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COMPARATIVE DIGITAL STUDY OF DAMAGE TO FLEXIBLE AND BIOSOURCE PVC PIPES

M. Jammoukh and K. Mansouri
Normal Superior School of Technical Education, SSDIA,
B.P.159, 28 820 Mohammedia, Hassan II University of Casablanca, Morocco

B. Salhi
Normal Superior School of Technical Education, LAMAT,
B.P. 6207, 10 100 Rabat, Mohammed V University of Rabat, Morocco

ABSTRACT

This paper proposes a numerical simulation of continuous improvement of the mechanical strength of the materials used to manufacture the industrialization of flow pipes by increasing their load of animal origin. This bioloading of 10% the horn of cows in powder form will allow the preservation of our ecological environment since the expansion of technological progress means that industrial activity exploits called on renewable fossil. Indeed, some performance criteria for sustainable materials are closely linked to those for environment protection. In this attention, we are considering a more sustainable new composite design of new material by charging polymers with renewable resources substances.

Keywords: **N**umerical simulation, Bio-loading, Ecological environment and Renewable resource substances.

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1. INTRODUCTION

In the perspective of this continuous improvement, a first experiment of the virgin biological load implemented made it possible to verify the hypotheses put forward, to acquire positive classification criteria and exploit its mechanical characteristics such as the maximum stress at break, the relative deformation and the Young module of material in question [1].

When renovating materials, it is encouraged to use biobased materials as a result of their significant contribution to the preservation of natural resources [2-3].

In order to benefit from the qualities of each component, it is very common to generate products mixing several origins (fossil, mineral, vegetable or animal) [4].

For an industrialist, the choice of a specific material depends on its cost of production and its varied offer; the improvement of its properties and functionalities; its environmental effect [5].

In terms of sustainable development, two principal approaches will be developed in this research future outlook: The development of the recycling of the animal bodies at the end of the lifetime thanks to the improvement of the performances of identification and the development of materials organic-charged with renewable resources starting from organic biomasses [2-6].

The considerable progress of information technology and its numerical calculation tools make it possible, on the one hand, to design and study the behavior of complex mechanical systems and, on the other hand, to develop and improve control systems.

Currently, the use of digital methods is becoming more and more frequent due to their low cost and speeds. This intense use is encouraged, on the one hand, by the possibility of integrating into the finite element calculation code used precise descriptions of the phenomena involved, such as behavioral laws and failure criteria. On the other hand, by describing the complexity of the structures studied, which is much higher than the descriptions used in the available analytical models.

Thus, it is necessary to prevent any accidental damage, to predict as much as possible the damage to the materials used and the resulting costs.

The numerical study presented in this section is dedicated to the study of the influence of defects on basic soft PVC (virgin) and reinforced soft PVC specimens with 10% animal filler in the form of horn powder (bio-loaded).

2. MATERIAL GEOMETRY

We conducted our digital study on bio-filled materials, virgin PVC and bio-reinforced PVC, the tensile strength is 25 MPa.

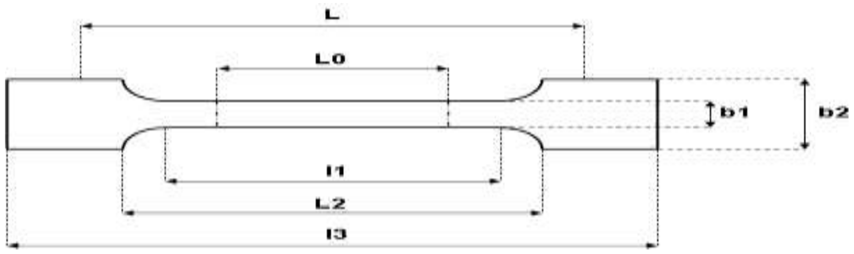

Figure 1 Specimen geometry

Table 1 Values normalized in millimeters of the dimensions of the specimen to be tested.

