RECOVERING OF THE MECHANICAL PROPERTIES OF A PEHD PLATE CONTAINING A NOTCH BY THE GRINDING TECHNIQUE

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Abstract : In this work, we present a repair approach of HDPE pipes. We use for this goal, a single Edge notched tension (SENT) samples with different notches lengths. We observe, in the first part, that the shapes of the force displacement curve change when the specimen contains a notch comparing to the tensile test of the plates without a notch and in the second part that the area value of the specimens decreases with the increase of the notch length. This area under the force-displacement curve represent the material deformation potential and the decrease of this energy indicate that the material loss his deformation potential in the presence of a notch. The aim of our contribution is to propose a rehabilitation method of the material deformation potential based on the mater removal around the notch by the grinding technique. We show that the recovering of the deformation potential of the material is possible by using this method. We, also, show that the mechanical properties of the material are better when the grinding well is bigger. To finish, we propose a recovering efficacy criterion based on the determination of the optimal value of a/W (where a is the notch length and W is the width of the sample), at eight percent (80%) of mechanical properties recovering, beyond witch the rehabilitation is ineffective.

Key words: HDPE, repair, notch, tension, recovering.

1. INTRODUCTION

Transport pipe is an enclosure under pressure transporting of the fluids at long distances. It is known as an adduction when it is intended for the transport of the large flows. It must resist to the internal pressures of the transported fluid and with the constraints of the ground in which it is hidden. The transport pipes are manufactured with concrete, cement asbestos, cast iron, steel, PVC or HDPE. The canalization safety is one of the public interest and a question of the first importance. The number of fractures per year is a criterion of the pipe reliability. The presence of the defects in a pipe is unavoidable. These defects can be internal such as microscopic cracks, pores, the brittle particle's inclusions, or external due to the presence of notch (macro cracks) resulting from the process of construction, a corrosion or a damage caused by thirds . When the state of the defect is not sufficiently serious to lead to a complete replacement of pipe, and if the conditions of flow remain satisfactory, the rehabilitation of the pipes is justified. The state of the canalization, the possibility of action and the cost of a probably reparation are the element which are considered in the choice of the rehabilitation technique:

2. ANALYZE EXISTING DEFECTS IN A PIPE

The analysis of the defects met in a pipe, enables us to use the following working hypotheses:

1. The defects, whatever their natures, are a geometrical discontinuities being able to be described simply by a notches which can be characterized by three parameters, the length a, the ray ρ and the angle of notch ψ.
2. Under solicitation, the notches lead to a local stress concentration.

In the case of HDPE pipes, the defects are induced by stress concentrations generated by the presence of external or interior defects (scratches, stripes, scratches and inclusions) caused during the process of extrusion or at the time of the implementation of the canalization by wrong movement. For example, a wrong movement during the handling which can cause a geometrical discontinuity at least visible on the external surface of the pipe [1 ; 2]. These stress concentrations generate, according to conditions' of temperature, loading, depth of notch and environment various types of propagation of crack, such as the slow propagation of crack (SCG:slow fox trot ace growth).This type of progression, which results from the creep or the loading of tiredness, is wished the least because it does not show any sign before the rupture of the tube [3].It can be ductile or fragile.Lu and Brown [3] suggested that the two processes occur simultaneously;and the rupture final depends on which process is faster under the loading, the temperature and the depth given of notch. To evaluate the behavior of the PEHD under the quoted conditions known several work is completed [3]-[4] and [5]; according to American Water Works Association the scratches which have a depth of 10 % thickness of wall of the tube in PEHD are tolerable [5] and above these 10% the product should not normally be used [6]. To give in service the tubes in PEHD presenting of the defects the PPI (Plastics Institute Pipe) published a technical note describing the various methods of repair according to characteristics' of the defect [7].

In this presented work we use the plates instead the pipe for obvious practical reasons. We chose the sample shape with Single Edge Notched Tension (SENT) because of the test simplicity and the possibilities that this geometry permit us in terms of repair by grinding or removal of matter.

3. PROPOSAL FOR TECHNICS OF REPAIR OF THE HDPE PIPE

A. Grinding reparation

The problem of stress concentration being related to the notch effect, we propose in our study a solution based on the modification of the shape of the notch. This solution consists on the reduction of the strong stress concentrations by the removal of adjacent matter at the least forced zones.

