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Impact Energy of $100Cr_6$ under low different velocities

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Abstract:

This study has been undertaken to postulate the mechanism of impact test at low velocities. Thin-walled tubes of 100Cr6 were deformed under axial compression. In the present work there are seven velocities (4.429,4.652,5.240,5.600,5.942,6.264, 6.569) m\sec were applied to show how they effect the load, change in length, also the kinetic energy. However, the comparison between the obtained results and the other studies (Alexandar[3] , Abramowicz[4], Ayad[5]) was made the present work and Ayad data show good agreement. Load, change in length, kinetic energy were determined to understand the impact test.

Keywords: Impact Energy

Introduction:

The use of thin-walled tubes collapsing plastically in axial compre-ssion is one of the most efficient means of energy absorption. These tubes are small in volume, easy to fabricate in weight, cheap, and stable during crushing. The crushing of thin tubes is a process by which the kinetic energy can be absorbed for example in vehicle cursh. The criterion upon which many energy absorbing devices are based, is that these devices undergo a large amount of plastic deformation before total collapse [1].

The active absorbing element of an energy absorption system can assume several common shapes such as tubes, honey combs, frusta, strips and rods. When impact velocity is less than 30 m/s, the impact is low speed impact. Buckling under a low velocity can be considered as a quasi-static behavior. While impact velocities larger than 30 m/s cause stresses above the yield stress of the material, the impact is high speed impact. Thin tubes deforms in one of the following modes [2].

(i) Column or Euler buckling.
(ii) Concertina or like axisy-mmetric buckling.
(iii) Diamond buckling.
(iv) Tearing of the tubes.
(v) Brittle fracture or shuttering.
(vi) Uniform compression.

Fig(1): Thin tube deform,(a) diamond mode type buckling, (b) concertina mode type buckling, (c) invert tubes showmen (left) External, inside-out, inversion (right), Internal , outside-in, inversion, (d) Tearing failure [2].

Many articles have been published on the static and dynamic crushing of circular tubes [1, 2]. The pioneer work of Alexander [3] and Abramowicz [4] of circular and square tubes under dynamic conditions. Alexander [3] was the first to present a mathematical model of crushing phenomena for thin walled tubular specimens, calculating the mean crushing force of tubes and collapsing in the axisymmetric or concertina mode.

While Abramowicz and Jones [4] have improved the Alexander model by modifying the effective crushing distance and the effect of material strain rate under dynamic loading. In this article. Three models namely Alexander [3], Abramowicz [4] and Ayad [5], were using thin-walled tubes which were made from $100Cr_6$ steel tested under different velocities impact.

Literature Review:

Abramoswicz [4] focuses on the range of dynamic load which give rise to a quasi-static crushing response. A series of axial crushing tests on steel circular cylindrical tubes loaded either statica-lly, or dynamically, is reported and compared with various theoretical predictions and empirical relations:

A modified version of Alexander's [3] theoretical solution for axisymmetric, or concertina, deformations, which includes a correction for the effective crushing distance, gives good agreem-ent with the mean of experimental static crushing loads.

Guillow and Grezbieta [6] tested 6060 aluminum alloy tubes with different range of (D/t), Internal diameter to thickness ratio from 10-450. It was found that the behavior of thin walled tubes can be described by the empirical formula.

$$\frac{Fav}{Mp} = 72.3\left(\frac{D}{t}\right)^{0.32} \text{------------ (1)}$$

where:

Fav: average crushing force.

Mp: plastic moment per unit length.

Also it was found that the ratio of Fmax/Fav increased substantially with an increase in the D/t ratio. Huang and Lu [7] presented an axisymmetric crushing behavior of metal tubes subjected to quasi-static axial loads. Based on the experimental results and finite element analysis, a theoretical model is developed by introducing the concept of effective plastic hinge length which is proportional to tube thickness. Seitzberger and Willminger [8] investigated steel alloy of different types of cross-sections (square, hexa-gonal, octagonal) which are fully or partially filled with aluminum foam. The results of the parameter studies confirm with the experimental observa-tions for given tube/filler combinations and the foam is a major parameter in the design of the collapse models.