ISO 527-2	1BA	I3>75	I1=30±0,5	b2=10±0,5
Haltère	b1=5±0,5	h> 2	L0=25±0,5	L2 +2; L2=58±2

3. NUMERICAL MODELING OF PVC

Following the promising experimental results that we previously carried out on virgin and biocharged PVC, a numerical comparison of the anticipation of damage to the flow lines for these two studied materials seems necessary to confirm our progress on the contribution of the biocharge to the improvement of mechanical properties in terms of breaking strength [1].

3.1. Mesh size

The test tube contains a semi-circular crack with an initial length of a_0=0.5mm and the thickness of the test tube is 2 mm; and has two planes of symmetry so we modeled only the quarter, we used 4620 triangular elements at 10knots (TE10).

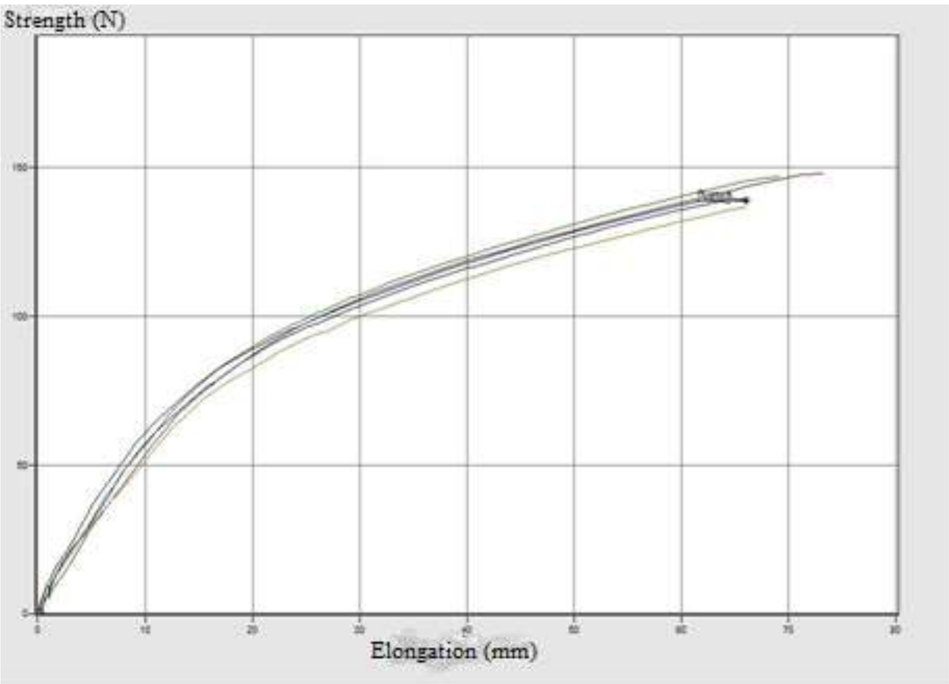

Figure 2 Traction curves of soft PVC

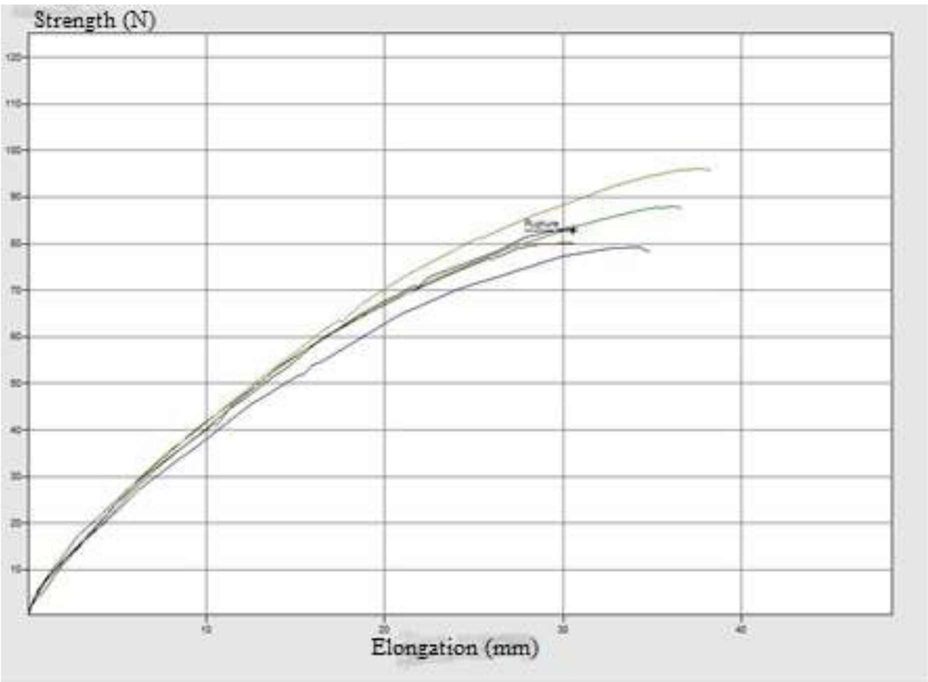

Figure 3 Traction curves of bio-loaded soft PVC

The material used: we have implemented the tensile curves (figure 2 and figure 3) in the program.

3.2. Charging and limits conditioning

We applied a 50 MPa tensile load and blocked the movement of the red line nodes (Figure 4):

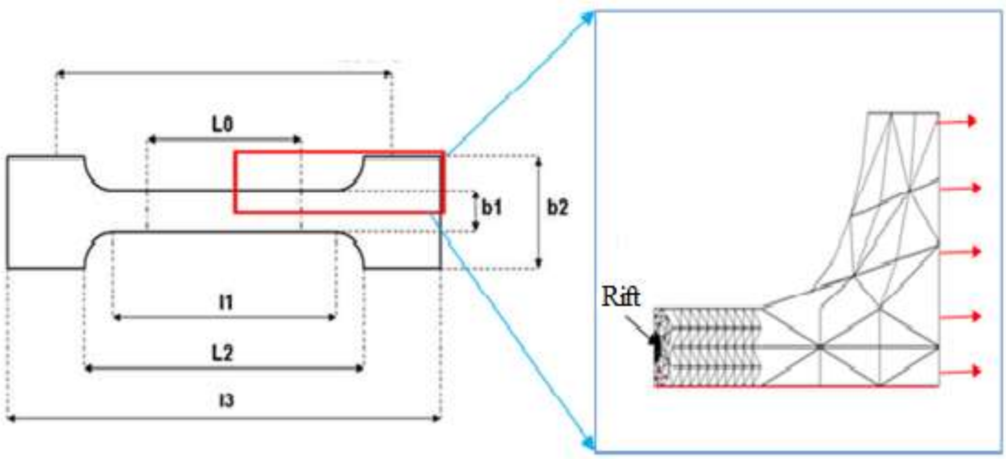

Figure 4 Mesh

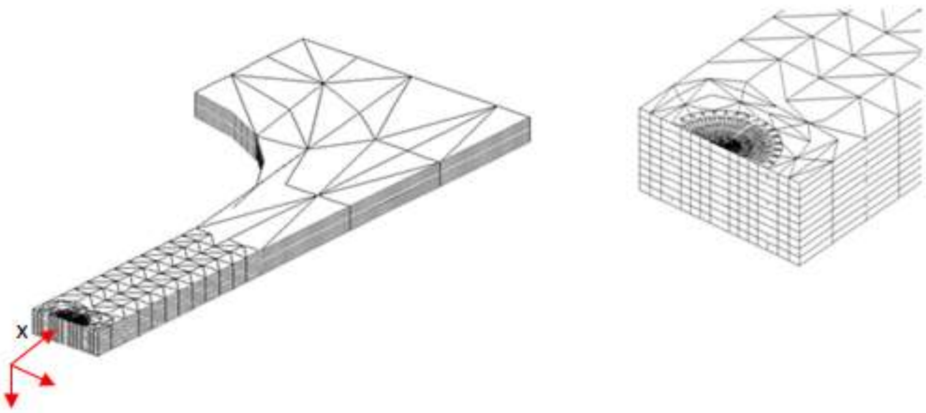

Figure 5 Zoom on the crack

This mesh refinement is performed in the vicinity of the defect using Barsoum elements.

