A comparison between SimSpar and Nastran for two rigs

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Introduction

SimSpar is a software dedicated to mast design and tuning. It manages mast definition, load evaluation and mast tuning, based upon a finite element basis. It allows a mast project to be quickly evaluated.
NASTRAN is an industrial finite element analysis program that is widely used among people involved into structural design.
The objective of this study is to validate SimSpar with an industrial finite element code : MSC-NASTRAN
The calculation method is divided into two steps. The first part is a linear finite element analysis that computes mast deformation and cable tension. The second one is a buckling coefficient evaluation.
This study takes place in the SimSpar developpement process, to evaluate the accuracy gain given by a new way to model the rig geometry. This feature should be available in SimSpar during year 2007.
Two different mast projects are modeled, both with SimSpar and with MSC-NASTRAN. Their results are then compared and criticized.

Geometry

The rig projects are :

- a multihull like mast project without spreader, called M100
- a two spreader sets mats with swept spreaders, called MR2130

Figures 1 and 2 show those rig geometry with Nastran.

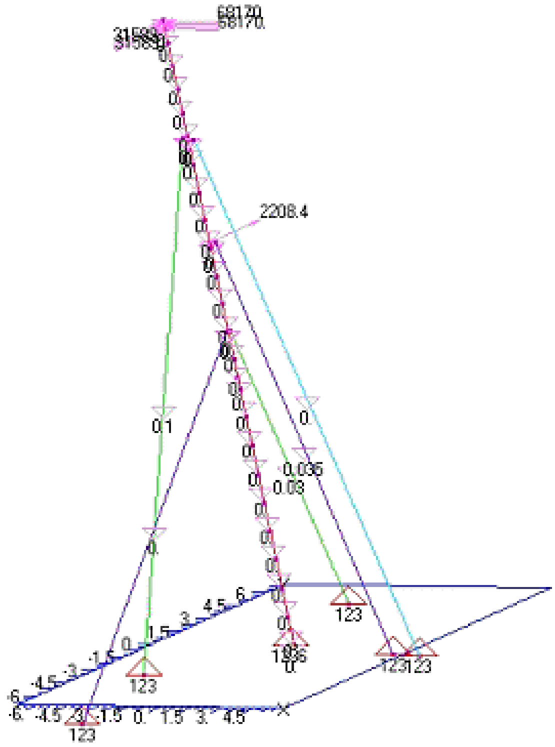

Figure 1 : M100 rig – Nastran model

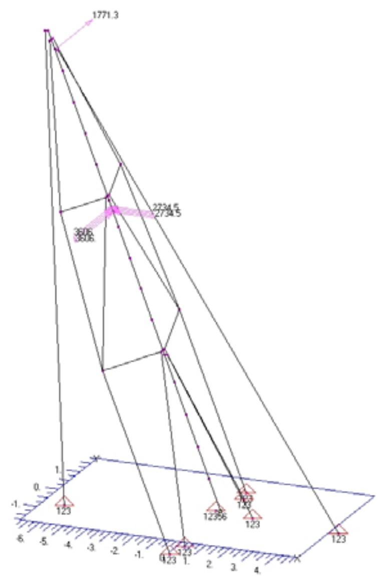

Figure 2 : MR2130 rig – Nastran model

Based upon these two rig geometries, two different arrangements have been tested

with SimSpar, depending of the cable attachement location.
In the first one, called “basic” geometry, cables are attached on the mast section neutral fiber. It is a common hypothesis when considering a beam model with the finite element theory, but neglects in first approach second-order moments.
In the second geometry, the distance between the section neutral fiber and cable attachement is taken into account by an additional element, which should improve Simspar’s accuracy. This model requires two elements for each cable instead of only one in the first case.

Figure 3 : Cable location

Calculation with Nastran code has been carried out only with the second geometry.

Loads

Load applied to the structure are sail loads and cable internal tension coming from mast tuning.
Loads are computed with SimSpar directly from the sail plan layout, then loads are applied to the Nastran model.

Mast deformation

The following figures show mast tube deformation for the three models in the longitudinal and tranverse direction.
Agreement between SimSpar and Nastran is very good with a maximum difference of 1% for one node and an average difference of 0.2%.
SimSpar “basic” model remains very close to SimSpar and Nastran for **MR2130** mast. Due to its wider mast tube section, significant differences occur for **M100** mast. This trend is more sensitive for transversal deformation, due to the lower cable / mast angle in the transversal plane than in the longitudinal plane where the geometry model is mode accurate. Nevertheless, the shape of the deformation curve remains the same for the three models.

