Numerical modelling of impacts on ski safety nets

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ABSTRACT

Safety nets are used to protect skiers during downhill competitions. However, although these nets are now able to retain skiers in almost all cases, the deceleration during such impacts can cause severe harm to skiers including hyperflexion injury or vertebra compaction.
Experience showed that the behaviour of the nets is highly dependant on:

- the material of which they are made of
- the boundary conditions (installation and fastening).

The aim of this study was :

- to analyse the net constitutive material under dynamic loadings to determine its characteristics.
- to analyse well defined impacts to be able to simulate them numerically
- to improve the net behaviour during real impacts
- to provide some recommendations concerning the geometry of the complete system.

This study continues Fayçal Ben Yahia's work which was presented in Paris in June 2001. The whole study was performed under the funding of the French company *Dalloz Montagnes* and with the technical collaboration of the *International Skiing Federation* (FIS).
As a first step, we used the tests on the net thread to model it in static and dynamic conditions. Then we compared the results from impact tests on small safety systems and simulations with LS-DYNA which led to the validation of the whole model. Finally, simulations of impacts on real size nets were used to study the influence of the boundary configuration on the net behaviour. The model developed during this study makes it possible to optimise the geometry of the whole system in order to increase skier protection.

INTRODUCTION

Last years, the evolution of ski equipment has contributed to increase the velocity of skiers in competitions ; security equipment should be developed consequently. It seams necessary then to analyse the behaviour of the safety nets that are installed along the ski slopes. When a skier looses control, he is retained by the security system, however, the strength of the impact could cause very serious damage as vertebrae compression or whiplash injury.

In order to improve the behaviour of those systems, a numeric model of it has been created using LS-DYNA and a first small optimisation has been performed to define better installation conditions.

To create and validate this model, experimental data was used as follows :

1. Static behaviour of the net cord
2. Dynamic behaviour of the net cord
3. Complete system analysis
4. Optimisation

APROACH

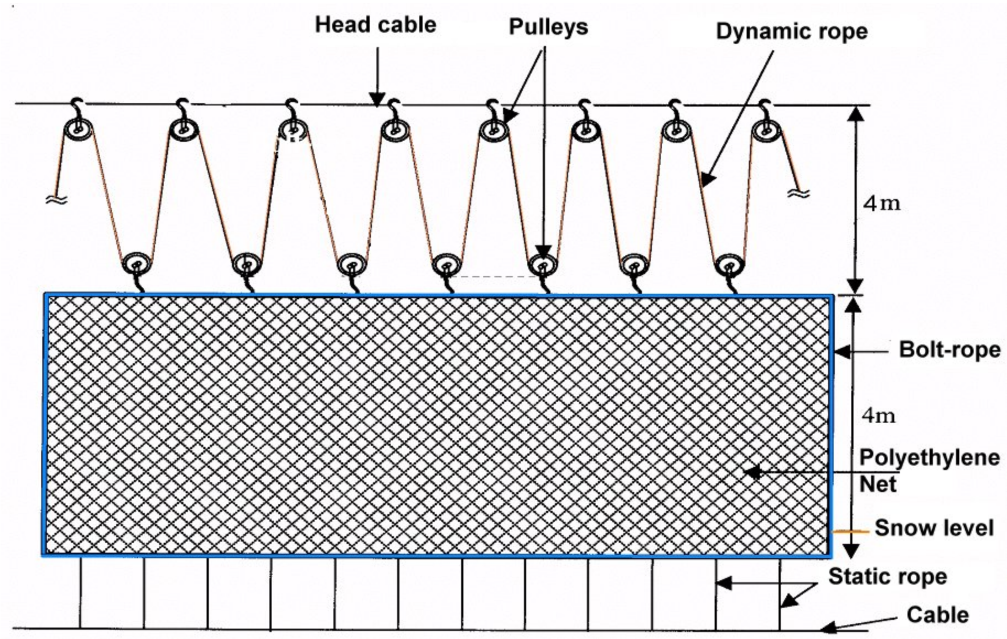

Figure 1 : Safety net system

The Figure 1 shows the complete safety system as usually found along ski slopes. A Kevlar tarpaulin is often fixed over the net. This avoids the net to be cut by the skis and makes the skier to slip to the centre of the system, where the elasticity is higher.

