MODELLING OF GUN DYNAMICS TO IMPROVE WEAPON SYSTEM ACCURACY

Céline DOFFEMONT

GIAT Industries – Weapon and Ammunition Systems Division

Frédéric TARTARY

DGA – Systems Evaluation and Test Directorate

Philippe VERDUN

GIAT Industries – Technological and Research Center

Modelling of gun dynamics to improve weapon system accuracy

CONTEXT

A knowledge of the dynamic behaviour of armoured vehicles or artillery systems is of fundamental importance in the development and optimization of weapon system accuracy.

To this end, we have developed dynamic behaviour models using ADAMS software including the following elements:

- structural flexibility,

- a high resolution interior ballistics projectile course model,

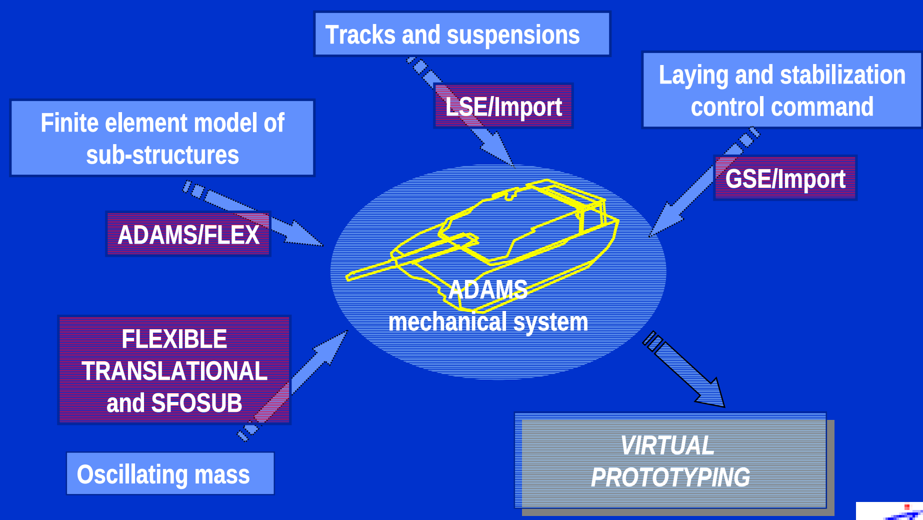
- a macroscopic representation of tracks and suspensions,

- laying in elevation - azimuth and gun stabilization during a firing.

The overall model have been validated against a large experimental data set collected from modal analysis, rolling and firing tests on an instrumented system.

15th ADAMS European User's conference- November 2000

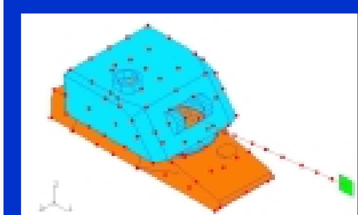
TECHNICAL OBJECTIVES



FLEXIBILITY

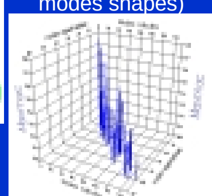
Why ? Local structures act upon global system behaviour for an artillery or a “firing-on-the-move” system

How ? Each FE sub-structure allows us to build a global FE model, validated from a large modal analysis test



FE model : topological correlation

Modal updating from modal parameters (frequency and modes shapes)

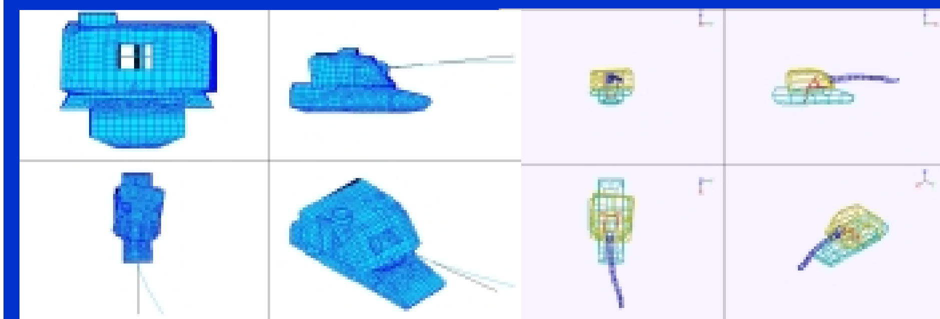


MAC MATRIX CRITERIUM

Experimental identification

FLEXIBILITY

Example of a first frequency and mode shape validation for an artillery system



Extraction of modal properties including damping of each sub-structures **in order to rebuild** the equivalent ADAMS model

