QUADRANT PLASTIC COMPOSITES

Technical Information

# Numerical simulation of the crash performance of structural components moulded in Glass Mat reinforced Thermoplastics (GMT)

## Introduction

This is a summary of a study carried out for Quadrant Plastic Composites AG (QPC) to calibrate a material model for Pam Crash simulation of destructive and non-destructive testing of structures moulded in glass mat reinforced thermoplastics (GMT). The tested and calculated component cannot be disclosed due to confidentiality. However, the results presented in this report belong to QPC and may be used for the purpose of simulation if agreed to by QPC. The materials used to produce the parts calculated in this report were “E100F40F1” and “B100F40F1”, which both gave the same crash response. The crash test results are shown for comparison to the calculations.

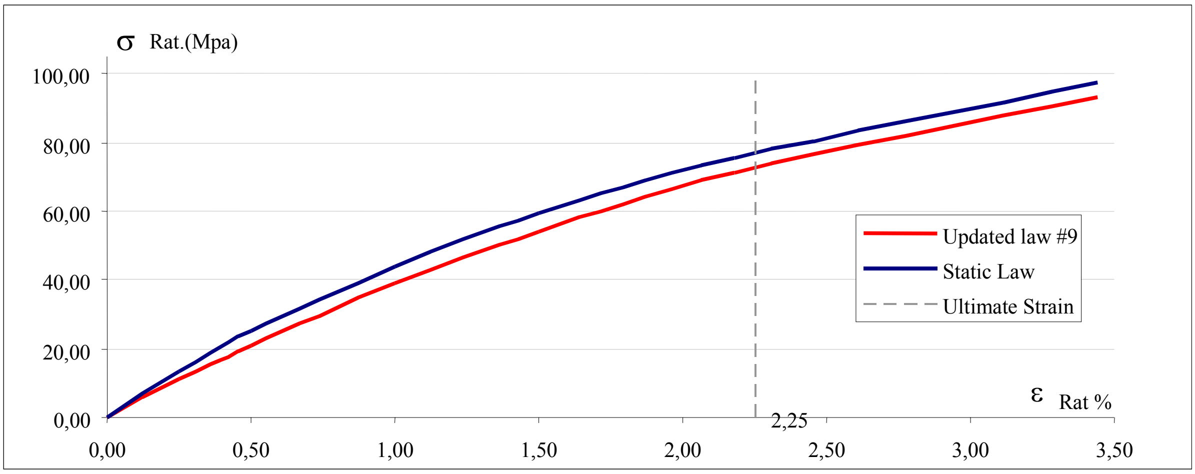
This program was carried out in collaboration with Valutec (Valenciennes, France) who carried out all the simulation work for QPC. The source text was written by M. Weyenbergh of Valutec and adapted for publication by QPC.

## Material law

The intitial data was taken from measurements carried out on specimen at rates between 0.6 mm/min up to $40x10^4$ mm/min. The static material law is presented by the engineering values of stress and strain. These stresses are called ”Initial Stress” (before updating). The Drop Test simulations for the two falling velocities - 1,8 and 3 m/s – have led to the following “updated stress” material law.

| Strain | Initial Stress | Updated Stress |
|---|---|---|
| % | Mpa | Mpa |
| 0,00 | 0,00 | 0,00 |
| 0,25 | 13,41 | 10,97 |
| 0,50 | 24,99 | 20,90 |
| 1,01 | 43,52 | 38,61 |
| 1,52 | 58,43 | 53,19 |
| 2,20 | 74,17 | 69,47 |
| 3,50 | 94,30 | 89,86 |
| E0 (Mpa) | 5364 | 4388 |

The following figure presents the initial and updated stress vs strain curves (true values). It also presents the retained threshold value of strain.




The sensitivity of the material law to the strain rate is modelled bye the Johnson Cook expression

$$\sigma (\varepsilon, \partial\varepsilon/\partial t\ ) = \sigma_o (\varepsilon)\ [1+(1/p)\ln (\max (\partial\varepsilon/\partial t /D, 1))].$$

The retained parameters for rate dependence are :

| D | P |
|---|---|
| 0.0005 | 14 |

The definition has been extended to the values of strain over 2.2%.
The maximum value of strain is limited by an damage and rupture model defined as :

$$\sigma_e (\varepsilon) = \sigma_o (\varepsilon)\ [1- D(\varepsilon)].$$

The damage model is described by 5 parameters and an ultimate threshold strain value.

