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15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

EXPERIMENTAL DETERMINATION OF DYNAMIC FRACTURE TOUGHNESS K_{ID} WITH HIGH STRENGHT METALLIC MATERIALS

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ABSTRACT
In this paper the investigation of methods for determination of dinamic fracture toughness, K_{Id}. Dinamic J-integral and equivalence energy methods are experimental confirm testing of steel Č 5432 and Č 4734. This paper presented of contribution in control methods what's to define behaviour of materials in condition of dinamic crack growth. Application this all methods presented very imported contribution of investigation behaviour construction materials in presence of crack.
Keywords: dynamic stress intensity factor, K_{Id}, dynamic J integral, equivalent energy.

1. INTRODUCTION
To ensure the safety of parts made of conventional metallic materials as well as new materials, it is necessary to clarify their behaviour in the action of impact loads in the presence of cracks. The performed experiments are directed toward testing the possibility of using the methods:
- dynamic J integral, and
- equivalent energy

for the determination of the critical dynamic stress intensity factor, K_{Id}, at room temperature [1,2].
The choice of testing material is carried out by the level of mechanical properties and operating conditions. Bearing in mind the current world trend of materials in modern construction, and especially the possibility of their use in domestic construction, materials that are relatively widely used and are selected as representative:
- C 5432 (1.6604.4)
- C 4734 (1.7734.4)

The shape and dimensions of specimens and fatigue conditions.

2. EXPERIMENTAL PROCEDURES AND RESULTS
All experiments are performed at room temperature with standard Charpy specimens of shape and geometry defined by ASTM E23-06 [3], Fig. 1. Due to dimensional constraints dictated by the distance between the supports of the tube on the pendulum, and in accordance with recommendations of ASTME 24/03/2003 [4] entitled “Proposed Standard Method of Test for Instrumented Impact

Testing of Precracked Charpy Specimens of Metallic Materials”, we have adopted an alternative relationship between B/W = 1, which is evident from the illustrated specimen.

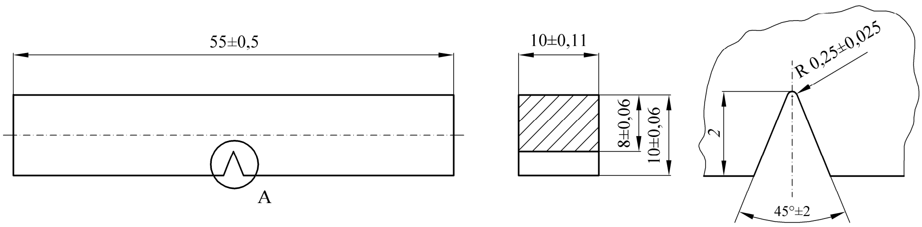


Figure 1. Specimen for impact testing

Conditions and parameters to create a fatigue crack in order to provide plane strain, are dictated by the type of material. The crack initiated from the machined notch root by an acting unidirectional repeated load. Terms of fatigue are defined and given in Table 1.
Initial conditions of fatigue include also the conditions after NP cycles that causes a fatigue crack. The final terms of fatigue include the conditions that provide controlled or stable crack growth up to prescribed length, or the number of cycles NK [5].

Table 1. Specimen fatigue conditions for creating a fatigue crack

Steel design.	**Ratio, $R = P_{min}/P_{max}$**	**Load amplitude, S (Ncm)**	**No of cycles, N**
C 5432 (1.6604.4)	0.1	3500	$5.8\times10^5 – 7.5\times10^5$
C 4734 (1.7743.4)	0.1	4250	$4.4\times10^5 – 6.1\times10^5$

The fatigue procedure is performed on a high frequency pulsator CRACKTRONIC. Using the proposed methods of dynamic J integral and equivalent energy, and by recording the force–time and energy–time oscillograms on impact bending specimens of steel, the resulting parameters are necessary for the calculation of the critical dynamic stress intensity factor, K_{Id}, or more popularly called dynamic fracture toughness [6]. Results of the determination of K_{Id} are given for:
steel C 5432 (1.6604.4) - Table 2,
steel C 4734 (1.7734.4) - Table 3.

A typical layout of force–time and energy–time diagrams, obtained during the impact bending test are shown in Fig. 2 for the steel C 5432 (1.6604.4) and in Fig. 3 for the steel C4734 (1.7734.4). Because of the abundance of diagrams obtained by testing a large number of specimens, other diagrams are not shown here.

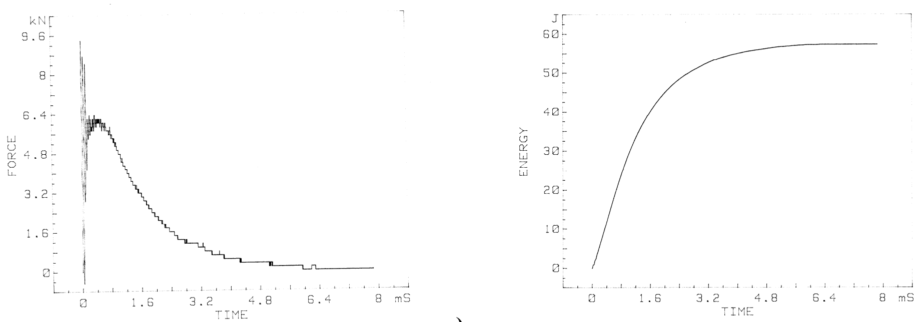
Table 2. Some results for K_{Id}, steel 1.6604.4, according to methods of dynamic J integral and equivalent energy

