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FRACTURE OF THE EGGSHELL UNDER IMPACT

LOM VAJEČNÉ SKOŘÁPKY PŘI RÁZU

Abstract

Hen's eggshell behaviour at the impact on a rigid plate is studied. The critical impact velocity at which eggshell damage starts has been determined. This velocity depends on the egg's shape. LS DYNA 3D finite element code has been used for the evaluation of the stress and strain distribution in the eggshell during its impact. This numerical simulation enables to evaluate the eggshell strength. This strength is independent on the egg shape as well as on the eggshell thickness. It seems that this strength is an intrinsic material parameter.

Abstrakt

V dané práci byla provedena numerická simulace deformačního a lomového chování vejce při jeho dopadu na tuhou překážku. Byl použit program LS DYNA 3D, který umožňuje modelovat i přítomnost kapaliny a vzduchu uvnitř vaječné skořápky. Ukazuje se, že kritická dopadová rychlost závisí na tvaru vejce. Pevnost vaječné skořápky je pak nezávislá jak na tvaru, tak na tloušťce vaječné skořápky.

1 INTRODUCTION

The knowledge of the resistance of eggshells to impact is very important namely at the evaluation of the eggs safety during their handling. The common handling of the eggs can lead to their impact loading at relatively low velocities, which are order of meter per second. The testing of the eggs under impact is mostly limited to the study of the eggshell behaviour. The behaviour of liquid component of the egg is mostly ignored. The impact tests involve dropping of an object (mostly a steel bar) onto eggshells from a definite height see e.g. [1] for a review. For a long time the evaluation of these tests has been empirical – see [2]. In the next step the experiments have been improved in order to record the time dependence of the impact force [3]. The study of this problem is a subject of the increasing interest owing to the importance of the study of food and generally of all

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agricultural products at impact loading [4]. The paper is focused on the evaluation of the maximum velocity of impact at which the eggshell do not exhibit any observable failure. The use of numerical simulation of this loading should lead to the determination of the eggshell strength.

2 MATERIALS AND METHODS.

Eggs of domestic hens (laying crossbreed of lines Rhode Island Red, Rhode White and Sussex light) have been used. In the first step the shape of the egg meridian has been described. The meridian of the egg is described by parametric equations, which are suggested in [5].

$$x = b\cos\theta \qquad y = (a + e\sin\theta)\sin\theta\ ,$$

where e/b is relatively small. The parameters a, b, e and thickness are given in Table 1. In this table the egg shape index defined by

$$EGGS \quad SHAPE \quad INDEX = \frac{width}{heigth} x100 \quad (\%)$$

is also given.

Tab. 1 Main parameters of the tested eggs

Egg No	a (cm)	b (cm)	e (cm)	b/a (%)	Thickness	h (cm)	V (m/s)	STRENGTH (MPa)
1	5.54	4.32	0.38	77.98	0.387	8.0	1.253	20.7
2	5.90	4.06	0.50	68.81	0.417	3.0	0.767	21.2
3	5.54	4.32	0.36	77.98	0.377	9.0	1.329	20.9
4	5.96	4.14	0.31	69.46	0.387	4.0	0.886	21.8
5	5.68	4.40	0.32	77.46	0.433	7.5	1.213	20.4
6	5.60	4.20	0.35	75.00	0.355	5.0	0.990	20.6
7	5.68	4.26	0.38	75.00	0.403	5.5	1.039	20.4
8	5.52	4.34	0.39	78.62	0.387	8.0	1.253	21.1
9	5.74	4.32	0.37	75.26	0.365	4.5	0.940	21.3
10	5.54	4.26	0.32	76.90	0.418	7.0	1.172	20.7
11	5.64	4.32	0.35	76.90	0.392	7.5	1.213	20.5
12	5.50	4.18	0.36	76.00	0.380	6.0	1.085	20.9
13	5.55	4.22	0.33	76.04	0.405	6.5	1.129	20.4
14	5.85	4.30	0.38	73.50	0.397	4.5	0.940	20.6
15	5.62	4.28	0.39	76.16	0.410	7.0	1.172	21.1
16	5.79	4.22	0.37	72.88	0.407	2.5	0.700	21.3
AVERAGE	5.67	4.26	0.37	75.05	0.395	6.0	1.068	20.9

The eggs dropped on the steel plate from the different heights h. The maximum height at which no damage of the eggshell occurred was found. The corresponding impact velocity V is given by well known relation

$$V = \sqrt{2gh}$$

The influence of the air resistance was found to be negligible. The obtained data have been used for the numerical simulation of this impact loading. The details of this procedure may be found in paper [6].