These parameters are:

$\varepsilon_i$ : Plastic strain value at the beginning of damage,

$\varepsilon_{int}, D_{Int}$ : Intermediate plastic strain and damage values,

$\varepsilon_u, D_u$ : Ultimate plastic strain and damage values.

$\varepsilon_p$ Max : Ultimate threshold plastic strain.

The retained parameters are :

| $\varepsilon_i$ (%) | $\varepsilon_{int}$ (%) | $D_{Int}$ | $\varepsilon_u$ (%) | $D_u$ | $\varepsilon_p$ Max (%) |
|---|---|---|---|---|---|
| 1,2 | 1,75 | 0,5 | 1.9 | 1 | 2 |

## Boundary Conditions

**Fixed:** The component was fixed on the test frame by screws on lateral turntables and supports. The 6 degrees of freedom were blocked at these points.

**Friction Condition – Contact control:** The friction parameters of the contact component / test frame and component / impactor were unknown. Their characterisation could not be carried out so the friction coefficient was readapted from 0.15 to 0.03 through comparison with the numerical results. This modification allowed to get a good cinematic behaviour and to stabilise the numerical process of calculation.

## Impact measurements

Impact measurements were carried out at two different velocities: 1.8 m/s and 3.0 m/s. The lower velocity was non-destructive and the higher velocity was destructive. The test parameters are listed below

| | |
|---|---|
| Material: | E100 F40 |
| Nominal Velocity: | 1.8 m/s (2x) and 3.0 m/s (2x) |
| Impacting Mass: | 58.2 Kg |

The curves used from each test :

- The accelerations vs time measured on the impactor,
- The intrusion values (Displacement of the impactor) :
    - Measured values and
    - Calculated values by a double integration of the acceleration values (Ddi),
- The value of kinetic energy obtained using the velocities of the impactor.
- The external work of the force of impactor (instantaneous accelerations * falling mass * Gravity) during its measured displacement.

The curve of intrusion of the drop test #1 presents a quasi- stationary stage at the time 10 ms followed by a rebound motion. This behaviour is directly linked to the component / impactor contact stiffness in one hand and the dynamical behaviour of the impactor and the test frame in the other hand.

Moreover, the external work of the force of the impactor oversteps the initial kinetic energy (131 and 115 J respectively for the tests #1 and #2 at 1.8 m/s). The measurement of the intrusion seems to be delicate to be exploited and was not retained for the updating the numerical model. The values of intrusion obtained via a double integration of the values of measured accelerations presented a better correlation with the real values.

The measurements also intrinsically consider the dynamic behaviour of the impactor. The measured values of accelerations show this fact in the signal dynamics: modulation around an average value at each time and an important dynamic amplitude of these average values : from 0 to 18 g.

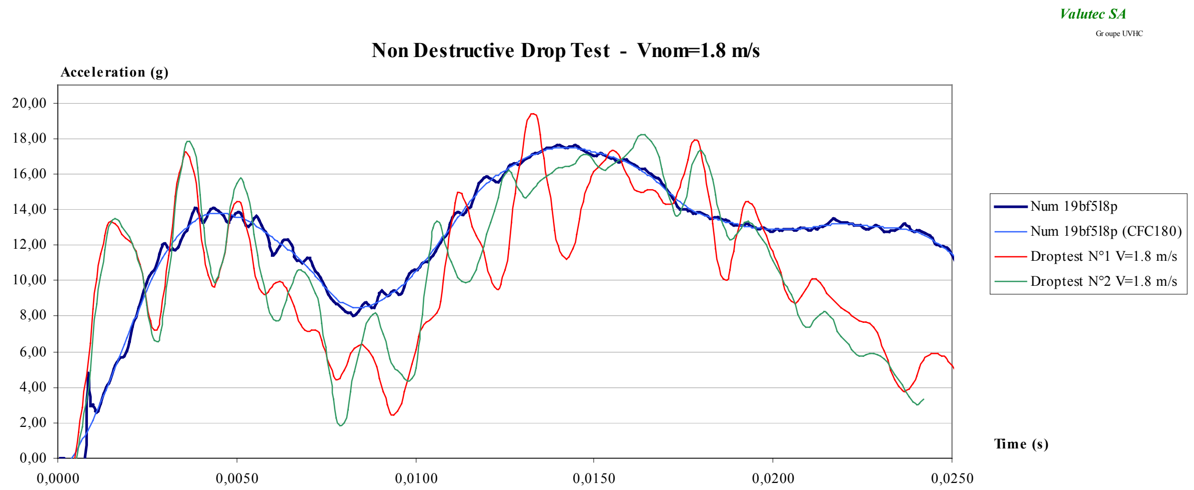
The kinetic energy consumption versus time also shows the phenomena through non monotonous slopes. This phenomena could also be observed in the results of the destructive drop test at a nominal velocity of 3 m/s.