Ayad Arab [5] studied the variety speed impact for thin walled cylinder made from 2024-T351 Aluminum alloy. A proposed mathematical model was presented based on the experim-ental data. This model can predicted the mean load, variation of load and deformation for static and dynamic conditions by falling axial mass with different velocities impact. The effect of folding parameter (m) and size of fold (h) on mean load and deformation have been studied.

Experimental Work

A series of 12 axial crushing tests was conducted on circular tubes specimens loaded either statically or dynamically. This section presents the experimental work done using $100Cr_6$ steel which is widly used in structures and in many industrial of automobiles.

Mechanical Properties:

Table (1) illustrates the mechanical properties of the metal used while Fig (2) shows the relation between the stress and strain (tensile test).

Chemical Composition:

Table (2) shows the chemical compos-ition of $100Cr_6$ in weight percentage.

Microstructure Evaluation:

A computerized optical microscopy was used to examine the microstru-cture of the sample. Photo micrographs was taken for sample which was examined by optical microscopy as shown in Fig (3).

Specimens Preparation:

Circular sectioned steel alloy tubes
formed by a deep drawing process were used. These tubes were cut to equal lengths by cutter machine. Fig. (4) shows the shape and dimensions of the specimens used in this study [9].

Test Rig:

The test rig used is described in details in reference [10].

Experimental Results:

The results recorded are divided into two groupes static and dynamic as follows:

Static Compressive Test:

A load of 2.5 ton at 1 mm/min head speed is chosen in order to compare the results with Ref. [8] who used the same condition of testing. The purpose of doing the test is to obtain the mode of deformation. The results are given in Table (3), and Table (4) gives the results at failure.

The energy absorbed was calculated using the equation :

$(Pm_f).(\Delta L_f) = E$ ----------------------(2)

where :

ΔL_f : deformation at failure (mm) .

Pm_f : mean load at failure (KN).

E:Energy absorbed by the specimen(J).

Impact test results:

12 specimens are tested at different speeds (4.429 - 6.569) by using a mass of (14.55 kg) at different heights. The results can be illustrated in table (5).

1) The velocity of the dropping mass was measured experimentally by the test rig end compared with the calculated velocity using the equation: $V = \sqrt{2gH}$

Where : H is the height of the dropping mass . The error of the results was about 5%. (H was taken from 1-2.2 m).

And $g = 9.81$ m/sec^2.

2) The failure deformation (ΔL_f) was measured from the specimen at failure

3) The dynamic mean load (Pm) was calculated from the equation:

$(Pm)dynamic = K.E/\Delta L_f = mV^2/2\Delta L_f$

Where: m is weight of the falling body = 14.55 kg

Figure (5) represents the increasing in the velocity leads to increase in the load as it is shown obviously in Abramowicz test [4] which the increment in the load is a higher than in the others, while this increment in the present work, Alexandar [3] and Ayad [5] is small . Most of the relationships seems to be horizontally linear. This is return to that the sample of Abramowicz which was obtained for steel show that the relation between the load and the velocity curve extremely according to the: $p_m = 11.13(1 + 0.06V^2)$ and its lead to give higher slope than in another's.

Figure (6) represents the results of $\Delta L/L$ which was plotted as a function of V, It is seen that the relation of present work is extremely close to Ayad work [5] and far from Alexandar, Abramowicz work. These relations have the same slops when they are linear proportionality. From figure (7), it is found that $\Delta L/L$ varying with the kinetic energy, and give the same conclusions which were obtained by $\Delta L/L$ and V, this is return to that the kinetic energy extremely related with velocity as : $K=1/2mV^2$, hence the results are the same at which obtained between $\Delta L/L$ and V.

Conclusions:

The behavior of $100Cr_6$ thin – walled tube under dynamic Impact loading
takes the followings :

A\ The p_m increases with increases in velocity V and takes a relation close to Abramowicz and Ayad models .

B\ The variation of the ratio $\Delta L/L$ against velocity V is taken the trend of Ayad model while Alexandar and Abramowicz are far away from the present results.

