# MODELISATION OF SCREEN RUPTURE DURING A MOBILE PHONE FREE FALL

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## ABSTRACT

Sagem brand mobile phone enjoys a strong presence in world markets thanks to continuous technological innovations associated to a high level of quality. We will approach here the case of the mobile phone screen (LCD), major part of a mobile phone whose integrity must be ensured throughout the life of the product. The specifications sheet specifies strict standards concerning the shock resistance: LCD should not be damaged during a series of 2 X 10 falls at a determined height (corresponding to average human height).

Answer of such requirements needs a best understanding and good analysis of the mechanical phenomena which appears in the LCD during the impact on the floor.

The work undertaken to this end by Sagem Communication was articulated along two directions:

- Development of a complete finite elements model of the mobile phone (with LsDyna software) in order to simulate drop tests (model readjusted by experimental drop tests with strain gauges).
- Installation of a methodology for a better prediction of the rupture in LCD (partnership with EXstream for the formulation of a statistical model of rupture).

We will present here the various phases of this work.

KEYWORDS:

Mobile phones, Drop Test Analysis, Rupture Criteria, LCD screen.

# INTRODUCTION

Computations with finite element models are quite useful when you want to predict very early (as early as 70 % of the CAD model) the mechanical behaviour of some major parts of a product. Sagem Communication uses this method to simulate the free fall of mobile phones and predict the shock resistance of some main parts (cover, screen or hinge ...). Indeed, the specifications sheet is very strict concerning the shock resistance and specifies that the LCD and cover should not be damaged during a series of 2x10 free falls to a human height. This ensures to our consumers a high level of quality of our products.

However such Finite Element models must be very precise in order to be predictive. It is thus necessary to characterise as well as possible the different constitutive materials (via tensile tests and bending tests for rupture criteria) and to readjust the model by making several experimental falls tests. Those experimental tests must be consistent to numerical models. That means that it is necessary to control the orientation of the mobile phone during impact. We use for this purpose a "Drop Tester" with a guide rail and a pneumatic system (with pen cylinders) for fixing and releasing the mobile phone at roughly 10 cm from the floor. The free fall is then filmed with a high speed camera (2500 frames per second) in order to control the impact angle. The strains are measured on LCD with strain gauges and can thus be directly compared with those computed with the corresponding numerical simulation (LSDyna).

Once the numerical model is well adjusted we can then apply our rupture model for the LCD. This one, based on a statistic analysis allows us to predict the probability of rupture of the LCD during the free fall. If necessary designers can thus make improvement as soon as possible during the project development.

# DROP TEST: FINITE ELEMENT MODEL

Mobile phone is composed of many parts: cover, hinge, screen, electronics components, keyboards, shields and so on... and all are made of different materials: plastics, metals, glass... In order to have a very accurate model, we have made the choice of represent almost all of parts (except very small components < 0,2 mm). The resulting FEM (see Figure 1 – 2) is thus big with an average of 400 000 elements and about ten materials data.

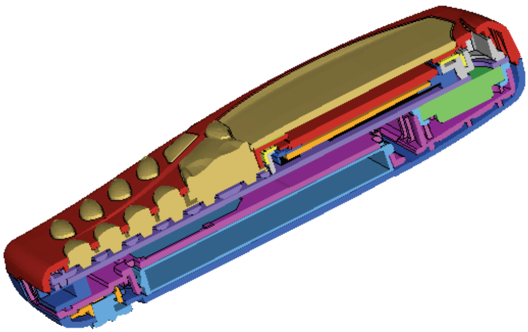

Figure 1: details of the mobile phone FEM.

The min element size is determined by the smallest zone we want to represent (fixed to 0,2 mm for us). Figure 2 shows an example of mesh. We have also used fully integrated solid and shell elements and some types of contact such as tied nodes to surface for represent the connections between components.

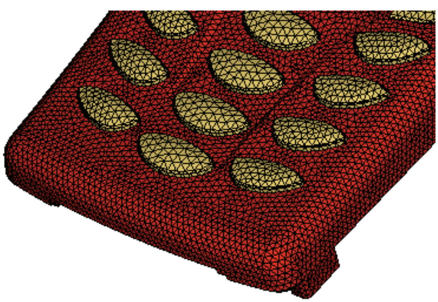

Figure 2: Example of cover and keypad meshing.

The computations are made with Lsdyna explicite formulation and take four hours with an eight CPU cluster.

## SETUP OF DROP TESTS FOR FEM IMPROVEMENT

The drop tester is described on Figure 3. The mobile phone is guided along a rail from 1m80 (without friction) and released with a pneumatic system at 10 cm from the floor to avoid rotations. The impact angle is also controlled with a high speed camera placed near the floor.