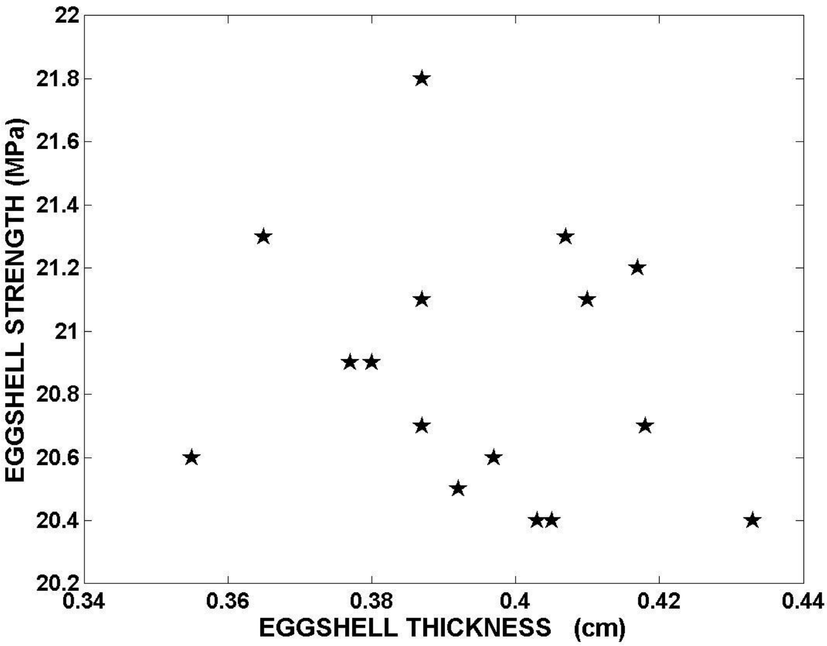

Fig.2 The effect of the eggshell thickness on the eggshell strength

3. EXPERIMENTAL RESULTS AND THEIR DISCUSSION

The values of experimentally found magnitudes h and V are given in Table 1. The detail analysis of these data leads to the conclusion that the critical impact velocity i.e. the velocity at which the eggshell cracks increases with the egg shape. It means that the maximum of this velocity can be achieved for a spherical shape of the egg. From the observation of the damaged eggs it has been found that the cracks originated at the point of impact.

The obtained data have been used for the numerical simulation of the egg impact. The finite model of the egg is described in our previous paper [6]. The eggshell is considered as linear isotropic elastic material. Its behaviour is than described by the Young modulus E and by the Poisson constant ν. From the numerical computation the stress at which the eggshell fracture occurs can be obtained. This stress represents the eggshell strength. These results presented in the Table 1 show that the eggshell strength is independent on the egg shape index as well as on the eggshell thickness – see Fig.2. The values of the eggshell strength are comparable with some results obtained in [7]. The eggshell strength is probably an intrinsic eggshell constant which may be affected by the eggshell microstructure, by its chemical composition and by some elements distribution. It is obvious that the verification of this hypothesis must be based on much more experimental and numerical results. Obtaining of these data is subject of the forthcoming papers.

CONCLUSSIONS

The experimental technique suggested in the given paper is very convenient for the evaluation of the eggshell strength under impact loading. Preliminary results show that the value of the critical impact velocity increases with the eggshell shape. The best resistance of the egg against the impact can be expected for the eggs of nearly spherical shape. If we take into account the whole shape of the egg as well as the eggshell thickness we can obtain the strength of the eggshell, which is independent on the eggshell geometry. This intrinsic material parameter will be a subject of our next research.

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