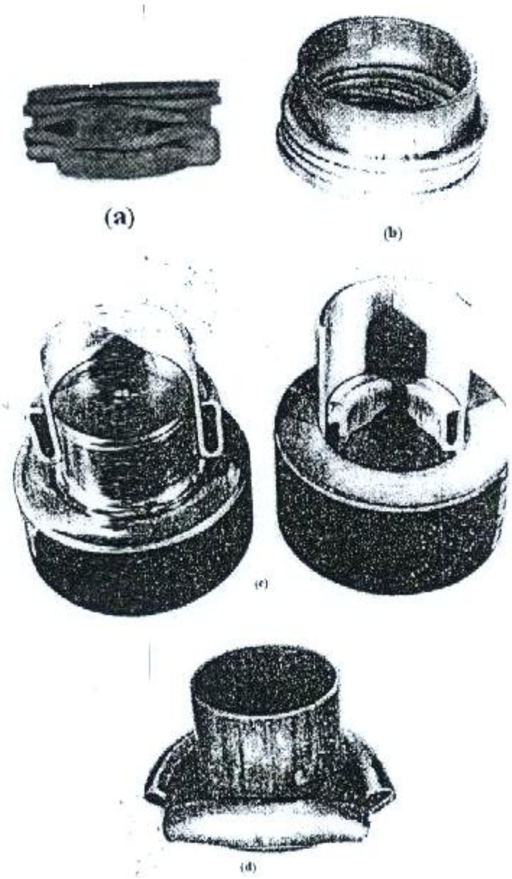

Fig. (1) Shows the most types of deformation of thin-walled tubes.

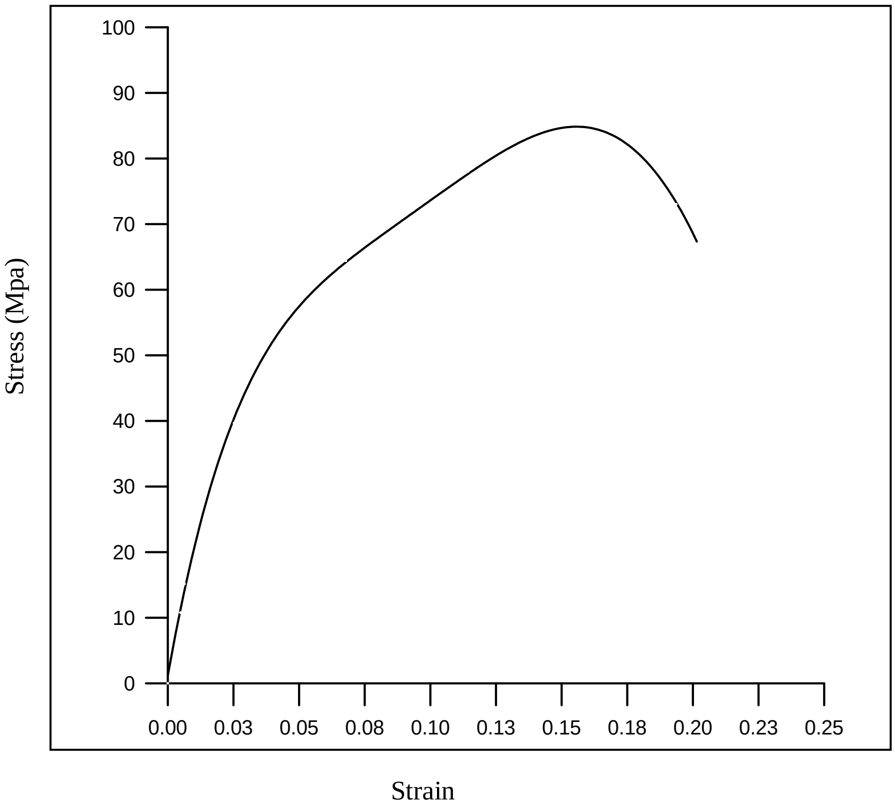

Fig. (2): Relationship between stress and strain

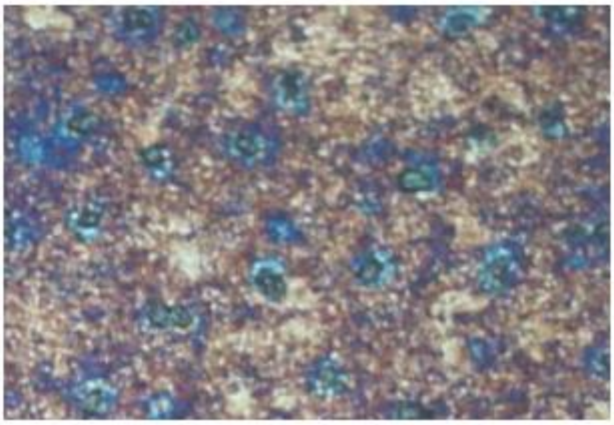

Fig. (3): Microstructure of the 100 Cr_6 with Mg (270X)

