The Effect of Grooves on Initial Peak Load and Plastic Work for Nonmetallic Tubes Statically

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Abstract

In this paper an experimental study of the effect of grooves on initial peak load and work done by plastic deformation of material is presented. A series of tests were conducted on polyvinylchloride PVC circular tubes with grooves and without grooves loaded statically and axially. The specimens with grooves were tested with constant depth of groove and constant axial length of groove. Load-deflection characteristics for the PVC circular tubes specimens and the influence of collapsing load were illustrated in this work. The experimental results were compared with proposed mathematical model giving a good agreement. Also in this work, it was showed that the value of plastic work decreases with increasing the number of grooves.

Key Words: Axial buckling, Plastic work, Compression tube

تأثير الأخاديد على قيمة الحمل الابتدائي الاقصى والشغل اللدن للانابيب لا معدنية أستاتيكياً

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الخلاصة

في هذا البحث تم دراسة تأثير الاخاديد على قيمة الحمل الابتدائي الأقصى والشغل المنجز بواسطة التشويه اللدن للمادة.سلسلة من الاختبارات اجريت على مادة البولي فينول كلورايد لأنابيب دائرية محدده وغير محدده حملت تحميلا استاتيكيا ومحوريا،النماذج اختبرت بثبوت عمق وطول الأخدود. خواص التحميل والانبعاج المحوري والمتمثلة بحمل الانبعاج والاختزال الطولي للنماذج تم عرضها في هذه الدراسة. موديل رياضي مقترح تم استنتاجه بالاعتماد على العمل التجريبي وتم مقارنته مع النتائج التي تم التوصل إليها في هذا العمل ونتائج البحوث السابقة . تم التوصل في هذه الدراسة أن قيمة الحمل الابتدائي الأقصى يقل ويتناقص بتأثير الأخاديد لكن هذا التناقص يبقى ثابت تقريبا مع زيادة عدد الأخاديد بالنسبة للمقاطع الدائرية المحدده.كذلك تم التوصل بان قيمة الشغل اللدن يقل مع زيادة عدد الأخاديد.

1. Introduction

Progressively collapsing tubes by plastic deformation are efficient kinetic energy absorbing structural elements and therefore mechanics of collapse under axial loading conditions has received considerable attention in the past [1,3,7]. Several experimental, analytical and numerical studies have appeared in recent years, which helped in understanding the plastic-mechanics of the collapse phenomenon. Experimental studies on metallic tubes and nonmetallic tubes[1-3] have shown that the mode of deformation and average force depend on geometrical shapes. The axial crumpling of metallic tubes has long been the subject of extensive research [4-6]. The effect of imperfection on shear force and mode of deformation was studied in literature [7-8] but these are much dependent on the amount of experimental data available, therefore it is desirable to develop an equation which can take

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into account, theoretically, the effects of plasticity of material and imperfections.

Experimental and numerical results on cylindrical shells with cutout [9] some conclusions of this study it's the thin-walled with circular cutout and rectangular cutout the limiting buckling moment was decrease on increasing the size of the cutout.

In the present work, PVC circular tubes with grooved and nongrooved specimens loaded statically were used to study the effect of grooves on initial peak load and plastic work by plastic deformation of material under axial compression.

2.Experimental Work and Results

The axial compression of PVC circular tubes that are grooved and non-grooved was carried out by compression universal test machine. The test material used was commercial rigid polyvinylchloride PVC[5]. This material is widely used in engineering applications. The stress-strain curve of which as obtained from static tensile test is given in Figure 1. The initial value of yield stress was estimated to be 0.069 KN.mm-2. Compression test machine was used to test the specimens at cross-head speed of 5 mm/min or over compression strain rate of 0.00066sec-1.

Details relating to the specimens dimensions are presented in Table1 refer to the geometrical representation of Figure 2. For the grooved specimens, the length of groove, L_g, and depth of groove, x were kept constant and equal (0.75±0.05mm) whilst the ring length, L_r, was varied in the range ($0<Lr/L\leq1$). All specimens were tested at room temperature.

The experimental results of variation of crumpling load with amount of reduction of axial length to all specimens at failure were obtained using autographic recorder as shown in Figures 3-8 and the deformation shape for specimens at complete reduction in axial length (δ) is illustrated in Figure10. The values of plastic work (WExp) by plastic deformation and initial peak load (Pmax) was deduced from the load–deflection curve as shown in Table 1. The value of the reduction of axial length (δ) at failure for all specimens which were tested (75mm).

The plastic work equal the energy dissipated by deformation of material and equal the area under the load –deflection curve.