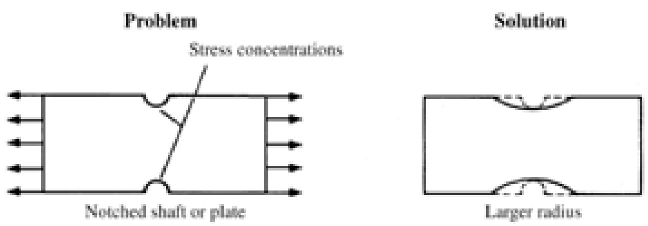

Figure1. Removal matter technic’s schematization [8]

This geometry treatment improves the profile of the defect by eliminating the existing cracks and by reducing the related stress concentration.

4. EXPERIMENTAL METHOD

The samples used are rectangular (see figure 2), They are tested in uniaxial traction for the law of behavior of the virgin sample (1), the notched ones (2) and the repaired ones by the grinding technics (3). These samples are taken on HDPE pipe, with external diameter of 600 mm and thickness of 30 mm in the circumferential direction (see figure 3), The notch is practiced in the direction of extrusion, Sample's dimensions are in conformity with standard ESIS [9] which stipulates that in the goal to have a planes stress in the ligament, it is necessary to observe the double following condition:

$$3b \leq l \leq \frac{W}{3} \qquad (1)$$

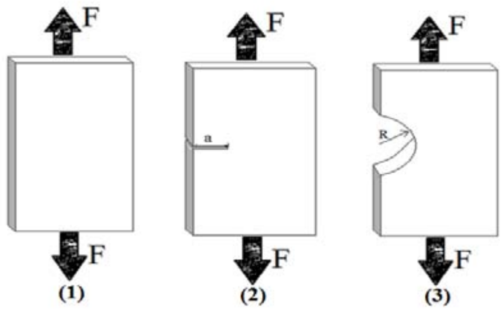

Figure2. sample used for the tensile test ;(1) : virgin sample; (2) : notched sample; (3) : sample repaired by grinding

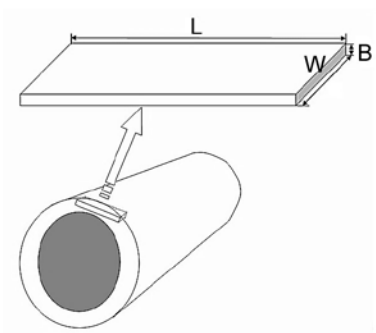

Figure 3. Sampling direction

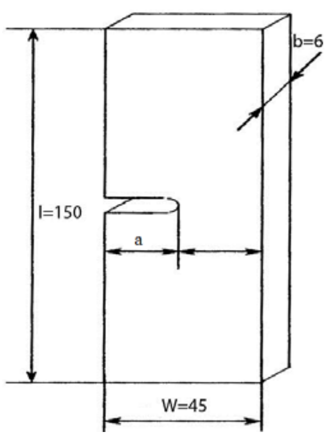

Figure 4. SENT Sample [4]

Table 1: Samples Dimensions

N° samples	Length l(mm)	Width W(mm)	Thickness b(mm)	Length of notch a (mm)
1	150	45	6	5
2				10
3				15
4				20
5				25

The tests are carried out on a IBERTEST tensile testing machine of +/- 100 kN load capacity. The forces and the displacements are measured by a load cell integrated into the machine and by a grip sensor directly posed on the sample respectively. The load-displacement curves are then collected and integrated by software into the machine in the form of Excel files.

5. RESULTS AND DISCUSSION

5.1. NOTCH'S INFLUENCE ON THE MATERIAL TENSILE BEHAVIOR

The notches carried out on the samples plainly change the material tensile behavior. We note that in the case of the virgin sample (see figure 5) we find the known behavior of the HDPE characterized by the succession of three stages which are:

1) The elastic phase with the thresholds of flow low and high;
2) The phase of flow elastic or viscoelastic;
3) The phase of hardening of material before its break off

In the case of the notched samples the viscoelastic phase disappears (see figure 5) and the elastic phase followed immediately the material break off. This indicating a great material embrittlement. This fact induces, also, a loss of a material deformation potential proportionally to the notch length.

