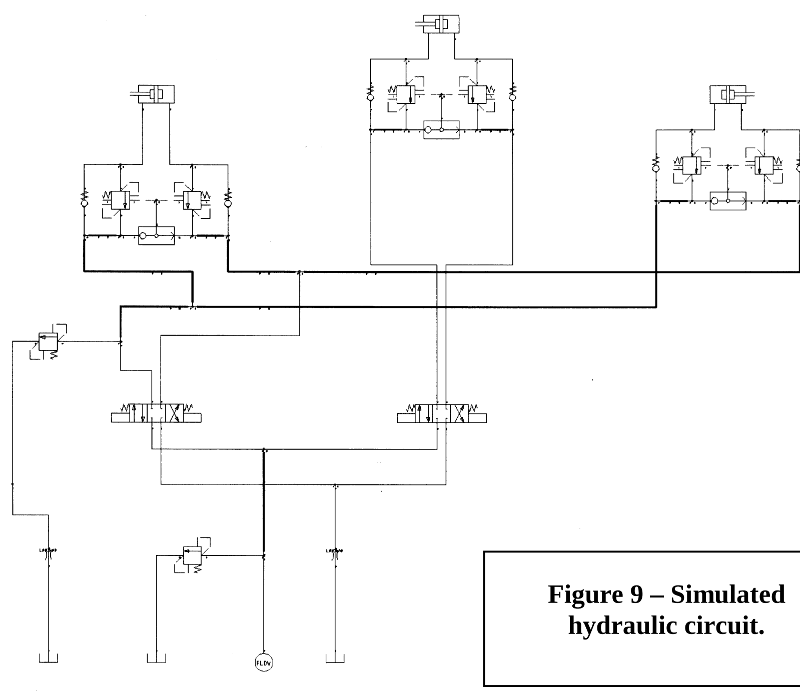

Figure 9 – Simulated hydraulic circuit.

required to side-shift cylinder are over its capabilities. With a wheel closed in the clamp, if cylinder rod-side chamber is fed, resultant force isn't large enough to move the system properly. So the translation happens very slowly.

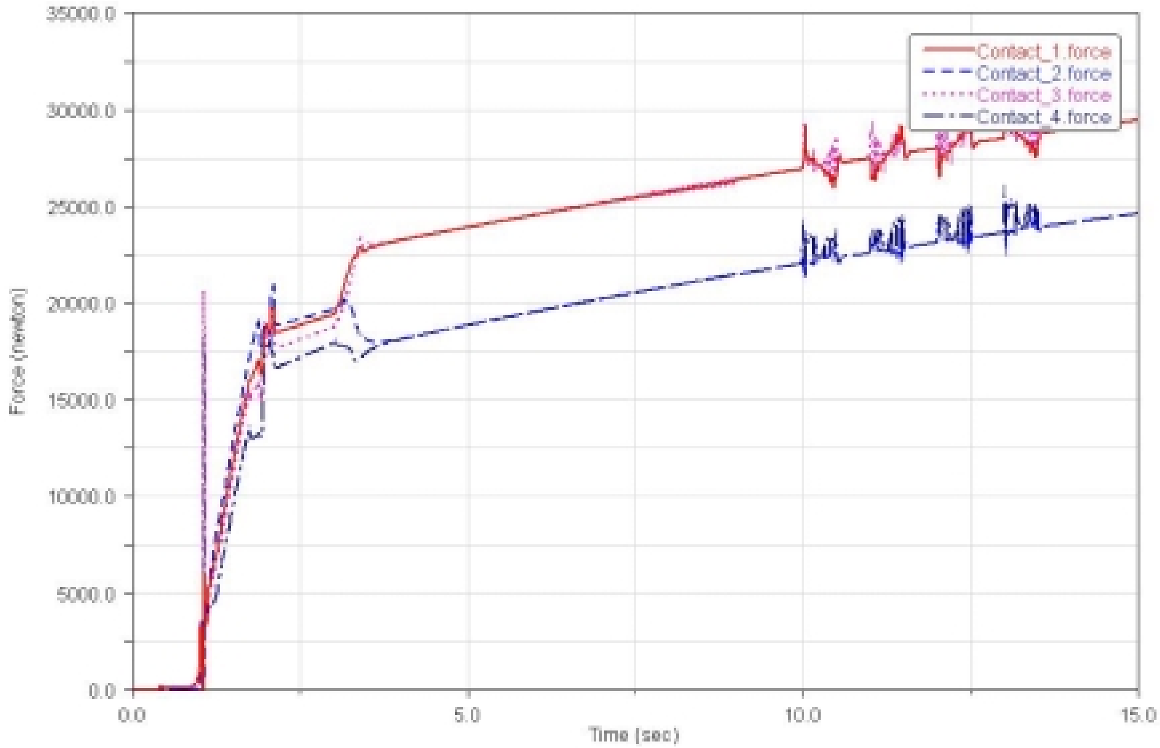

Figure 11 – Contact forces between clamp pads and wheel.