Theoretical Models

The Plastic Work :

Based on the experimental results in Table 1 , and previous researches [3,10] for the PVC circular tubes, it could be inferred that the value of work done by plastic deformation of the material is a function of a number from variables, namely; yield stress, thickness, mean diameter, reduction in axial length and ratio of the ring circumference to initial axial length as in equation 1. In this work the assumptions are that the material is rigid-perfectly plastic and the energy dissipated by friction is neglected [3,6].

$$W = q(\sigma y.t.Dm.\delta)(0.02999 \times \frac{L_r}{L} + 0.2742 \quad (1)$$

where q=5.0638 is a constant for the material used in the present work and $D_m = \frac{D_r + D_i}{2}$

Initial Peak Load :

For the PVC circular tubes without grooves and with grooves the value of initial peak load can be calculated from equation (2) and (3) respectively [3,7,10] .

$$P = \sigma y.A^{\circ} \quad (2)\ \text{(With grooves)}$$

$$A^{\circ} = \frac{\pi(D_g^2 - D_i^2)}{4}$$

$$P = \sigma y.A \quad (3)\ \text{(Without groves)}$$

$$A = \frac{\pi(D_r^2 - D_i^2)}{4}$$

3.Discussion and Conclusions

The plastic analysis based on mechanism of plastic collapse and mode of deformation, and assuming rigid-perfectly plastic material, allowed the prediction of the value plastic work and initial peak load for PVC circular tubes with the grooved and the non-grooved cases. Table1 shows the values of plastic work and initial peak load for rigid PVC tubes.

The value of internal plastic work calculated from equation 1 gave good agreement with present experimental results. Figure 9 shows that the maximum value of internal plastic work carried out when the ratio of (L_r/L=1) then the plastic work decreases in the range (0<Lr/L<1) with increasing the number of grooves. The value of plastic work in Ref[10] calculated by multiplying the average load with deflection. The values of plastic work in present work compared with experimental data were very close [3,10], and the difference in some data refer to several causes such as geometrical imperfections, shapes of deformation, cross-head speed and strain hardening.

The values of initial peak load were calculated from equation 2. But the value of the initial peak load of specimen one in Table1 was calculated from equation 1, [3,7]. These equations gave good agreement with the experimental results for the specimens. Column 12 in Table 1 observes that the value of maximum initial peak load carried out when no grooves (n=0) this value refer to that the ratio (Lr/L=1) then the value of initial peak load decrease with range of the function (0<Lr/L<1) but this decrease stable with increasing the number of grooves in column 8 approximately, [10]. The experimental results of initial peak load for present work compared with experimental data for previous researches in column 13 and gave good agreement with data for present work.

Notations:

A : cross-sectional area without grooved region of the tube

A° : cross-sectional area of tube grooved

D_g : outside diameter of grooved region of the tube

D_r : outside diameter at a ringed region of the tube

Di : inside diameter of tube with grooves and without grooves

Dm : mean diameter of tube

L : axial length of tube

Lg : axial length of a groove

Lr : axial length of a ring

t : thickness of tube at groove

n : number of grooves

x : depth of a groove

Pmax : experimental initial peak load

P : theoretical initial peak load

σy : yield stress

Wexp : experimental plastic work

W: theoretical plastic work

δ: reduction in axial length or(deflection)