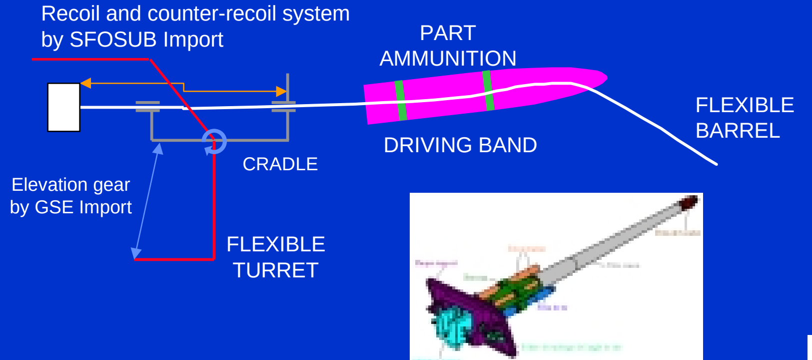
INTERACTION BETWEEN GUN AND AMMUNITION

Why ? The ammunition and barrel dynamic behaviour are closely inter-dependant and are a function of boundary condition evolution of the recoiling mass on the oscillating cradle

How ?

Dynamic gun/ammunition interaction by “FLEXIBLE TRANSLATIONAL” General Force

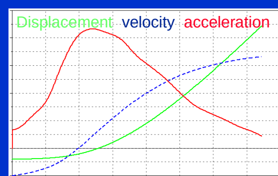
Recoil and counter-recoil system by SFOSUB Import



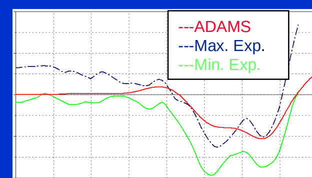
INTERACTION BETWEEN GUN AND AMMUNITION

Update of the recoiling/oscillating mass from experimental firing tests on instrumented and analytical systems

During firing

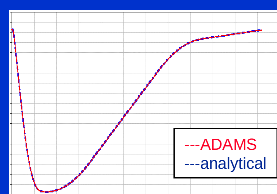


Ammunition behavior

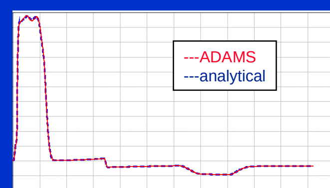


Z displacement at muzzle

After firing



X displacement at breech



X force at Brake1

TRACKS AND SUSPENSIONS

Why ? Track systems (road wheel, sprocket, tensioner device, belts, connectors,…) are complex, usually unknown and **incompatible with our context**

How ?

$$\begin{Bmatrix}\hat F_c\\ \hat F_{10}\end{Bmatrix} = -\frac{1}{\omega^2}\begin{pmatrix} m\omega^2+ic\omega+k & -(ic\omega+k)\\ (ic\omega+k) & (ic\omega+k)\end{pmatrix}\begin{pmatrix}\hat\gamma_c\\ \hat\gamma_s\end{pmatrix}$$

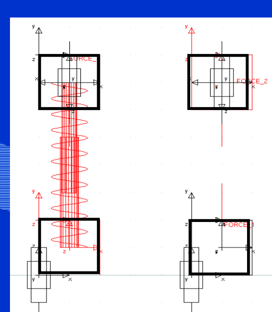
Transformation in a continuous form

Reformulation in linear state equation

LSE Import (state matrix) via ADAMS/Engineering

Identification process of sample data

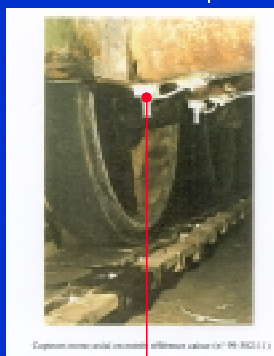
FRF extraction



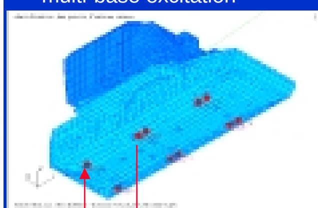
TRACKS AND SUSPENSIONS

Sample data such Fc, γc, γs at each connection points are extracted from mixing experimental and analytical tests

Experimental rolling test on a standard road profile



update FE model subjected to a dynamic multi-base excitation



ADAMS rough model with the same road profile and well-known speed

γs^{ADAMS}

Fc^{FE}

γc^{exp}

Modelling of gun dynamics to improve weapon system accuracy

TRACKS AND SUSPENSIONS

Solution required $F_c(\omega) = H_1\gamma_c(\omega) + H_2\gamma_s(\omega)$ from time expression of Fc, γc, γs

Simultaneous identification of (H_1, H_2) using an ARMAt process :

$$\sum_{i=0}^{p} a_i F_c(t-i) = \sum_{j=0}^{q} b_j \gamma_c(t-j) + \sum_{k=0}^{r} c_k \gamma_s(t-k)$$

So, after a z sample transformation of the finite difference equation :

$$H_1(z) = \frac{b_j z_j}{a_i z_i} \text{ et } H_2(z) = \frac{c_k z_k}{a_i z_i}.$$

Using a sample/continuous translation $H(s) = \dfrac{\prod_{i=1}^{m}(s+z_i)}{\prod_{j=1}^{n}(s+p_j)}$