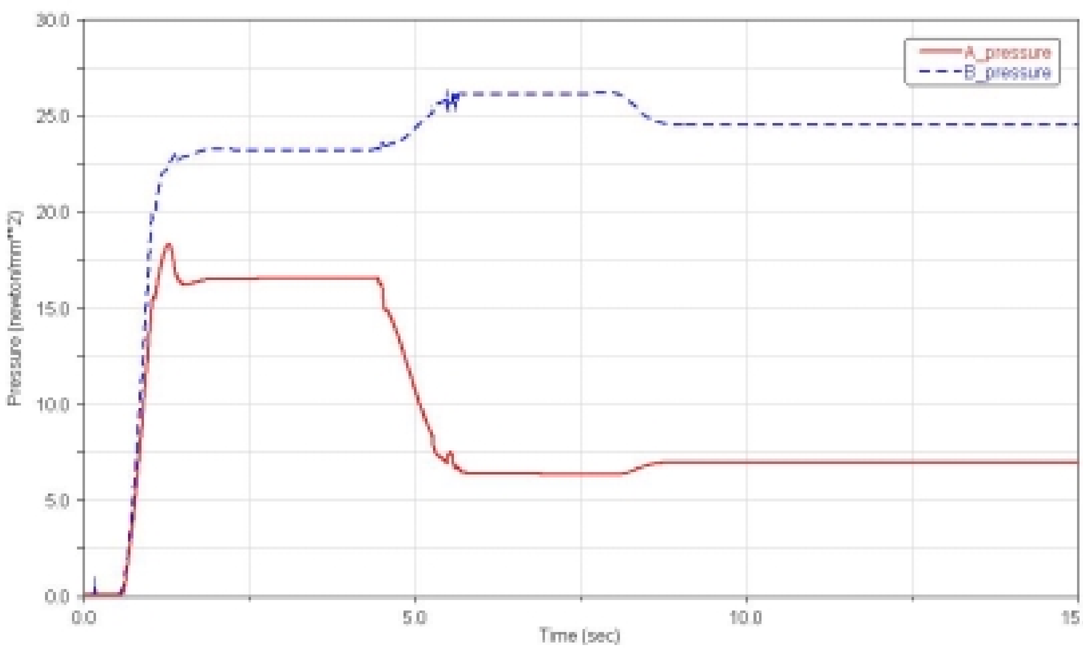

Figure 10 – Cylinder pressures for the clamp closing phase.

CONCLUSION

- Virtual prototyping technology allowed us to verify the correct working of the manipulator in various conditions, also considering external interference.
- With ADAMS Hydraulics we have verified the correct dimensions of hydraulic circuit, dynamically driving complete mechanical system.
- A virtual model allows to design and optimise clamps for different wheel dimensions starting from the existing one, with relevant time savings and performances increase.

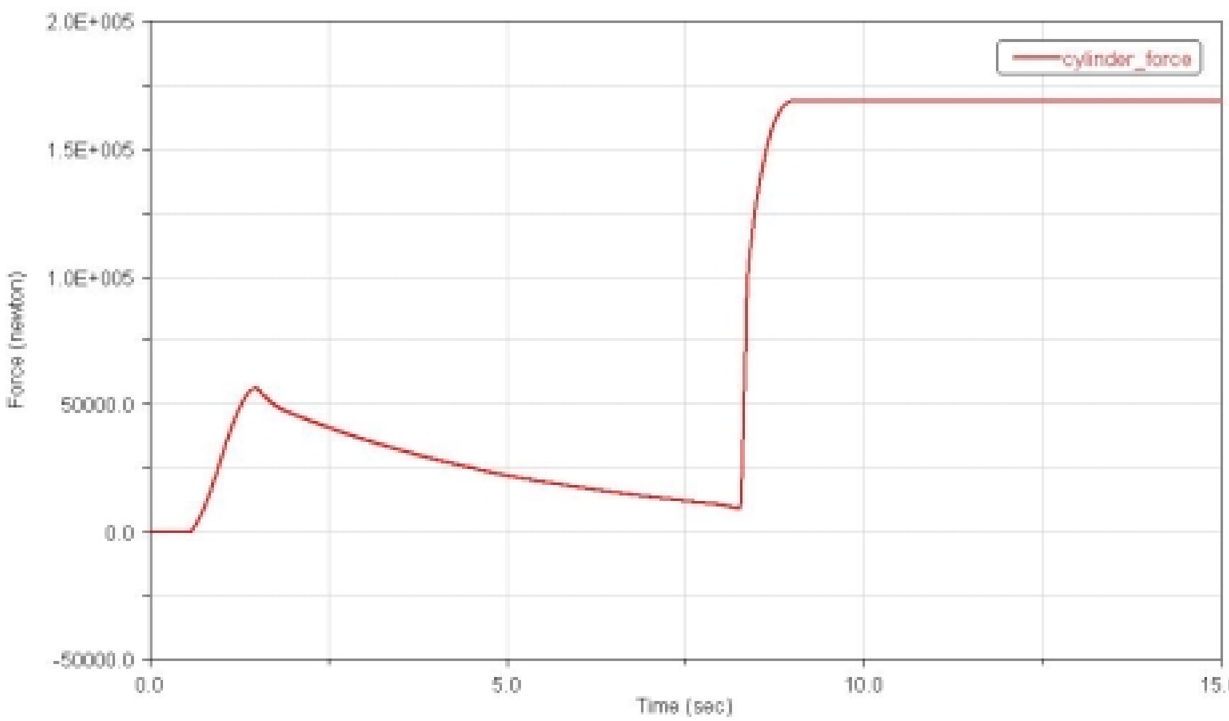

Figure 12 – Force exercised from the translation cylinder.