3.3. Numerical results

3.3.1. Stress concentration coefficient

We quantified the stresses at the Hole in the specimen by calculating the Stress Concentration Coefficient Kt by the relation:

$$Kt = \frac{\sigma\ max}{\sigma\ nom} \quad (1)$$

σ_{max}: real down hole stress;

σ_{nom}: nominal stress observed in the absence of a hole.

Tables 2 and 3 present the numerical results of the numerical stress calculated along the specimen axis σ, the nominal stress and the stress concentration coefficient Kt for PVC and reinforced PVC.

Table 2 Numerical values of the stress concentration coefficient for virgin PVC

Axis x (mm)	σ	σ_{nom}	Kt
0	103	25	4,12
0,4	60	25	2,4
0,5	29	25	1,16
1	27	25	1,08

Table 3 Numerical values of the stress concentration coefficient for bioreinforced PVC

Axis x (mm)	σ	σ_{nom}	Kt
0	70	17	4,12
0,4	48	17	2,82
0,5	22	17	1,29
1	18	17	1,06

σ: Stress along the horizontal axis;

σ_{nom}: Numerical nominal constraint;

Kt: Stress concentration coefficient.

For tables 2 and 3, we can see that for reinforced PVC and virgin PVC the stress is maximum in the vicinity of the defect (103 MPa for virgin PVC and 70 MPa for reinforced PVC), this value decreases to a minimum value (27 MPa for PVC and 18 MPa for reinforced PVC).

3.3.2. Evolution of the numerical stress along the horizontal axis of the test tube

The curve in Figure 6 shows the evolution of the numerical stress along the horizontal axis of the test tube for virgin PVC and reinforced PVC materials.

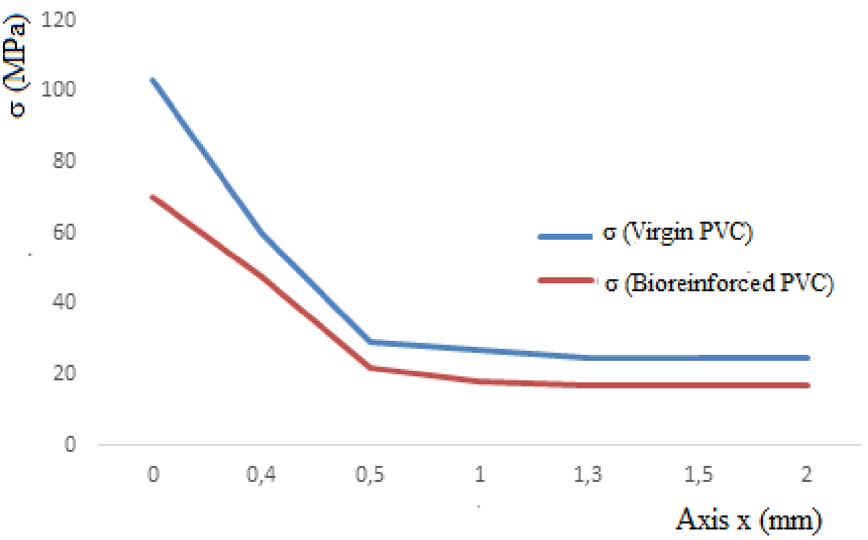

Figure 6 Evolution of the numerical stress along the horizontal axis of the specimen

In both cases, the numerical study reveals that the maximum stress is in the vicinity of the defect and then gradually decreases over the 0 to 1mm range. Beyond this distance, the value of the said stress tends towards a limit value equal to the nominal stress as indicated in Tables 2 and 3.