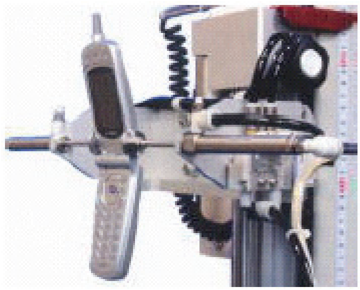

Figure 3: Drop tester.

LCD is equipped with five strain gauges; cf. Figure 4 (four linear and 1 rosette with three measuring grids). Strains are then measured on the LCD during the shock and compared with those computed with the simulation (cf. Figure 5).

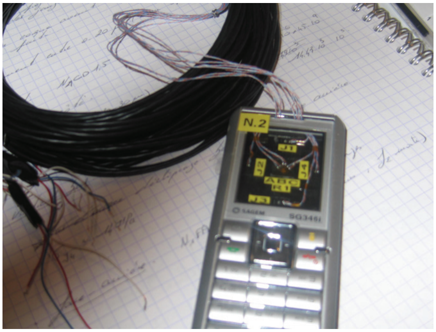

Figure 4: LCD equipment

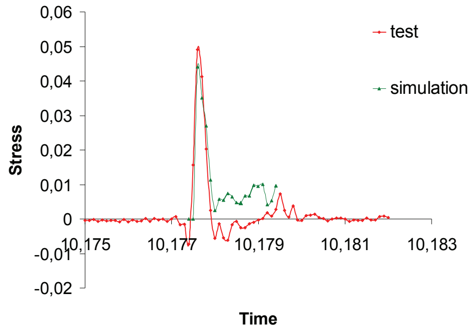


Figure 5: comparison of the two signals

The comparison of the two signals is not good enough to consider that we have a good model which estimates well the strain on the LCD. Indeed we have chosen in our FEM to represent the LCD like a homogeneous block with glass properties. That is too far away from the real architecture of the LCD composed of two glasses, a light guide, a driver, liquid crystals …. So we need to develop a more accurate LCD model if we want to use a rupture criterion.

## LCD MODEL

The Screen of a mobile phone is made of different parts described in figure 6. All these parts have various materials properties as shown in table 1. The goal of the present study is to reduce all these parts in a unique block with equivalent properties and not the glass properties.

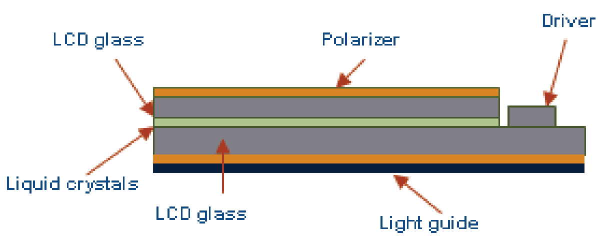


Figure 6: LCD screen architecture

We need for this to manage bending tests on the whole LCD (glass + polarizer + driver …) see Fig. 7 and measure the deflexion as a function of the applied force. We make then the numerical model of this test and compute it with the implicit solver of Lsdyna. The equivalent Young modulus is then the value which permits to obtain with the F.E model the experimental deflexion (at a given force).

Table 1: LCD parts mechanical properties.

| Module parts | Young's modules(Mpa) | Poisson's ratio | Density(ton/mm^2) |
|---|---|---|---|
| LCD glass | 77080.3 | 0.22 | 2.510E-09 |
| Polarizer | 3000 | 0.37 | 1.300E-09 |
| Driver | 169799.2 | 0.066 | 2.324E-09 |
| Mold | 2665.4 | 0.3 | 1.310E-09 |
| Light guide | 2099.6 | 0.4 | 1.010E-09 |
| Adhesive tape | 200.1 | - | 3.000E-10 |

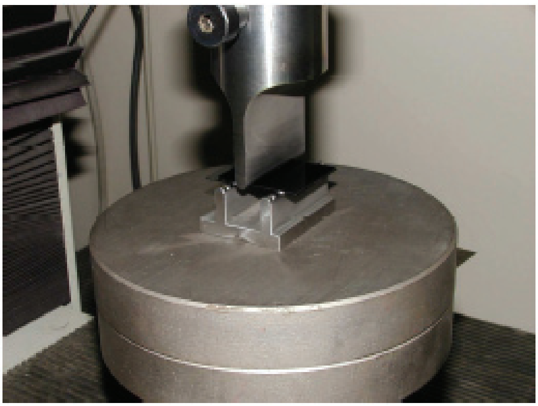

Figure 7: Bending test on the LCD modulus.