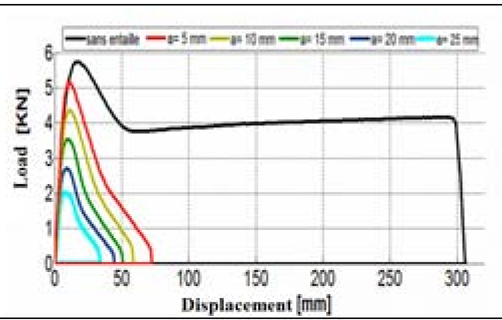

Figure5. Curve load –displacement of the samples not notched (1) (black curve)and notched (2)(color curves)

5.2. PROPOSITION OF THE RECOVERING TECHNIQUE OF THE ELASTIC FLOW POTENTIAL

The material embrittlement observed previously is a problem and a proposed solution to avoid this situation is consisting on the total or partially recovering of the loss energy by rehabilitation or a repair technique. In our study we were inspired by the Eckstein [5] work who proposed a rehabilitation solution based on the removal of matter thanks to an operation of grinding of the cracked part (see figure 6).

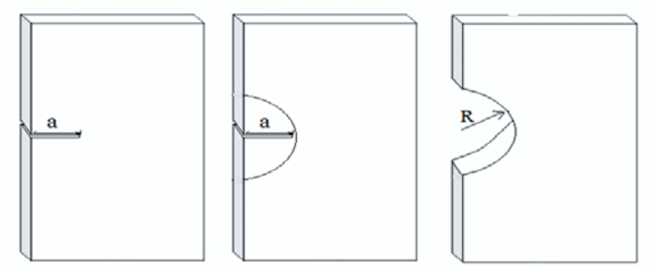

Figure 6. principle of the grinding technique used

The principle of rehabilitation is very simple; it acts to grind the cracked area thanks to a wheel. To optimize this repair we use several diameters of a grinding wheel so as to be able to reach repair optimal. After the matter removal, we carry out tensile tests on the repaired samples and we compare the tensile diagram of the notched sample with that of the repaired samples (see figures 7 and 8).

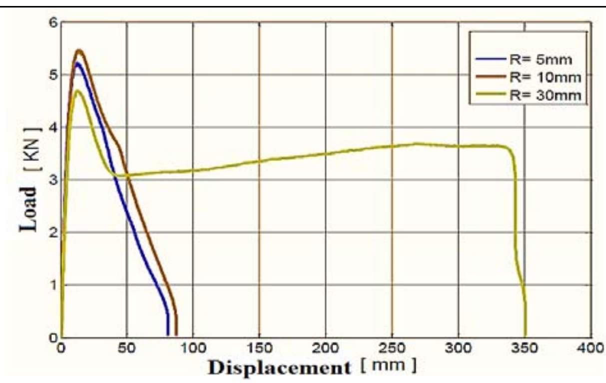

Figure 7. Curve load-displacement of the samples repaired with radius of 5, 10 and 30 mm for notch's depth a = 5 mm

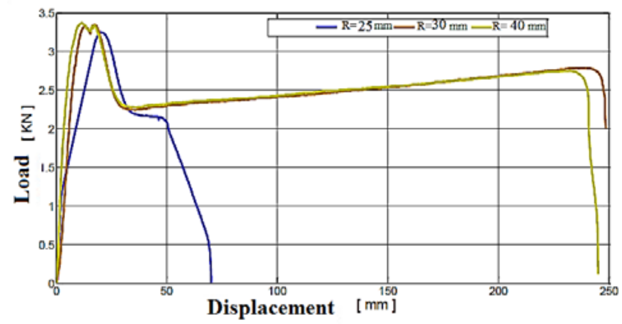

Figure 8. Curve load-displacement of the samples repaired with radius of 25, 30 and 40 mm for a = 20 mm

We measure the material viscoelastic potential by the area under the tensile curve which is considered as the total energy dissipated during the notched sample fracture. We compare, then, this energy with the one dissipated during the tearing of the virgin sample. The test results are regrouped in a table which contain for each sample tested the notch length a, the grinding ray R, the maximum loading Fmax and the value of the area under tensile curve Wr.