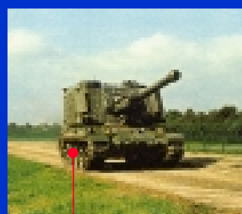
and a Cauchy form algorithm, we find the Linear State Equation expression

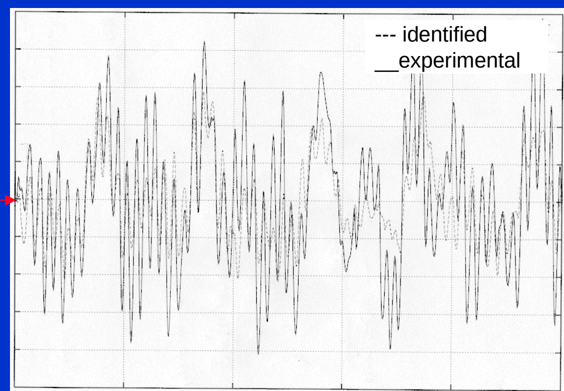
$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \end{cases}$$

… and state matrix are automatically introduced using the LSE/IMPORT

TRACKS AND SUSPENSIONS

Comparison between a FE analysis and an identified value from ARMAt of a Fc

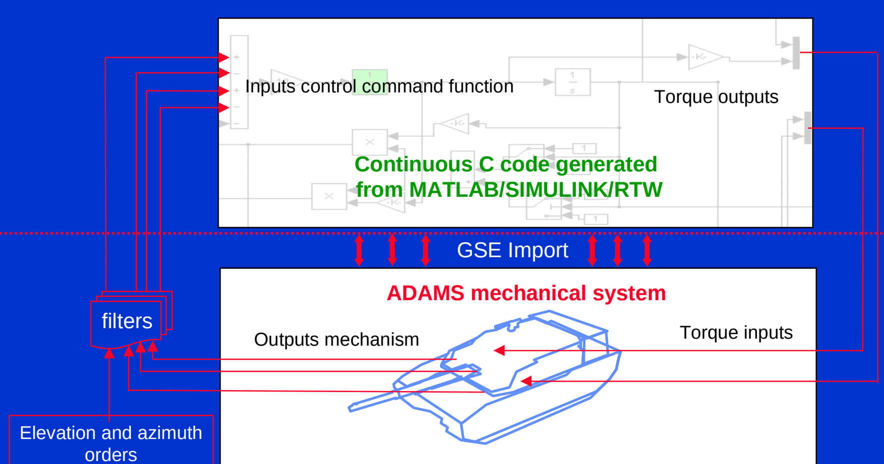




Conclusion :

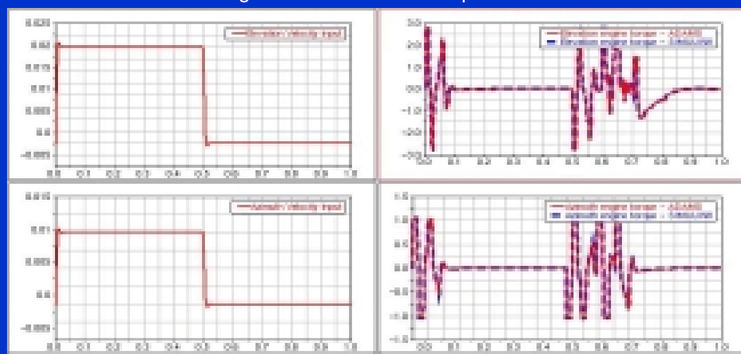
- validation of the identification process from ARMAt
- validation of the experimental/analytical data set mixing choice

LAYING AND STABILIZATION CONTROL COMMAND



LAYING AND STABILIZATION CONTROL COMMAND

Comparison between the stand-alone SIMULINK schema
and
the integrated ADAMS/GSE Import solution

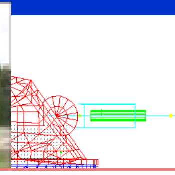


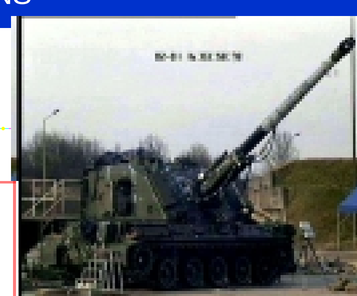
Conclusion :- validation of the integrated ADAMS/GSE Import solution
- validation of the separation between mechanical and control command functions in ADAMS

GIAT industries

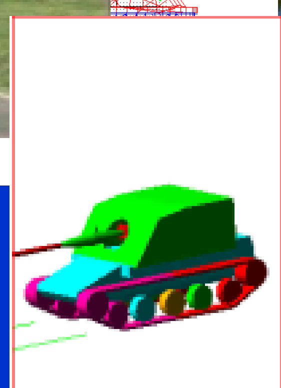
DGA

CONCLUSIONS





Each functionality is introduced in a unique overall model able to simulate the rolling, laying and firing phases



Integrated in aero-balistic software, kinematic conditions of the projectile at muzzle will allow us to estimate the shot accuracy

GIAT industries

DGA