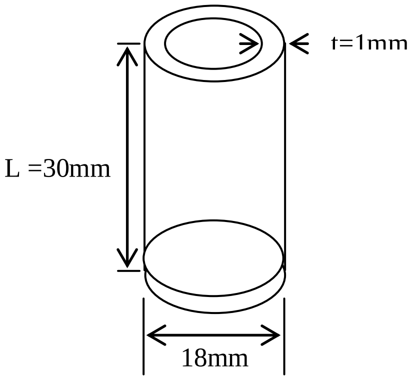

Fig. (4) : shape and specimen dimensions

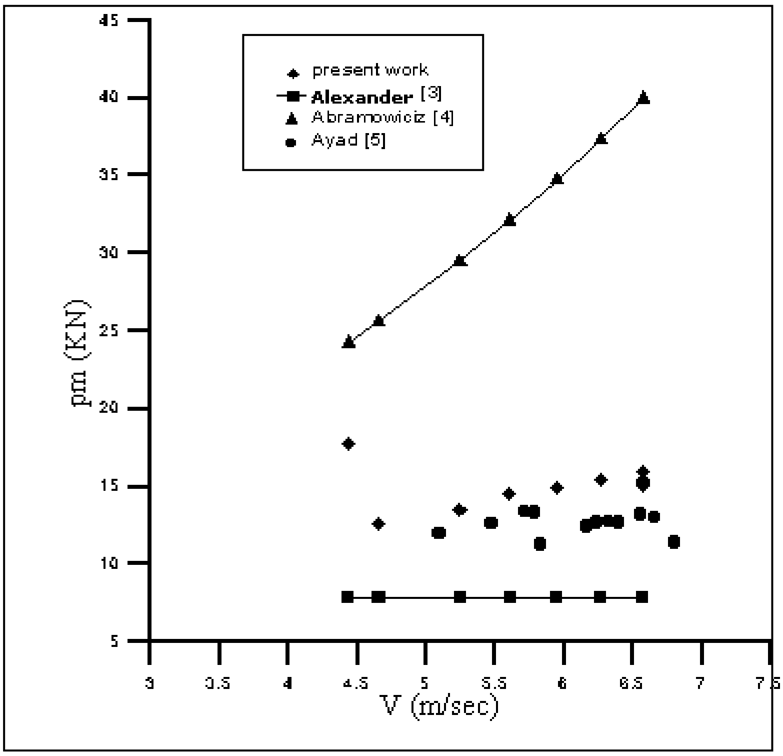

Fig. (5) : Relationship between load and velocity

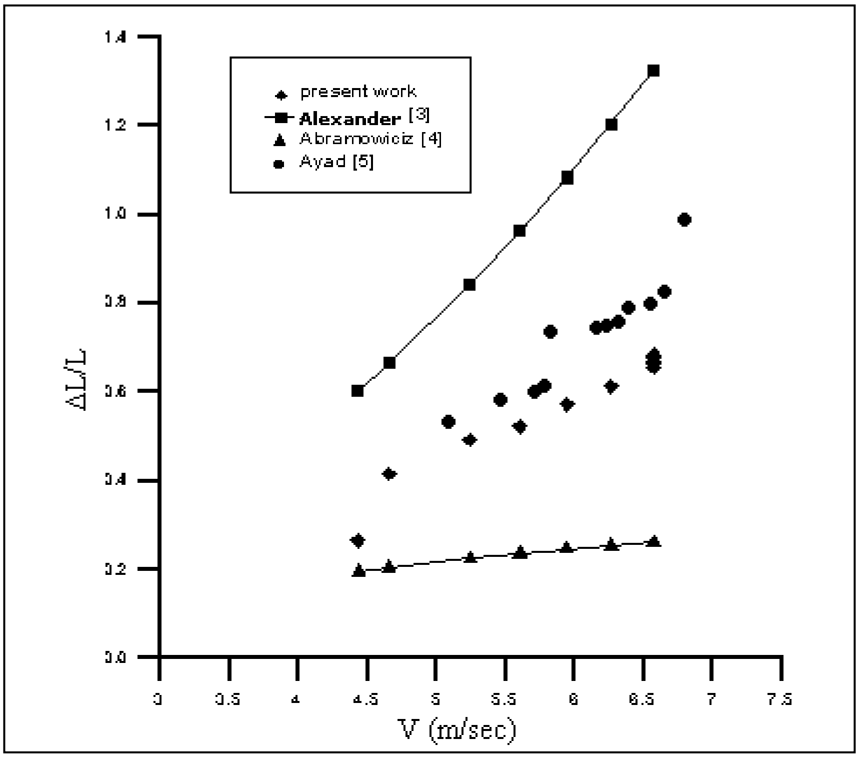

Fig. (6) : Relationship between deformation and velocity.

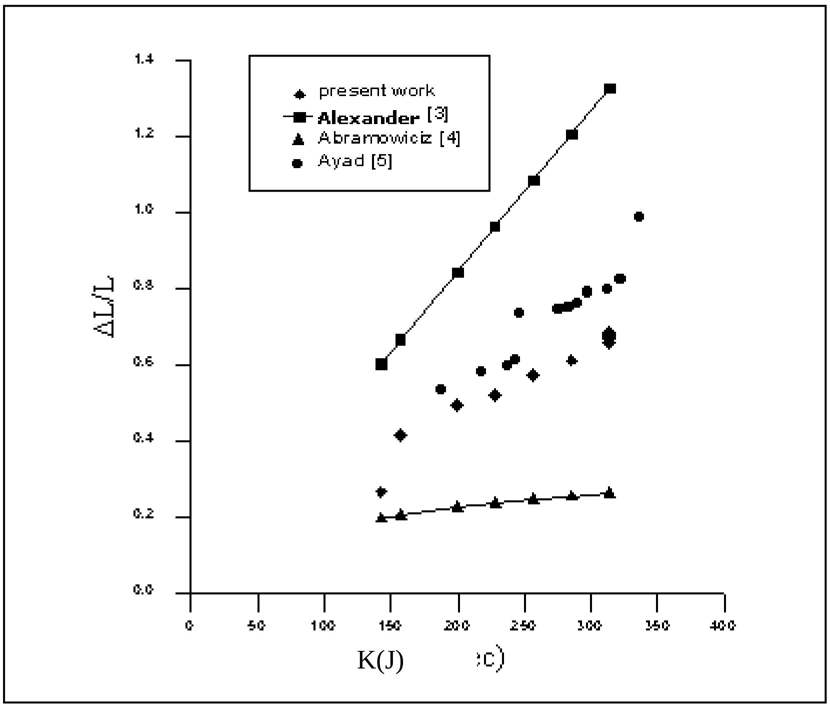

Fig. (7) : Relationship between deformation and kinetic energy.

Table (1) mechanical properties of 100Cr$_6$

σ_y (MPa)	σ_u (MPa)	Elong.%	Brinell Hardness	G (Gpa)	E (Gpa)	μ	K
310	840	7.2	211	88.46	230	0.3	287.5

The above data is the average of three readings.

Table (2) Chemical Composition of the material used.

C	Mn	Si	P	S	Cr	Ni	Mo	Cu	Fe%
1.05	0.40	0.23	0.016	0.009	1.77	0.07	0.03	0.17	96.122

* The above analyses was done by Thermo ARL 3460 -OE SPECTROMETER.