M100 Project

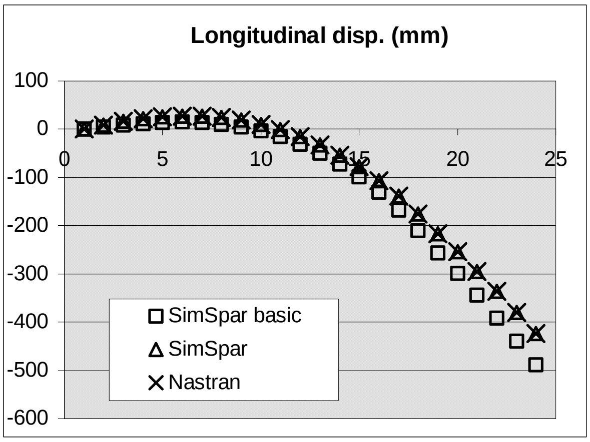

Figure 4 : M100, longitudinal mast deformation

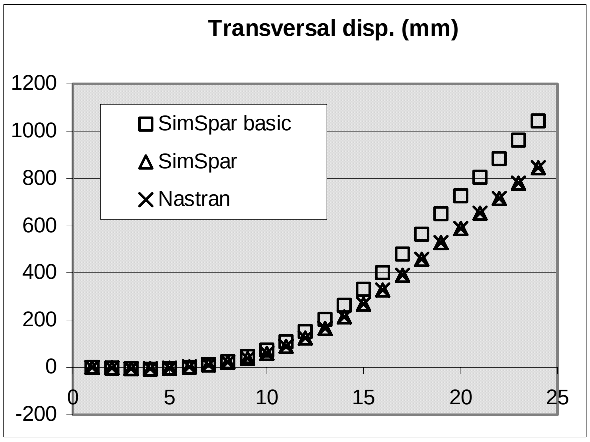

Figure 5 : M100 transversal mast deformation

MR2130 project

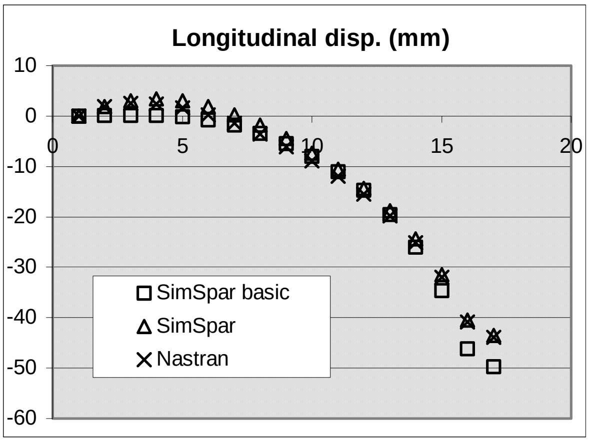

Figure 6 : MR2130, longitudinal mast deformation

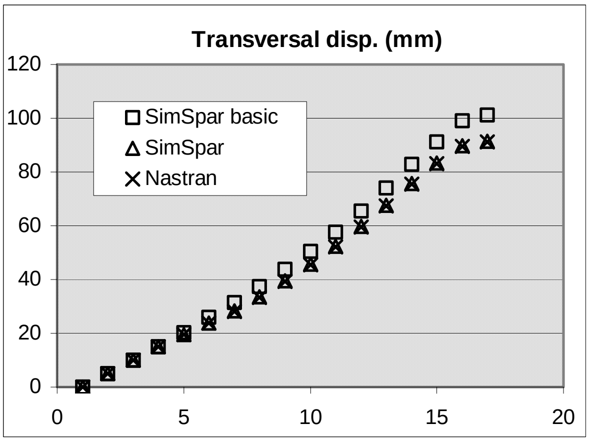

Figure 7 : MR2130, transversal mast deformation

Cable tension

The following tables show cable tension computed with SimSpar and Nastran. The agreement between the two programs is very good with an average difference of 0.3%. The maximum difference is below 1% except for the runner in the M100 project.

M100 project

Element	Simspar "basic"	SimSpar	Nastran
Forestay #1	7.29	7.02	6.95
Forestay #2	3.56	3.48	3.46
Windward shroud	2.84	2.51	2.52
Runner	1.00	1.41	1.33

Figure 8 : Cable tension in tons

MR2130 project

Element	Simspar "basic"	SimSpar	Nastran
V1 leeward	0.49	0.50	0.50
V1 windward	1.77	1.70	1.71
D1 leeward	0.51	0.49	0.48
D1 windward	1.73	1.67	1.66
V2 leeward	0.36	0.39	0.40
V2 winward	0.99	0.98	0.99
D2 leeward	0.13	0.10	0.10
D2 windward	0.78	0.72	0.72
D3 leeward	0.36	0.40	0.40
D3 windward	1.00	0.99	1.00
Forestay #1	3.15	3.11	3.12
Backstay	1.79	1.81	1.81

Figure 9 : cable tension in tons

Buckling

Once deformation and tension are computed, a major point of interest for a mast designer is then the buckling behavior of the mast, which actually defines the mast safety.
When analysing mast behaviour, it is convenient to separate longitudinal mast behaviour from transversal, in order to understand the underlying physics and also to properly define section mechanical properties and rig layout in each direction.
In order to compare results between our two softwares, we have to introduce the calculation methods implemented in SimSpar and Nastran and to discuss the differences that arise.