Table2. Comparison of F_{max} and W_R before and after repair by grinding

a [mm]	**R [mm]**	**W_r [J]**		**F_{max} [KN]**	
		Before Reparation	after Reparation	before Reparation	After Reparation
Without notch		1240	1240	5.78	5.78
5	5	183.37	235.12	5.18	5.22
	10		274.78		5.46
	30		1192.50		4.69
10	5	132.09	210	4.35	4.73
	10		333.52		4.45
	25		373.91		4.60
15	5	92.32	130.56	3.54	3.54
	25		309.40		4.14
20	25	62.65	140.05	2.72	3.25
	30		625		3.35
	40		617		3.37
	25		306.58		2.7

25	30	39.36	580.57	2.03	2.58
	40		1022.1		3.05

We notice in table 2, on the one hand, that each time repair is undertaken the Wr energy dissipated during tearing increases proportionally with the grinding ray, what indicates that grinding has a positive effect on the HDPE potential of deformation, in addition, we notice that the value of Wr drops proportionally with the length of the defect, These two observations, allow us to propose an optimum of repair which would take into account these two parameters.

1. REPAIR OPTIMIZATION

To account for the depth to which repair the notch could be effective we standardize all the values of energy of repair of the samples presented in table 1 at 60 mm of displacement, just at the necking end, we compare, then, the energy dissipated under the traction curve for the sample without notch (see figure 9) with the energy of the samples repaired, The results of these measurements are gathered in table 3:

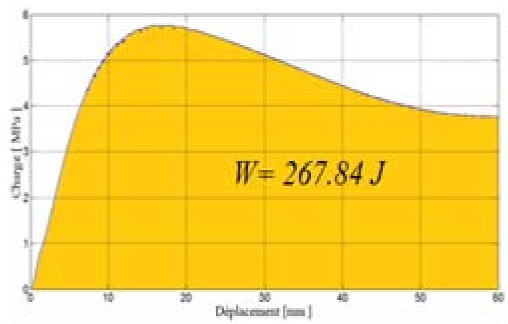

Figure 9. Measure standardized energy of the healthy sample

Table 3: Table gathering the values of standardized energies of repair,

a [mm]	[mm]	L [mm]	**W_{rn} [J]** standardized to 60 mm of displacement [J]
0	0	0,00	267,84
5	30	33,17	207,41
10	10	20,00	200,11
10	25	40,00	210,13
15	25	45,83	182,77
20	30	56,57	143,45
20	40	69,28	150,89
25	25	50,00	122,83
25	40	74,16	131,60

To find the optimal value of repair, we plot a graph connecting the fracture energies standardized to a geometrical parameter which is report/ratio length of notch a over the ligament length W (a/W) as represented on figure 10,

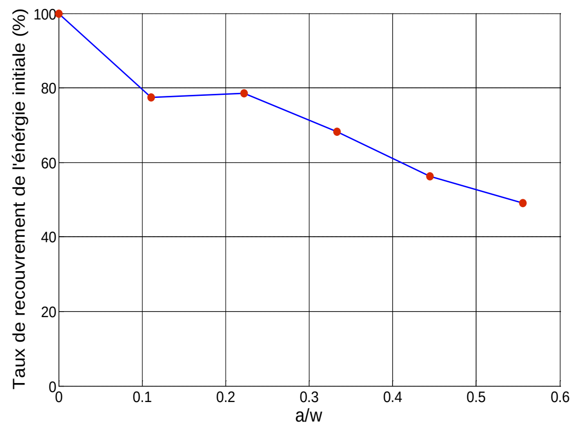

Figure 10. Recovery rate of energy dissipation as a function of aspect ratio (a / W)

In Figure 10, we note that the fracture energy of the material decreasesW_{rn}=267,84J corresponding to 100% of the energy is dissipated in the breakdown of the virgin sample W_{rn}= 207 J representing about 80 % for samples rehabilitated it then stabilizes between a (a/W) ratio ranging from 0.1 to 0.22 and then begin to decline until a rehabilitation rate of 50% of the energy dissipated. To optimize the repair we recommend a rehabilitation rate of energy dissipation of 80% which corresponds to an optimum aspect ratio a/W =0,22 beyond which the repair is not recommended and replacement of the section notched is recommended.

6. CONCLUSION

This work allowed us to shed light on the vulnerable behavior of HDPE in the presence of notches. It also allowed us to propose a solution for the rehabilitation of this material by the technique of grinding. The tests helped to highlight the influence of the grinding radius on the repair. It is shown that the material rehabilitation is better when the grinding radius is the largest. The close relationship between the ability to rehabilitate the material expressed by its ability to recover its qualities of plastic deformation expressed by its potential for dissipation of fracture energy normalized with the geometric properties of the samples expressed as the ratio (a/W) has determined an optimal value of this parameter at which the grinding repair method of HDPE is more efficient.

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