All cords and ropes were modelled using Belytschko-Schwer tubular beam elements (elform 5) and elastic-plastic material (type 3). All impactors and fixing device are modelled as rigid-bodies.

1 Static behaviour of the net cord

A first estimation of the material characteristics of the polyethylene cord is obtained using comparison-correction method between experimental data and simulation, stress-strain profile are compared. Figure 2 shows the experimental device for tensile tests and the corresponding model.

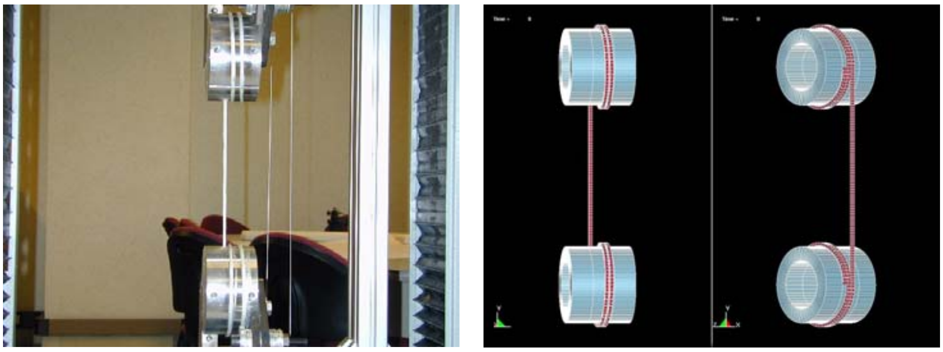

Figure 2 : Tensile device

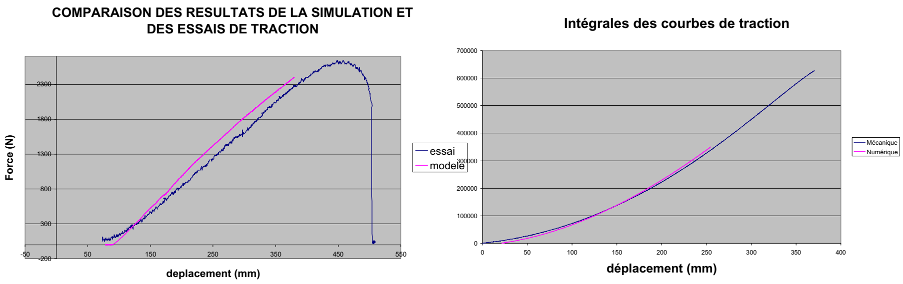

Figure 3 : Comparison between test and model

As failure is not considered here, the stress-strain profiles obtained are satisfying ; the profile integrate are compared too in order to evaluate the energy absorption in both cases.

2 Dynamic behaviour of the net cord

The second step for modelling the net is to consider it in a dynamic load. Thus, impact tests were performed on a cord at 2.5, 4.5, 5.6 and 6.4 m/s. Figure 4 shows the impact device used for test and the modelling of it. During the tests, displacement and acceleration of the impactor were recorded. The material law parameters were modified to better fit the experimental data.

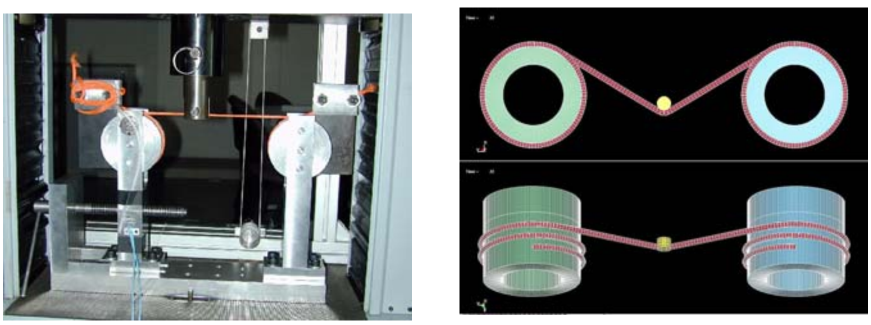

Figure 4 : Impact device

The Figure 5 shows the results in terms of impactor's acceleration. The material parameters obtained here allow lead to a quite good estimation of the polyethylene cord behaviour.