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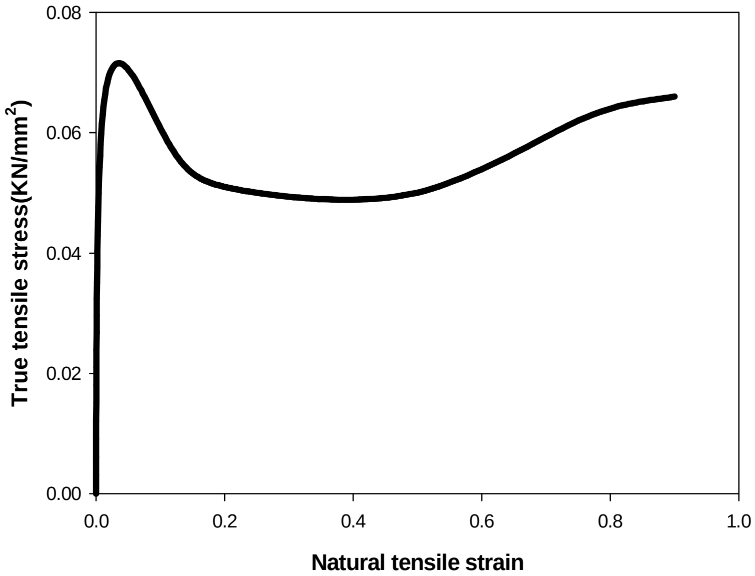
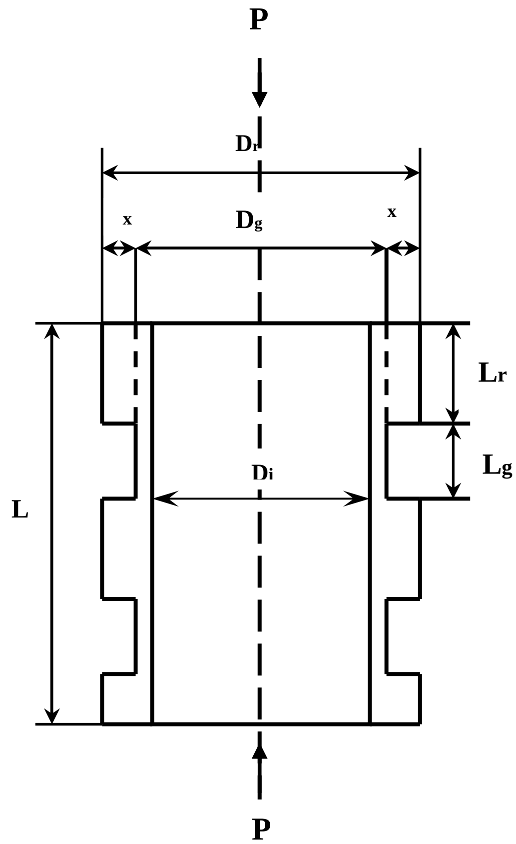
Table(1): The variation of values of plastic work and initial peak load on PVC circular tubes.

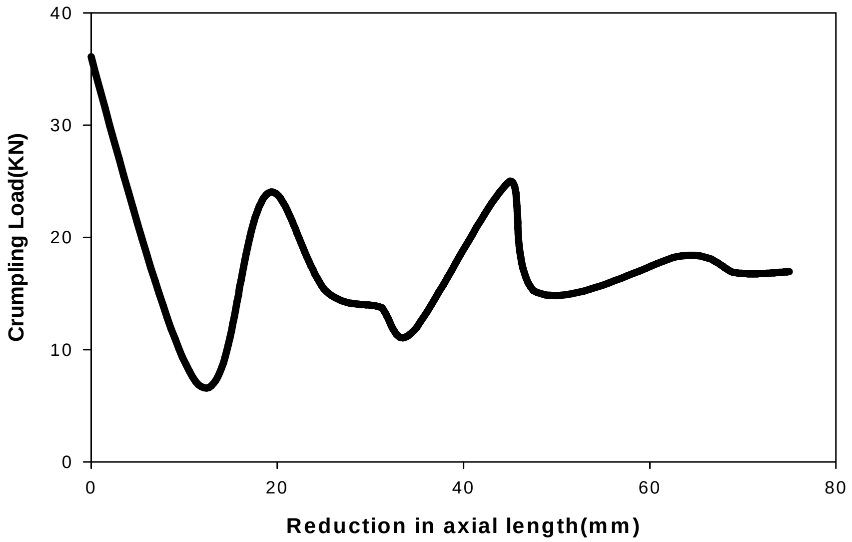
No	Axial Length (L) (mm)	Ring length (Lr) (mm)	groove length (Lg) (mm)	Inside diameter (Di) (mm)	Outside diameter		Number n grooves	Experimental plastic Work (WExp) (KN.mm)	Theoretical plastic Work (W)(KN.mm)	Theoretical Initial peak load (P)(KN)	Experimental Initial peak load	Experimental data [10] peak load (KN)
					(Dg) (mm)	(Dr) (mm)						
1	125	125	-	41.5	-	49	0	1402	1352	36.1	36.1	26.6
2	125	22	3.125	41.5	47.5	49	5	1320	1243	29.4	29.4	22.4
3	125	18	3.125	41.5	47.4	49	6	1300	1232	31	31	-
4	125	12.5	3.125	41.1	47.41	49	8	1275	1228	30	30	-
5	125	6.25	3.125	41.1	47.41	49	14	1260	1226	29.8	29.8	22.1
6	125	3.125	3.125	41.2	47.6	49	20	1244	1222	30.2	30.2	20