Buckling modes

Nastran proceeds to a three-dimensional calculation of buckling whereas SimSpar splits buckling evaluation into two bidimensional calculations, one for longitudinal buckling and one for transversal buckling.
Hence, buckling coefficients calculated with Nastran correspond with the two first buckling modes, which have then to be identified by the user as the longitudinal or transversal mode. So, if the weakest direction is the transversal one, the transversal buckling coefficient will be the first one and the longitudinal buckling

coefficient will be the second one, and vice versa.
This difference also implies that the second buckling mode could be affected by the first and weakest one, whereas there is no coupling into SimSpar. But since the first mode isn't polluted by the second one (higher energy), it has no effect on safety of the structure.

Internal cable tensions

The second main difference between the two models lies in that, even though both programs compute buckling for the whole structure including cables, cable pretension load is considered constant in Nastran model. Therefore, Nastran buckling coefficients don't include sensitivity to cable pretension variation, whereas Simspar considers pretension as part of the 'incrementable load'.

Results

Buckling coefficients, computed for the three models, are shown in the following tables.

M100 buckling coefficients

	Long.	Trans.
SimSpar "basic"	0.397	1.018
SimSpar	0.386	0.980
Nastran	0.335	0.746

MR2130 buckling coefficients

	Long.	Trans.
SimSpar "basic"	0.501	0.369
SimSpar	0.484	0.371
Nastran	0.390	0.322

These results show that buckling coefficients of the 3 models are consistent. This is confirmed by the similarity of the buckling waves, as can be seen on the two following figures.
Nastran coefficients are about 20% lower than Simspar coefficients.

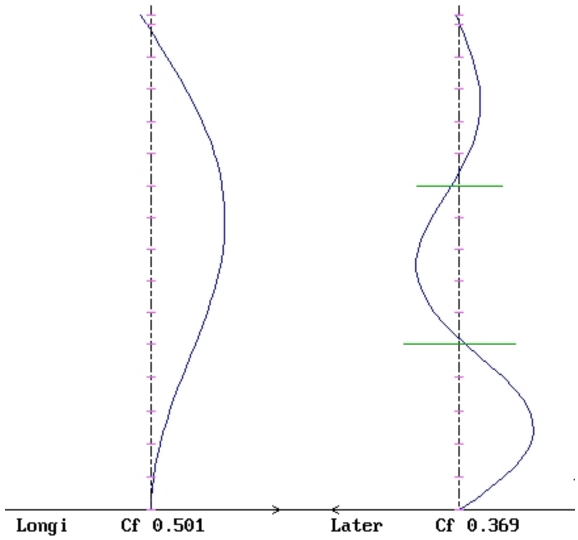

Figure 10 : SimSpar buckling modes for MR2130

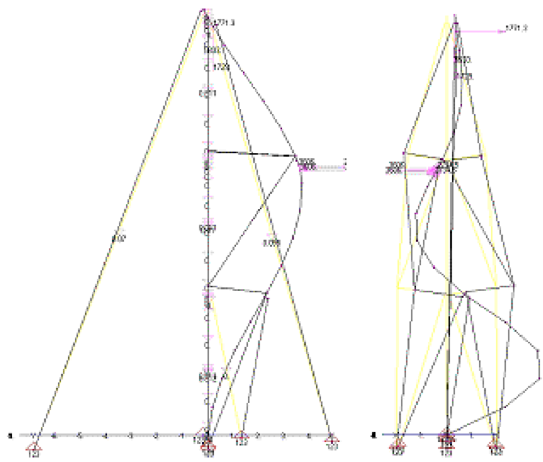

Figure 11 : NASTRAN buckling modes for MR2130

As mentionned above, this difference mainly stems from the fact that cable pretension efforts on the mast tube are not considered as part of the 'buckling incrementable load' in Nastran calculation process.

To validate SimSpar's calculation method, the SimSpar model (i.e. with sensitivity to cable pretension load) was implemented in MSC-NASTRAN software. It lead to a difference of 0.3% between SimSpar and Nastran buckling coefficients.

This part of the study validates SimSpar buckling calculation and points out the subtlety of buckling modeling. The

adopted model for mast calculation seems closer to reality than the one proposed by Nastran.
SimSpar buckling coefficients are slightly higher when using the "basic" geometry rather the enhanced one, mostly because the second model leads to lower mast bending. This effect is more sensitive with small angles between cable and mast tube (i.e. for narrow rigs).

Conclusions

This study validates the SimSpar model for mast calculation and shows a very good agreement of SimSpar with an industrial finite element software such as MSC-NASTRAN.
SimSpar "basic" model, that represents a common way to model mast geometry with the beam theory, is consistent but its accuracy will be enhanced by about 5% with the new proposed formulation.
It also points out that the buckling calculation performed in SimSpar is consistent and fits the needs of mast designers taking into account rig tuning and cable pretension.

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