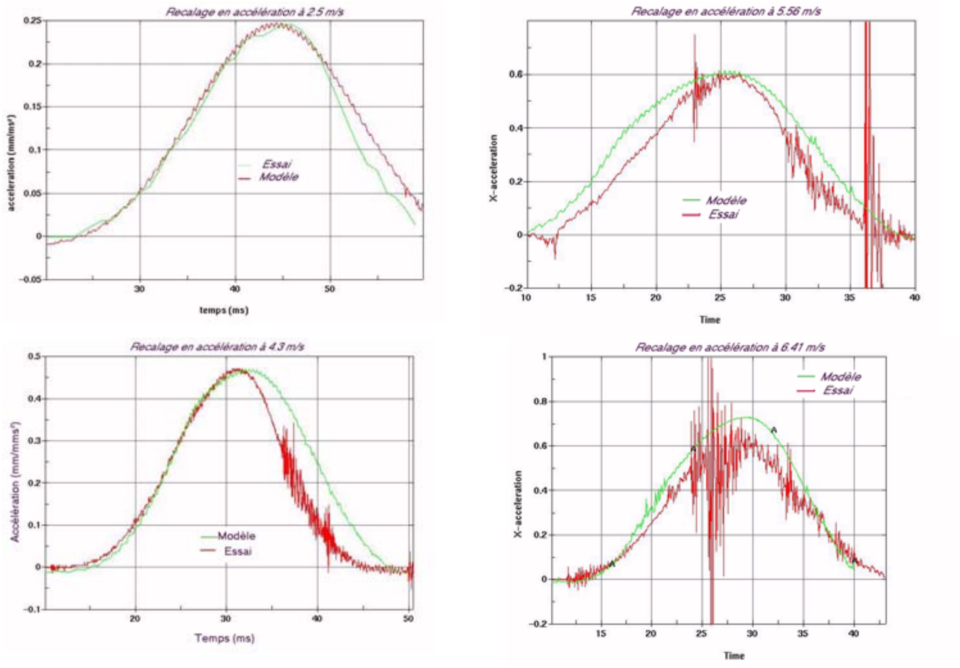

Figure 5 : Acceleration for different impact velocities

3 Complete system analysis

In order to validate the material law an the whole safety system model, some impact tests were done on small but complete and quasi-complete systems. Both square and rhombus nets were used.

Quasi-complete :

The polyethylene net with a bolt-rope was impacted by a 1m20 sphere at different velocities between 4.4 and 10 m/s. Figure 6 shows the experimental facility and the corresponding model.

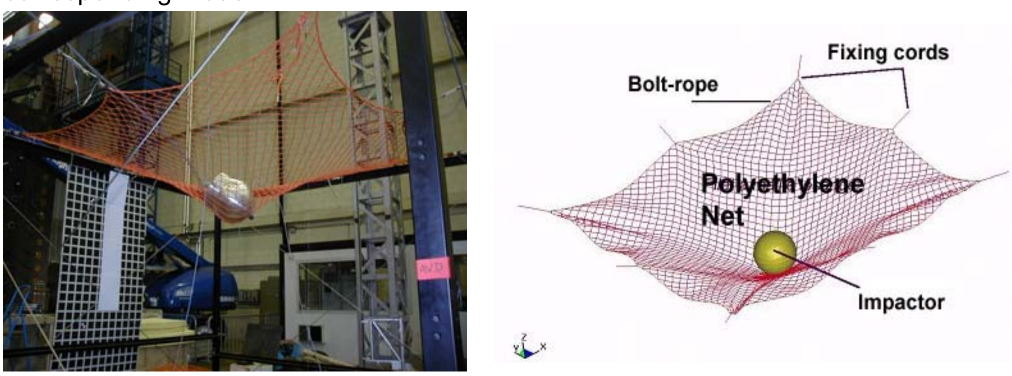

Figure 6 : Quasi complete system impact tests

Complete system :

As the whole system contains pulleys, a small complete system was tested. The impact tests were done on polyethylene nets with bolt-rope. Ten pulleys and a dynamic polyamide rope are used for lateral fixing (Figure 7).