In the finite element simulation, the impactor is modelled as a rigid body without any vibration mode shape. The calculation cannot simulate the dynamic behaviour of this part.  For the same reason, the dynamic behaviour of the test frame can not be simulated.

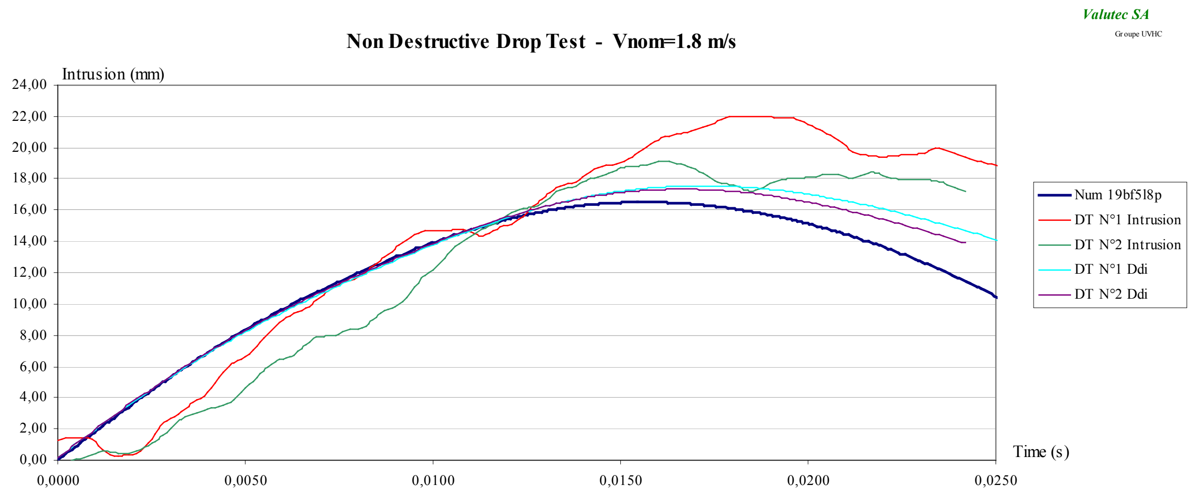
**Non Destructive Drop Test - Comparison of calculation and measurements**

The following figures presents the PamCrash numerical acceleration vs time, intrusion vs time and energy vs time  curves superimposed to the measured curves.

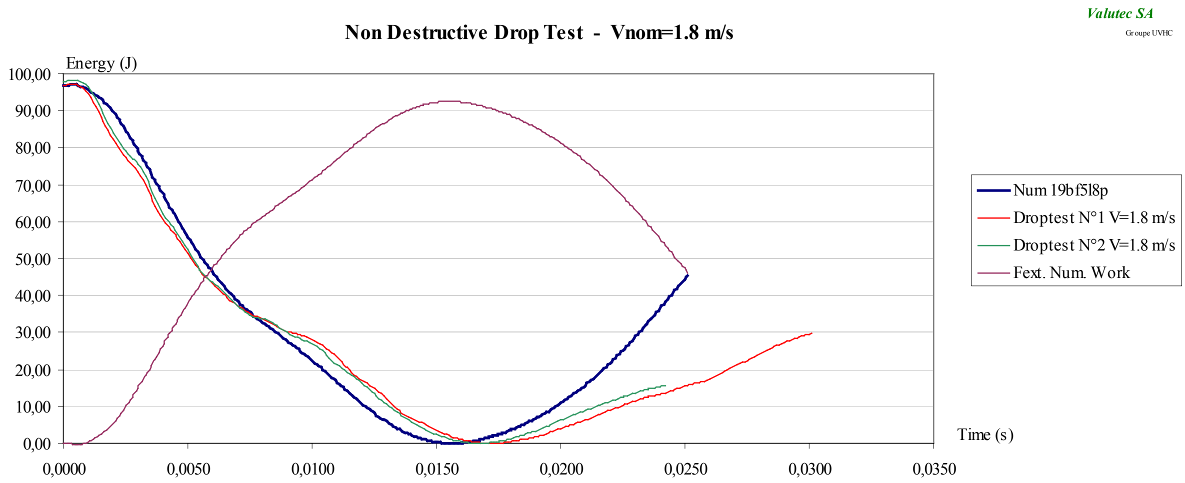
The acceleration levels show two  increases and decreases before the end of the impact. This chronology can be found on the measured curves with a slightly higher vibrational amplitude.