Spec. design.	**Ratio *a/W***	***f(a/W)***	**ΔE_M (J)**	**ΔE_M (J)**	**J_{Id} (N/m)**	**K_{Id} (MPa√m)**	**F* (N)**	**Ratio *a/W***	**K_{Id}* (MPa√m)**
A1	0.456	0.395	7.05	3.50007	64339.6	116.24	12315.2	2.325	114.55
A2	0.467	0.424	6.80	3.78733	71056.8	122.16	12548.8	2.404	120.65
A3	0.477	0.451	6.95	4.04140	77273.4	127.39	12715.1	2.478	126.06
A4	0.486	0.478	6.35	3.73991	72760.8	123.61	12015.6	2.549	122.51
A5	0.489	0.487	6.65	4.07220	79690.8	129.36	12462.6	2.573	128.27
A6	0.495	0.506	6.85	4.33842	85909.4	134.32	12707.3	2.623	133.30
A7	0.503	0.532	6.15	3.72835	75017.1	125.51	11586.0	2.691	124.70
A8	0.515	0.575	6.10	3.62866	74817.8	125.35	11141.3	2.798	124.71
A9	0.522	0.601	6.25	4.05424	84816.8	133.46	11597.6	2.864	132.87
A10	0.531	0.637	5.25	3.36153	71674.4	122.69	10350.0	2.952	122.22

Table 3. Some results for K_{Id}, steel 1.7734.4, according to methods of dynamic J integral and equivalent energy

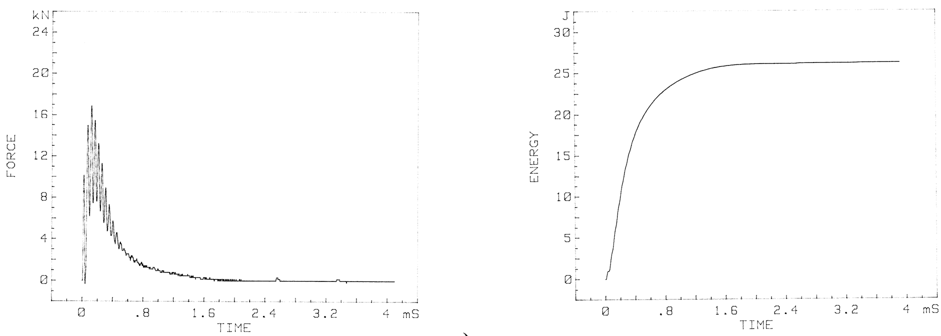
Spec. design.	Ratio a/W	f(a/W)	ΔE_M (J)	ΔE_M (J)	J_{Id} (N/m)	K_{Id} (MPa√m)	F* (N)	Ratio a/W	K_{Id}* (MPa√m)
B1	0.452	0.385	6.35	3.56313	65020.5	116.85	12517.4	2.298	115.05
B2	0.462	0.411	6.45	3.71495	69051.1	120.42	12546.5	2.368	118.82
B3	0.471	0.435	6.30	3.80971	72017.2	122.98	12489.8	2.433	121.56
B4	0.477	0.451	6.25	3.78042	72283.3	123.21	12297.7	2.478	121.92
B5	0.485	0.475	6.15	3.99888	77648.1	127.70	12449.5	2.541	126.54
B6	0.493	0.499	6.05	4.06220	80122.4	129.71	12346.5	2.606	128.70
B7	0.507	0.546	5.85	4.17981	84783.2	133.43	12164.4	2.726	132.64
B8	0.513	0.568	5.65	4.12199	84640.5	133.32	11926.0	2.780	132.62
B9	0.527	0.621	5.85	4.22106	89240.1	136.90	11702.9	2.913	136.34
B10	0.536	0.659	5.15	3.89674	83981.5	132.80	11017.3	3.003	132.34

ΔE_M – Energy for crack
ΔE_M – Adjusted energy for crack
J_{Id} – Dynamic J integral
K_{Id} – Critical dynamic factor intensities, voltage in method of Dynamic J integral
F* – The peak force of brittle fracture
K_{Id}* – Critical dynamic factor intensities, voltage in method of equivalent energy.



a) b)

Figure 2. A typical relationships of force–time (a) and energy–time (b) diagrams, for the steel C 5432 (1.6604.4)



a) b)

Figure 3. A typical relationships of force–time (a) and energy–time (b) diagrams, for the steel C4734 (1.7734.4)

3. CONCLUSION

This work is a contribution to the control methods that define the behaviour of materials under dynamic conditions of crack growth. Application of these methods along with other methods for determining fracture mechanics should be a significant contribution to the study of behaviour of structural materials in the presence of cracks. The two developed methods are applied for determining the critical dynamic factor, K_{Id}, namely: the dynamic J integral method, and the equivalent energy method.

The experimental work has been successful with these methods applied onto steels C5432 and C4734, as representative structural materials. By comparing the results in Tables 4 and 5 it is concluded that the data dispersions are between 10 and 15%, which is within permissible limits and is considered to be with an acceptable level of accuracy.

4. ACKNOWLEDGEMENTS:

This work was carried out aspart of the project 35024, wich supported by the Ministry of STD of the Republic of Serbia.

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