We note for the virgin PCV the calculated numerical stress is always higher than the value of the numerical stress of the reinforced PVC.

3.3.3. Evolution of the numerical stress concentration coefficient on the horizontal axis

The curves given in Figure 7 show the evolution of the numerical stress concentration coefficient along the horizontal axis for virgin PVC and reinforced PVC materials.

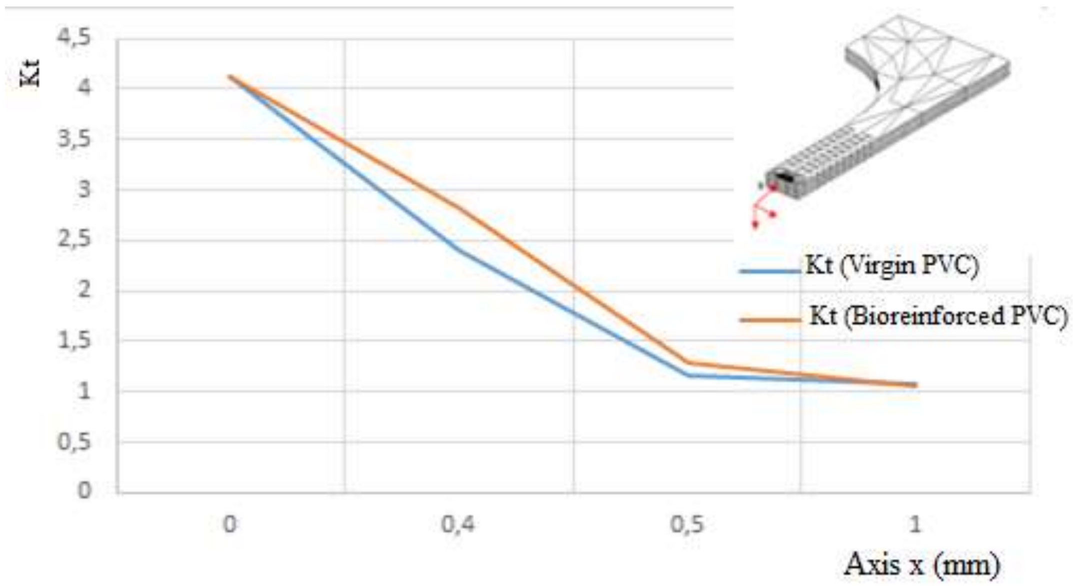

Figure 7 Evolution of the numerical stress concentration coefficient on the horizontal axis

Figure 7 shows the evolution of the stress concentration coefficient along the specimen axis for virgin PVC and for reinforced PVC, for the applied stress σ=25Mpa, we see a drop in the value of the stress concentration coefficient Kt along the horizontal axis of the specimen, then a stabilization from 1mm. The value obtained for Kt in the vicinity of the defect is maximum and is 4.12 for both materials.

3.3.4. Calculation of numerical stress intensity factor

The numerical study is performed in plane stress in Mode I, we used the numerical method G- Theta under CASTEM2016 code; the calculation of the stress intensity factor is given by the formula:

$$J = G = \frac{(KI^2)}{E} \quad (2)$$

K_I: stress intensity factor in mode I;

E: Young's modulus in MPa.

We calculated K_I at each numerical increment of the crack in Table 4, which shows the results found:

Table 4 Numerical values of the stress intensity factor

crack length a (mm)	Stress intensity factor K in Mpa√m (reinforced PVC)	Stress intensity factor K in Mpa√m (virgin PVC)
0,5	0,013	0,015
0,9	0,02	0,023
1	0,023	0,027
1,5	0,03	0,032
2	0,04	0,043

Figure 8 shows the evolution of the numerical stress intensity factor as a function of crack length for virgin PVC and reinforced PVC materials.