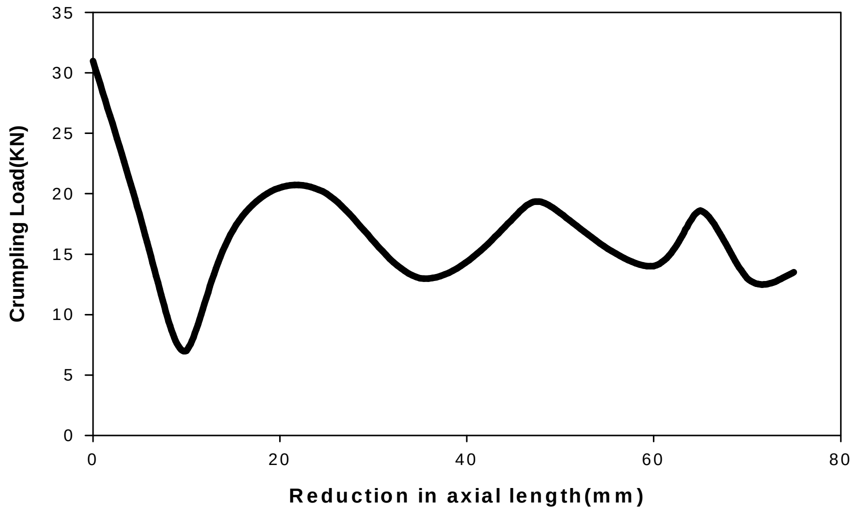
Fig(1): Stress-strain curve for rigid Polyvinylchloride(PVC).



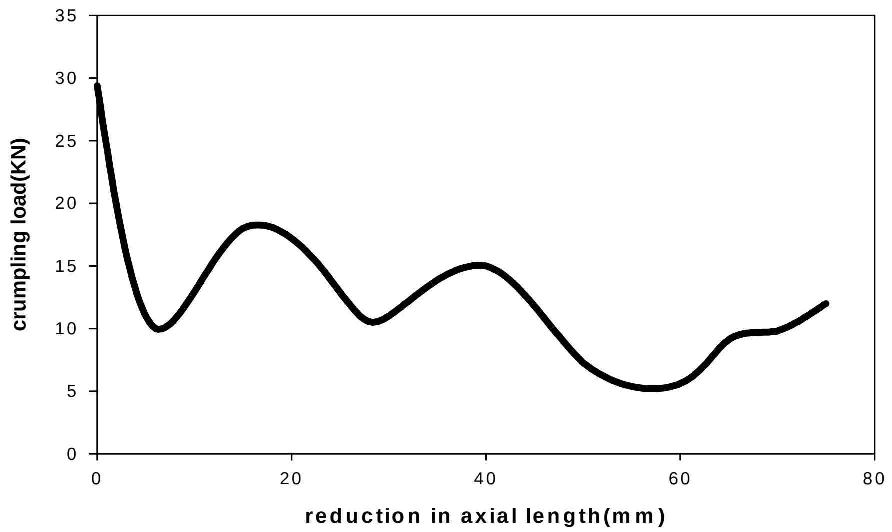
Fig(2). Diagram Section of a grooved tube



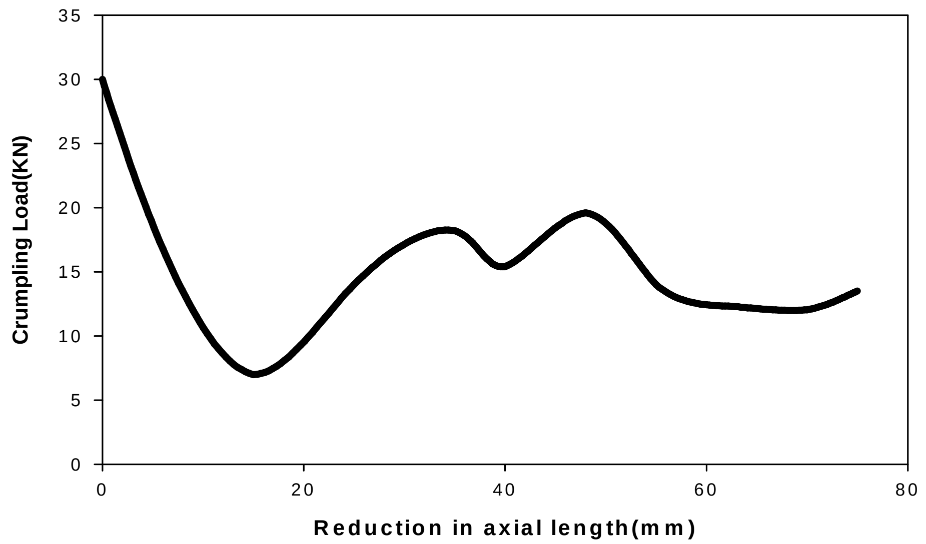
Fig(3): Load-deflection curves for specimen (1).