*Non Destructive Drop test – Vnom =1.8m/s  - Updated Acceleration vs Time Curves – filtered CFC180 and unfiltered*




*Non Destructive Drop test – Vnom =1.8m/s  - Updated Intrusion vs Time Curves*

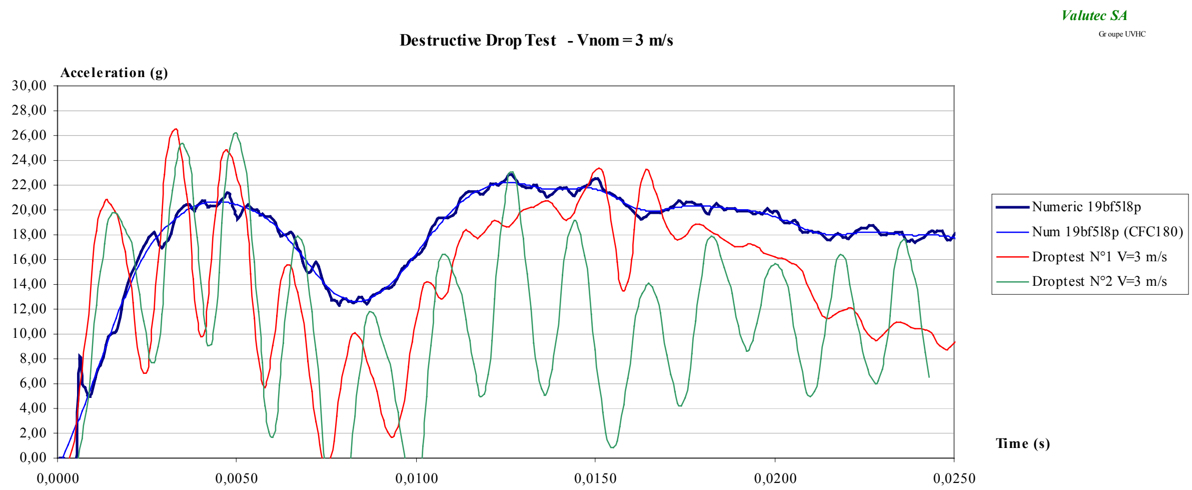



*Non Destructive Drop test – Vnom =1.8m/s - Updated Energy vs Time Curves*

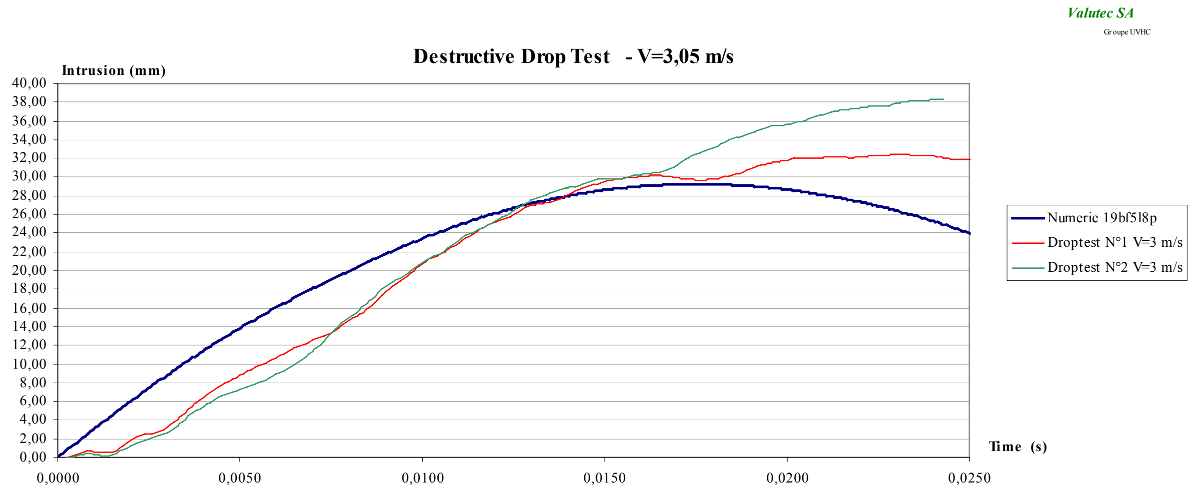
Regarding strain levels calculated in the part in this case of drop test at a nominal velocity of 1.8 m/s, no elements present any minimal plastic strain above the threshold strain.