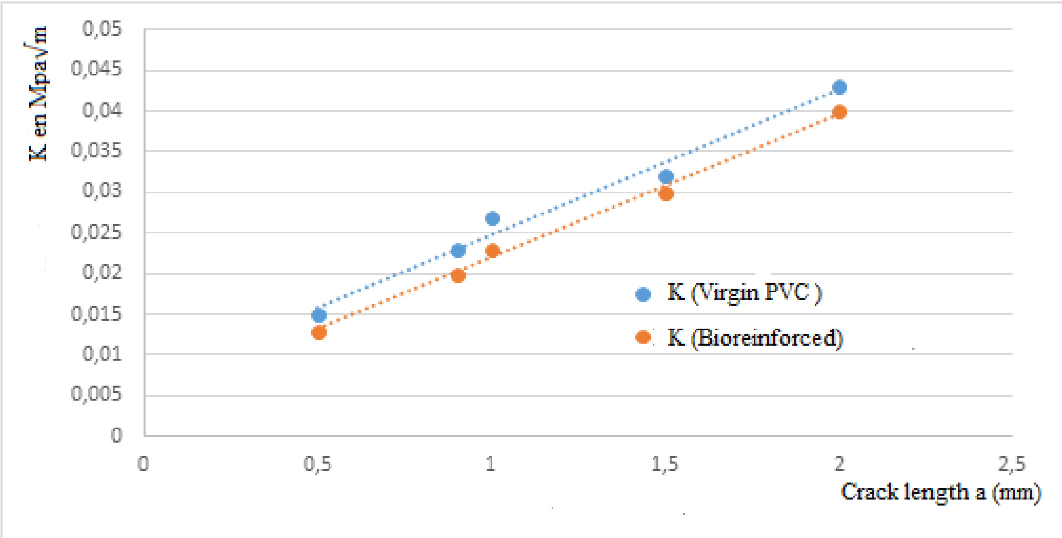

Figure 8 Evolution of digital "K" as a function of the fault length

According to Figure 8, we see that the stress intensity factor increases with each increase in the crack and this is logical because according to the relationship

$K = \alpha\sigma\sqrt{(\pi a)}$ or has the length of the crack and "α" coefficient related to the geometry and "σ" the stress applied, so for a given geometry and stress at each advancement of the crack the value of "a" increases, hence the increase in "K". The values of the stress intensity factor for reinforced PVC are lower than for virgin PVC

3.3.5. Evolution of the digital propagation speed as a function of the fault length

Any material has defects (heterogeneities, inclusions, manufacturing defects, etc.) at the microscopic level and any part may have changes in cross-section or more or less rough surface conditions. However, since all these conditions favor the occurrence of local stress concentrations, it is often necessary to take into account the possibility of crack initiation and possible crack propagation when calculating a structure.

Therefore, engineers responsible for designing structures or components subject to loading must not only consider the possibility of crack formation, but also evaluate their speed.

The cracking rate curve as a function of crack length (Figure 8) is carried out by application of the Paris law:

$$V = C\,(K)m \qquad (3)$$

With:

C=3. 6x10 -10 and m=3,

K: the numerical constraint intensity factor.

We have digitally determined the digital cracking rate curve as a function of its crack length.

Table 5 shows the values of the digital cracking rate as a function of crack length

Table 5 Numerical values of cracking rate

Crack length a (mm)	Stress intensity factor K in Mpa√m (reinforced PVC)	Stress intensity factor K in Mpa√m (virgin PVC)	Cracking speed V (reinforced PVC)	Cracking speed V (virgin PVC)
0,5	0,013	0,015	0,079*10-14	0,121*10-14
0,9	0,02	0,023	0,288*10-14	0,121*10-14
1	0,023	0,027	0,438*10-14	0,121*10-14
1,5	0,03	0,032	0,972*10-14	0,121*10-14
2	0,04	0,043	2,3*10-14	0,121*10-14

Figure 9 shows the evolution of the digital propagation rate as a function of crack length for both virgin PVC and reinforced PVC materials.