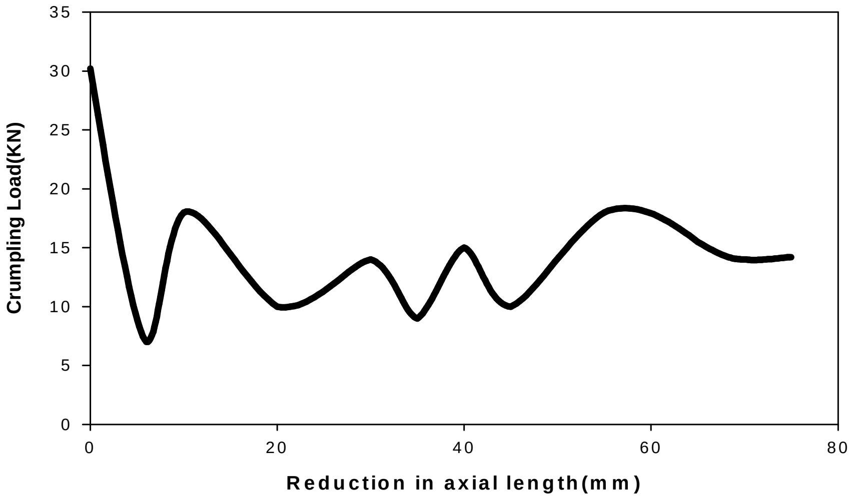
Fig(4): Load-deflection curves for specimen (2).



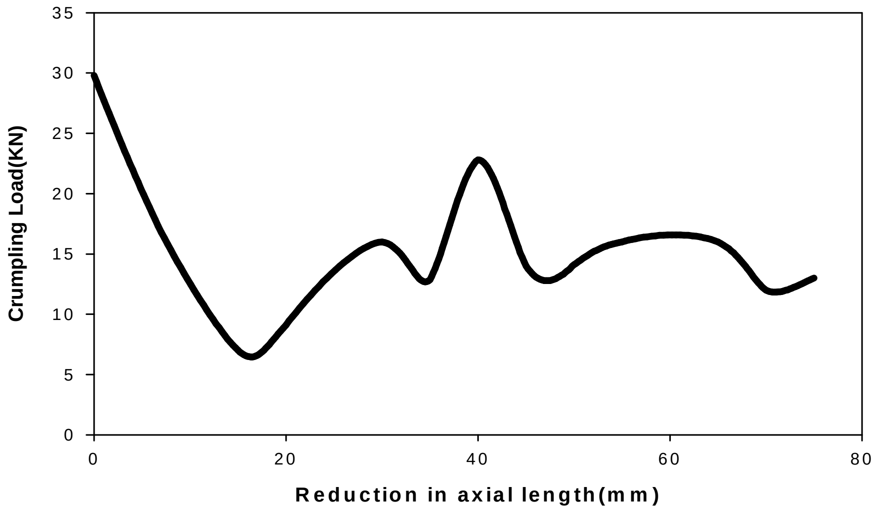
Fig(5): Load-deflection curves for specimen (3).



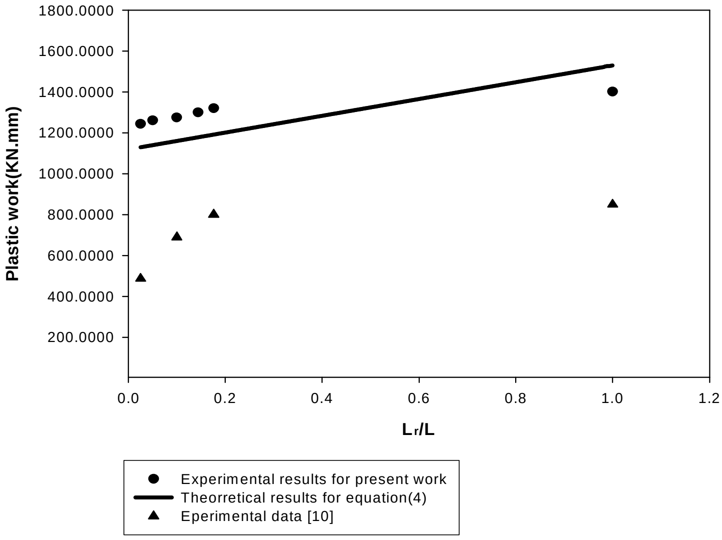
Fig(6): Load-deflection curves for specimen (4).



Fig(7): Load-deflection curves for specimen (5).



Fig(8): Load-deflection curves for specimen (6).



Fig(9):Variation of plastic work with ratio of length of ring to initial length of specimen.

Fig(10): The stages deformation at failure (complete deflection) for tube with grooved.