## LCD RUPTURE CRITERIA

Once the equivalent elasticity modulus is found, we can formulate a rupture criterion for the whole LCD. The bending tests show that the LCD behaves like a brittle material (rupture occurs with almost no strain). We must then use a probabilistic criterion based on a statistical analysis.  Figure 8 represents the results of the bending tests on the whole LCD. We can observe two main peaks which correspond to rupture of the first and the second glass of the LCD. We consider that the LCD modulus is broken when just one glass is broken. The rupture criterion is then based on values measured at the first peak.

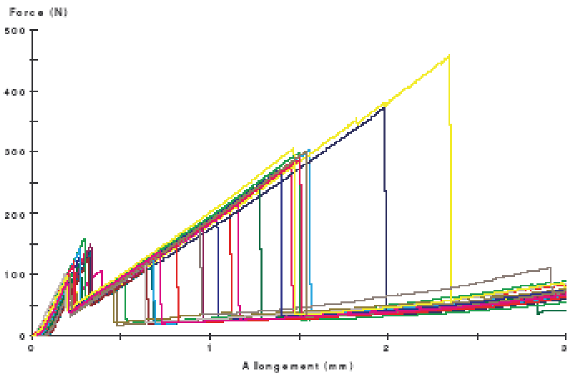


Figure 8: Bending tests on LCD modulus: force versus deflection.

The probability of brittle rupture is commonly described by the following function named Weibull density probability:

$$f(x) = \alpha\beta x^{\beta-1} e^{-\alpha x^{\beta}} \text{ if } x > 0 \quad \text{(Eq. 1)}$$

$$= 0 \quad \text{else}$$

The probability of rupture for a given stress $x_0$ is then given by:

$$p(x = x_0) = \int_0^{x_0} f(x)dx = 1 - e^{-\alpha x^{\beta}} \quad \text{(Eq. 2)}$$

with:

$$\mu = \frac{\Gamma\left(1 + \frac{1}{\beta}\right)}{\alpha^{1/\beta}} \quad \text{(average)} \quad \text{(Eq. 3)}$$

and $$\sigma^2 = \frac{\Gamma\left(1 + \frac{2}{\beta}\right) - \Gamma\left(1 + \frac{1}{\beta}\right)^2}{\alpha^{2/\beta}} \quad \text{(standard deviation)} \qquad \text{(Eq .4)}$$

$\mu$ and $\sigma$ are deduced from experimental data (see Fig. 6). In order to be representative we should test a minimum of 25 specimens of LCD. Once the curves forces versus time are obtained we computed then the corresponding stresses at the first peak at the middle of the LCD via the numerical model (using the equivalent elasticity modulus evaluated before).

$\alpha$ and $\beta$ (from Eq. 2) are evaluated by resolving the system (Eq. 3 – Eq. 4) and substituted in Eq.2 allow to determine then the probability of rupture.

## IMPLEMENTATION OF THE RUPTURE CRITERIA IN THE FREE FALL MODEL.

Exstream has implemented for us a macro in our post-treatment software (HyperView a modulus from HyperWorks distributed by Altair®). This tool allows us to visually detect the elements which go past the criterion (defined by a critical probability that we have fixed beforehand). You can see on Figure 9 an example of distribution of probability of rupture on the LCD. If we consider on this case that failure occurs when probability of rupture is equal to 50 %, then 19 elements (the red ones) are broken. The most difficult step is to fix this "critical" probability. It depends on our experience and on the capitalisation of the results of our mobile phones free fall tests. This step is still in progress.

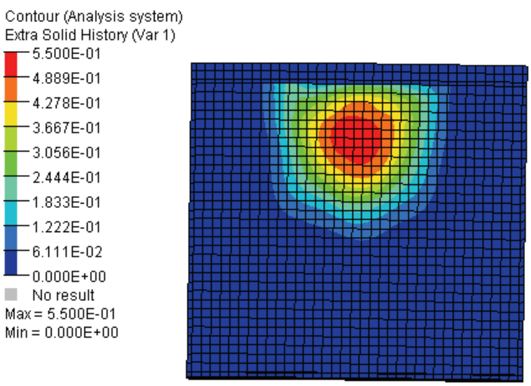


Figure 9: Distribution of probability of rupture on the LCD at time 0.24 ms.

# CONCLUSION.

We have developed a methodology to predict the glass rupture on LCD during the free fall of our mobile phones. This one based on the formulation of finite elements models coupled with experimental tests has allowed us to estimate the probability of rupture on the LCD. The rupture probability has been implemented in our post-treatment software by Exstream by allowing us to detect it visually. The main problem is then to define the "critical probability" (threshold corresponding to the rupture of the LCD during a free fall). This one has been fixed arbitrarily here to 50 %. Consequently the last step of this study is to evaluate with more accuracy this fundamental parameter.

# ACKNOWLEDGEMENTS.

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