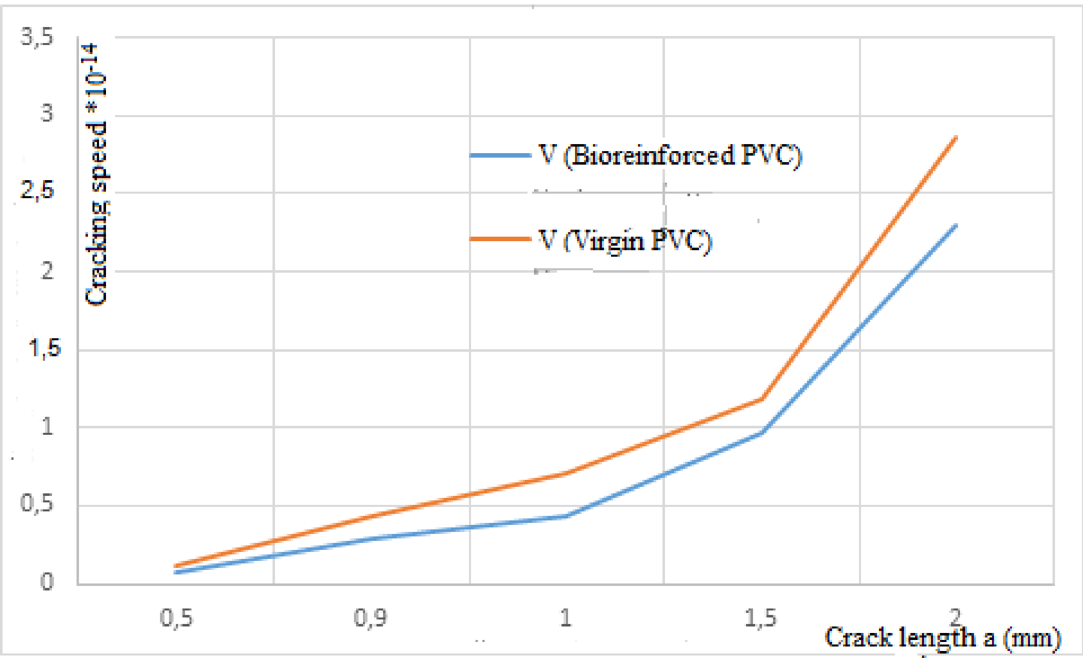

Figure 9 Evolution of K according to the progress of the crack

Analysis of these results shows that there is a significant increase in cracking rate with crack length. The cracking rate values of virgin PVC are higher than those of rigid PVC.

4. CONCLUSION

A numerical finite element study using Cast3m2016 software on virgin PVC and reinforced PVC specimens loaded in mode I was carried out for different defect lengths. The numerical results obtained allow us to validate our numerical approach for complex loading and/or geometry cases.

Test tube with defects in virgin PVC and reinforced PVC, stressed in tension, were considered, causing the crack to open with two symmetry planes and therefore only a quarter of the test tube was modeled.

Mesh refinement is performed in the vicinity of the defect using Barsoum elements.

The contribution of bio-filler in these basic polymers has made it possible to slow the spread of cracks in new eco-composite pipes (bio-charged PVC). Indeed, this bio reinforcement has just improved their mechanical resistance to breakage in the face of internal tensions due to fluid flows in the flow tubes and external environmental aggressions and conferred on them a longer duration of better quality over time required by the user, thereafter.

To this end, we have contributed to this new modeling, thus making it possible to digitally analyze this industrial concept of reliability.

SCIENTIFIC OBSTACLES

The development of materials organic-sources and organic degradable requires the development of specific tests of evaluation of the biological breakdown of formulated materials. The end-of-life by composting must be maintained whatever the physical properties of materials and the surface treatments carried out. The development of materials from resources first and secondary requires obtaining increasingly important purity in order to aim at applications to strong added values.

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