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Research Paper

Testing and simulation of the three point bending anisotropic behaviour of hazelnut shells

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In order to improve the performance of shelling machines, and to enhance the numerical modelling of anisotropic behaviour of hazelnuts shells, the mechanical properties of shells are useful experimental data. A procedure to obtain an effective numerical model and to calibrate anisotropic material properties by means of experimental testing is described. The procedure was applied to a commercial variety of Italian hazelnuts and the mechanical properties were experimentally obtained for shell on specimens obtained from conform hazelnuts. The numerical finite element model investigates single and double curvature geometry simulation performance of the shell specimens.

1. Introduction

According to FAO data, hazelnut in shell production has reached 500,000 t year^{-1} in Turkey (world's largest producer, 73%) followed by 125,000 t year^{-1} in Italy (world's second largest producer). Shelling is the basic and critical operation in hazelnut processing: machinery must crack the shell keeping intact the fruit inside.

In some earlier papers (e.g. Güner, Dursun, and Dursun, 2003, Koyuncu, Ekinci, and Savran, 2004, Valentini, Rolle, Stévigny, and Zeppa, 2006, Vursavus and Özgüven, 2005) experimental values of the compressive load needed to crack the shell of hazelnuts, walnuts and pine nuts (Fig. 1) were given, according to the different shapes of the species involved. Here the experimental values related to "Tonda Gentile Trilobata" Italian hazelnut cultivar (from the Piedmont region, Italy) are given and shell elastic coefficients and anisotropic behaviour are discussed.

In the preliminary study by Delprete and Sesana (2014) nut slices were subjected to bending, stresses and deformations were calculated through the Winkler-Bach curved beam theory, but shell material was considered isotropic. However, the shell of the hazelnuts is similar to that of wood; fundamentally it is anisotropic with respect to the mechanical properties, so they vary with the considered direction. It is also not

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Nomenclature

ΔV	Fractional volume of hazelnut shell material [%]
ϕ	Hazelnut sphericity [%]
A, B, C	Main hazelnut shell dimension [mm]
D_p	Mean geometric diameter [mm]
E_A, E_B, E_C	Hazelnut shell elastic modulus in A, B, C direction [MPa]
E_s	Hazelnut shell elastic modulus [MPa]
$E//$, $E\perp$	Hazelnut shell elastic modulus in direction parallel and perpendicular to fibres [MPa]
FEM	Finite element method
SI_n	Nut shape index [–]
V	Approximate volume of the hazelnut shell [mm^3]
υ	Approximate volume of the hazelnut kernel [mm^3]
t	Average hazelnut shell specimen thickness [mm]
UBS	Ultimate bending stress [MPa]

correct to attribute, to a non-homogeneous material, constant material properties and the properties obtained from experimental testing must be properly applied as “average data”, and consequently broadly indicative.

It should be emphasised that the mechanical properties of a single specimen of wood, and in this case of the shell, vary according to the temperature and especially to its moisture, while different specimens of the same sample will have mechanical properties which differ from each other, largely depending on the material discontinuities and on the material density.

Finally there are also important variations of deformation and resistance related to duration of the applied stresses or deformations rates, making the wood one of the group of materials with viscous-elastic behaviour.

In order to improve the performance of processing machines for the selection of damaged hazelnuts, finite element method (FEM) models of the shells, calibrated by means of the experimental mechanical properties of hazelnuts, can be implemented to fit experimental data. Modelling the fruits using measured properties is also useful to test the model of new machines, thus improving shelling techniques and reducing kernel damage.

In this paper simulations are performed with the software DDS SolidWorks (Dassault Systemes, v. Premium 2012 ×64 Edition SP4, 175 Wyman Str., Waltham, MA, USA) with the aim to find a rapid procedure to replicate experimental data from a variety of samples. Experimental evidence shows that the behaviour of the shell under a compression load is quite linear and the failure is instantaneous.

The paper also proposes also a comparison between the experimental tests and numerical simulations in order to refine an anisotropic model of the “Tonda Gentile Trilobata” Italian hazelnut.

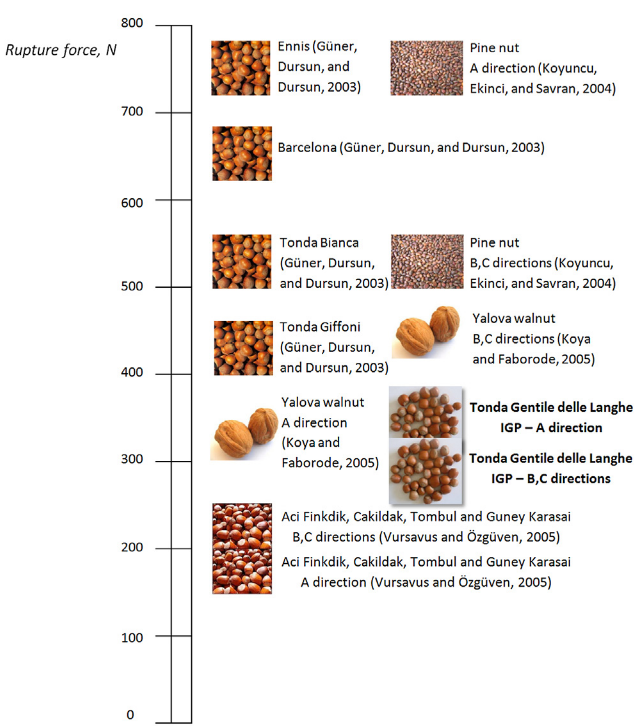

Fig. 1 – Average compressive cracking loads.

2. Experiments

2.1. *Evaluation of fibre anisotropy*

The aim of the experiments was to measure the modulus of elasticity of hazelnut shells along three principal directions as defined in technical literature (Güner et al., 2003; Koyuncu et al., 2004; Valentini et al., 2006; Vursavus & Özgüven, 2005). The main hazelnut shell dimensions are (Fig. 2) length (*A*), width (*B*) and thickness (*C*) and they define the corresponding

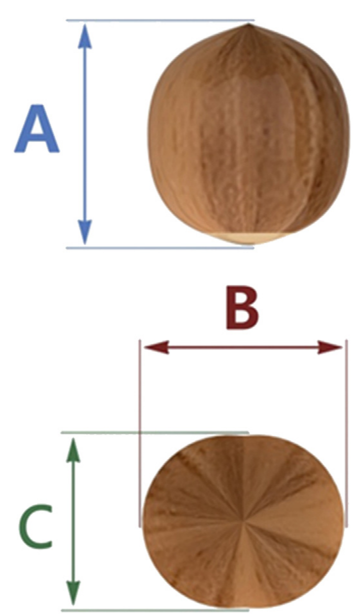

Fig. 2 – Reference dimensions of the hazelnuts.