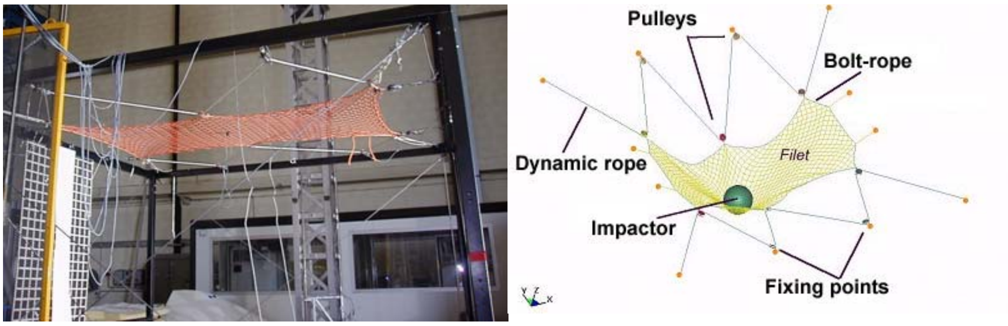

Figure 7 : Complete system impact test

Results :

The impactor's acceleration and displacement were recorded during the tests and were compared to values from simulation. The model of the safety system leads to estimate acceleration, velocity and displacement with an average error of 3%. Square and rhombus nets lead to similar results, however, from a practical point of view, rhombus nets are remarkably difficult to install, they are almost never used. The model is then validated for the range of velocity.

4 Optimisation

Once the model is validated, it may be used now to analyse the global behaviour of the safety net and to optimise it.

The optimisation may be done upon several elements of the system such as the cords dimension or material. However, this first usage of the model expects to give advice for installing the actual systems without changing any element of it.

Thus, the influence of length of the dynamic rope has been studied with four different configurations (Figure 8).

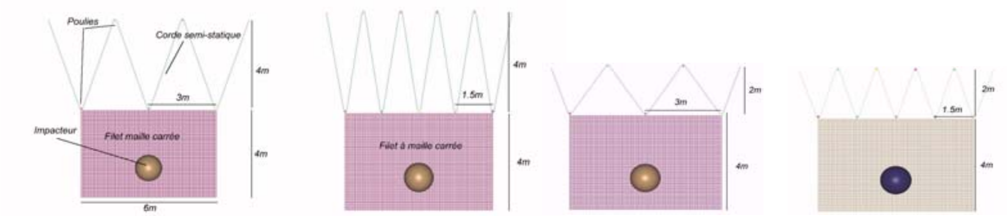

Figure 8 : Four cases studied : a) unmodified, b) horizontally modified c) vertically modified, d) horizontally and vertically modified

The criteria for evaluation of each configuration were :

- *Energy distribution* : does each part absorb as much energy as it is able to?
- *Head Injury Criteria (HIC)* : is the deceleration smooth enough to avoid brain damage of the skier?
- *Recommended free distance* : does the deflexion of the system need a wide free distance behind it?

This small study allowed to define some conclusions about the influence of the dynamic rope length.
Figure 8a shows the safety device as used today.
In Figure 8b, the pulleys have been brought closer horizontally ; this model leads to a lower deceleration and a much better energy distribution and he deflexion being higher, the system must have a wide free place behind it.
In Figure 8d, the pulleys have been brought closer horizontally and vertically ; the system becomes then more rigid and the deceleration felt by the skier is too high and may cause serious damage.

As a first optimisation, the installing conditions of the safety net can be easily modified to improve the response in case of impact. Adding pulleys horizontally leads to a smoother and more efficient system.

SUMMARY

Basic experiments on the polyethylene cord compared to simulations allowed to obtain the parameters for modelling the cord behaviour and a complete model of the safety device has been created and validated.
It is now possible to use it to optimise the response in case of impact, as the small example shown here. A deeper analysis should give precise recommendations for installation.
Further research may be done to create an even more accurate model using for example dummies…

REFERENCES

1. BEN YAHIA Fayçal – Rapport de master : *Etude numérique et expérimentale des systèmes de protection par filets de rétention* – Septembre 2000 – Dynalis.
2. CEAT – *Données d'essai d'impact sur des filets de rétention* – Juin 2001- DGA.
3. CEAT – CD-ROM : *Caractérisation dynamique de filet de rétention* – Juin 2001 – DGA.
4. DJC-Dalloz **–** http://www.djc-dalloz.com – Mars 2002.