### Non Destructive Drop Test - Comparison of calculation and measurements

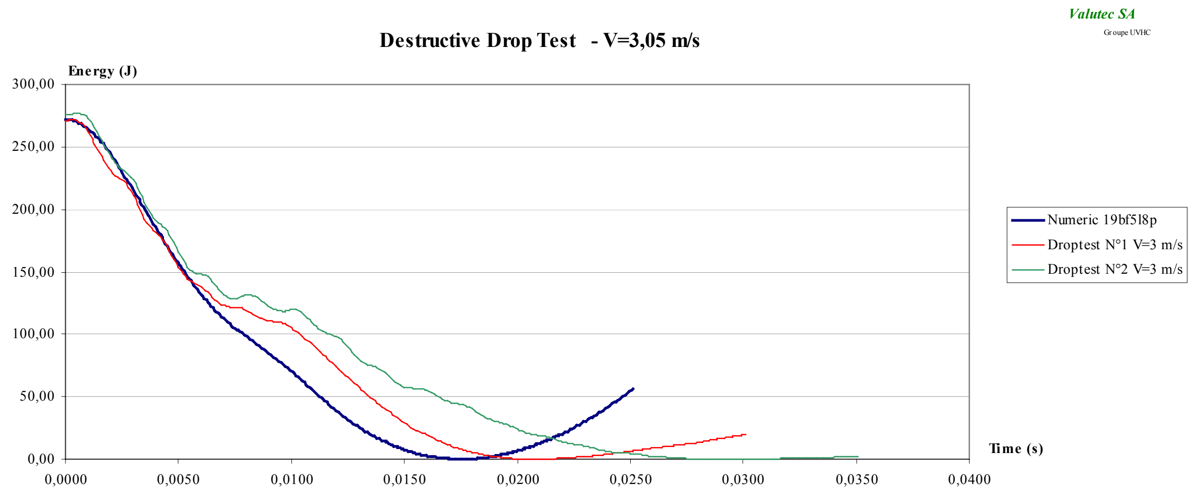
The following figures presents the PamCrash numerical acceleration vs. time, intrusion vs. time and energy vs. time curves superimposed to the measured curves. As previously seen at the non-destructive rate, the chronology of loading can be found on the measured curves with a slightly higher vibration amplitude.




*Destructive DropTest –Vnom =3 m/s - Updated Acceleration vs Time curves – filtered CFC180 and unfiltered*




*Destructive DropTest –Vnom =3 m/s - Updated Intrusion vs Time curves*




*Destructive DropTest –Vnom =3 m/s - Updated Energy vs Time curves*

In this case of drop test at a nominal velocity of 3 m/s, some elements present a minimal plastic strain sufficient enough to introduce an effective rupture.
The eliminated elements are not drawn any more. The scales of values present the results relative to the presented elements.

## Conclusion

The aim of this calculation note is the improvement of the finite elements component PamCrash modelling by the updating of the E100F40 law material. The initial description of the stress vs strain law was made on tensile test specimen tested in a wide rate interval. These different series of tensile test performed on specimen have allowed to define base values of the material law and also has presented the restrictions of the mathematical models to simulate the dynamic material behaviour.

The integration of this law in the drop test simulations have been made and the material law has been updated in order to take into account the real cinematic motions, the local mechanisms (traction, compression, bending…) and all the material non-linearity (fibre orientation, mass distribution , thickness distribution…). The finite elements model assumes a perfect geometry and isotropy which is not represented in the actual part.

Other updates have also been performed (boundary conditions, friction coefficient) in order to respect the actual cinematic and dynamic behaviour of the component on its test frame. The final proposed material law allows to obtain a good approximation of the accelerations, efforts and intrusion values versus time.

It has to be clearly noticed that due to the analytical model restrictions, the universal character of the proposed law cannot be assured. Its definition is directly linked with the geometry of the specific components used.

A complete and actual definition of the material law would need more research investigations and more accurate analytical models using a more accurate formulation and parameter set.

This law may be used in others applications in order to obtain some first numerical investigation results. The obtained results should be accurate enough in validate or invalidate an industrial design during the early phases of a project.

For more information in this matter, please contact Quadrant Plastic Composites AG for assistance.