Table (3) static compressive test for 100Cr$_6$

Load (KN)	ΔL (mm)	Load (KN)	ΔL (mm)	Load (KN)	ΔL (mm)	Load (KN)	ΔL (mm)
14.0 17 15 13	0.057 0.122 0.22 0.31	10 7 11 13 16	0.44 0.51 0.62 0.78 1.000	14.5 12 10 16 18 17	1.1 1.2 1.5 1.8 2.1 2.3	14 13 11 10 18 19 20	8 10 11 13 14 17 18 failure

Table (4) static results at failure

Failure	E (J)	ΔL$_f$ (mm)	Pm$_f$ (KN)	Mode
Complete damage of specimen	252	18	14	Concertina buckling

Table (5) Dynamic results of 100Cr$_6$ under 14.55 kg

Spec.No	V(m\s)	ΔL$_f$ (mm)	Pm (KN)	H (m)	Mode of def.*
4	4.429	8	17.838	1	C
5	4.652	12.5	12.595	1.2	C
6	5.24	14.8	13.496	1.4	C
7	5.6	15.7	14.531	1.6	C
8	5.942	17.2	14.933	1.8	C
9	6.264	18.4	15.513	2	C
10	6.569	19.7	15.935	2.2	C
11	6.569	20.4	15.388	2.2	C
12	6.569	20.1	15.161	2.2	C
13	6.569	20.5	15.463	2.2	C
14	6.569	20.3	15.312	2.2	C
15	6.569	20	15.086	2.2	C

Table (6) shows the comparison between three references [3], [4], [5] with the

Spec No	V (m/s)	Present work			Alexandar			Abramowicz			V (m/s)	Ayad		
		Pm(KN)	ΔL/L	K(J)	Pm (KN)	ΔL/L	K(J)	Pm(KN)	ΔL/L	K(J)		Pm (KN)	ΔL/L	K(J)
4	4.429	17.838	0.266	142.706	7.893	0.602	142.706	24.239	0.196	142.706	6.82	11.279	0.983	338.374
5	4.652	12.595	0.416	157.438	7.891	0.665	157.438	25.592	0.205	157.438	6.67	12.946	0.819	323.65
6	5.24	13.496	0.493	199.749	7.892	0.843	199.749	29.477	0.225	199.749	6.57	13.084	0.792	314.018
7	5.6	14.531	0.523	228.144	7.891	0.963	228.144	32.085	0.237	228.144	6.411	12.563	0.785	299.002
8	5.942	14.933	0.573	256.858	7.893	1.084	256.858	34.722	0.246	256.858	6.332	12.681	0.754	291.683
9	6.264	15.513	0.613	285.449	7.891	1.205	285.449	37.347	0.254	285.449	6.253	12.586	0.745	284.452
10	6.569	15.935	0.656	313.923	7.891	1.326	313.923	39.962	0.261	313.923	6.172	12.316	0.74	277.126
11	6.569	15.388	0.68	313.923	7.891	1.326	313.923	39.962	0.261	313.923	5.839	11.172	0.73	248.026
12	6.569	15.161	0.67	313.923	7.891	1.326	313.923	39.962	0.261	313.923	5.8	13.228	0.61	244.731
13	6.569	15.463	0.683	313.923	7.891	1.326	313.923	39.962	0.261	313.923	5.73	13.269	0.594	238.852
14	6.569	15.312	0.676	313.923	7.891	1.326	313.923	39.962	0.261	313.923	5.486	12.511	0.575	218.948
15	6.569	15.086	0.666	313.923	7.891	1.326	313.923	39.962	0.261	313.923	5.108	11.863	0.528	189.812

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طاقة الصدمة لفولاذ $100Cr_6$ تحت سرع منخفضة مختلفة

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الخلاصة:

أجريت هذه الدراسة لتخمين آلية اختبار الصدمة عند سرع منخفضة مختلفة . استخدمت عينات أنبوبية قصيرة رقيقة المقطع من معدن الفولاذ من نوع $100Cr_6$ وقد تم تشويه العينات تحت تأثير قوة ضغط أحادية المحور في هذه الدراسة تم تسليط سبع سرع (4.429 ، 4.652 ، 5.240 ، 5.600 ، 5.942 ، 6.264 ، 6.569 m\sec) لبيان تأثيرها على القوة ، التغير في الطول ، الطاقة الحركية .

وبناءً على ذلك أجريت مقارنة بين الدراسة الحالية ودراسات اخرى (Alexandar[3] , Abramowicz[4] , Ayad[5]). الدراسة الحالية تتوافق بشكل جيد مع دراسة Ayad[5] . لقد تم حساب القوة اللازمة، التغير في أبعاد العينة، الطاقة الحركية لفهم آلية الاختبار المستخدم (اختبار الصدمة) .