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Methodological aspects of development of a 3D solid model of a broad bean seed huller. Part II. The 3D solid model of a broad bean seed huller

LESZEK MIESZKALSKI
Department of Production Management and Engineering, Warsaw University of Life Sciences – SGGW

Abstract: *Methodological aspects of development of a 3D solid model of a broad bean seed huller. Part II. The 3D solid model of a broad bean seed huller.* Methodological aspects of development of the huller concept design have been presented. The numerical 3D model of the huller was developed in the Solid Edge V19 environment. Individual parts of the huller were designed and then integrated into a functional model. The solid 3D model is the starting point for further dynamical analyses of the huller operation.

Key words: broad bean seed, huller concept, 3D solid model

INTRODUCTION

Consideration of physical – in particular, mechanical – properties of the internal structure of the seed coat serves as a basis for searching for the huller design concept [Engleson and Fulcher 2002, Razavi et al. 2008, Firouzi et al. 2010]. In years 1985–2001, at the University of Warmia and Mazury, research on physical characteristics of broad bean seeds was conducted [Mieszkalski 1991, 1992a, b, 1993], and the huller design concept was analyzed [Bassey and Schmidt 1989, Bassey and Mbengue 1991, 1989, Atolagbe 1991, Mieszkalski 1993, 1999a, Grochowicz 1996, Guz and Panasiewicz 2000, Doehlert et al. 2001, 2007, 2009, Panasiewicz et al. 2002, Shitanda et al. 2008]. The 3D modeling of objects of plant origin, characterized by irregular shape, is of great significance in the huller design process [Dobrzański et al. 2007, Mieszkalski 2013, 2014a, b]. Weres [2010] proposes a system, which, on the basis of the seed cross-section photographs, allows for automatic extraction of data on geometry of the caryopsis examined. Theodoridis and Mavroforakis [2007] are of opinion that the Support Vector Machines algorithm can be used for numerical analysis of geometric interpretation images and constitutes a new research tool for assessment of huller operation. Scientific research, conducted at the University of Warmia and Mazury, concerning use of broad bean seeds, resulted in designing and patenting of the first hullers for coarse seeds, including broad bean [Mieszkalski 1991].

Powierża [1997] writes that designing is an information measure, consisting of instrumentalized development of the informational version of the system. Development using the 3D spatial model method, with such software tools as Solid Edge, Solid Works, Catya, has become the basis for integrated production [Kazimierczak et al. 2004, Przybylski and Deja 2007, Luźniak 2009]. Herández and Bellés [2007] propose 3D analysis using the finite element method (FEM) to determine the stress observed in the hull under external loads. Buliński and Łyp-Wrońska [2014] propose the defect analysis method – useful in the design process – for determination of defect cause. At the design stage, it is necessary to take into account the problem of reserves in the company, which can be caused by the designed product [Buliński et al. 2012]. A vertical huller for hulling of various kinds of seeds, used in mills and groats plants, "Ekonos", cannot be used for hulling of broad bean seeds. Hołownicki [2010] underlines the importance of scientific research in creation of original ideas and the role of concept originators in the process of implementation of innovations. The growing interest of fodder producers in high-protein seeds other than soybean results in the need for a design of a broad bean seed huller. Among the patented hullers, one has been selected to develop a prototype, which was thoroughly examined [Mieszkalski 1993], and then used for production at the Fodder Mixing Plant.

The objective of the study was to develop the 3D model of a broad bean seed huller. The basis for development of 3D models of the huller components and for the solid model was analysis of the internal structure of the broad bean seed on the basis of research results, obtained earlier [Mieszkalski 1992a, b, 1993, 1999a, b], as well as the hulling concept (part I) and the designed huller concept.

THE 3D SOLID MODEL OF BROAD BEAN SEED HULLER

Research works, conducted earlier, provided theoretical and practical knowledge, which constitutes a starting point for designing of the 3D model of the broad bean seed huller. The impact of sharp edges of the grinding wheel on unevenness of the surface of the seed coat should result in its cracking, cutting of micro-layers and tearing off of the coat fragments. This process takes place as a result of multiple hits of the seed against the grinding wheel and the cylindrical casing in the working space of the huller. Smaller and bigger fragments of the seed coat should be removed after hulling using the pneumatic separation method.

On the basis of analysis of the microscopic images of cross-section of the seed coat and the seed leaves, it is possible to develop the hulling process concept and the broad bean seed huller design. The concept of the working unit of the huller should be based on a revolving grinding wheel, mounted on a vertical shaft in a cylindrical casing (Figs 1, 2).

As a result of impact of the seed against the internal surface of the cylindrical casing and the protruding seeds on the surface of the revolving grinding

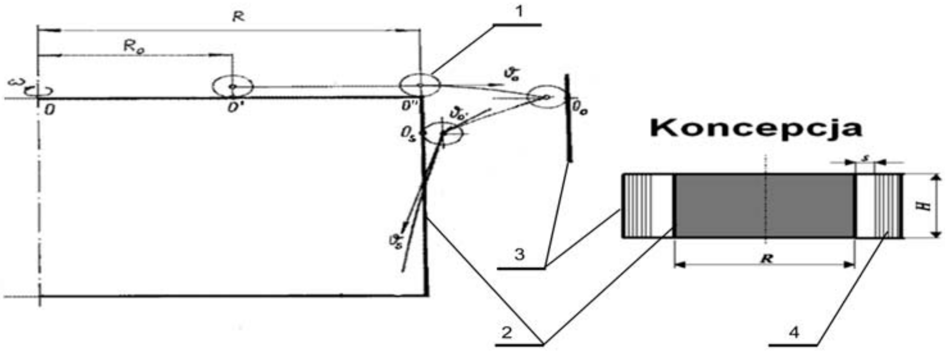

FIGURE 1. The concept of enforcement of the broad bean seed movement in the working space of the huller: 1 – broad bean seed, 2 – grinding wheel, 3 – huller casing, 4 – cylindrical inserts, *R* – grinding wheel radius, *H* – grinding wheel height, *ω* – grinding wheel angular velocity, R_o – radius of the start of movement of the seed along the grinding wheel (*O*'), v_o – velocity, at which the seed is discharged from the grinding wheel (*O*"), O_o – point of impact of the seed against the huller casing, O_s – point of impact of the seed against the revolving grinding wheel, $v_{o'}$ – velocity of impact of the seed against the grinding wheel, v_s – velocity of the seed after hitting the revolving grinding wheel, *s* – the working slot size (own materials)

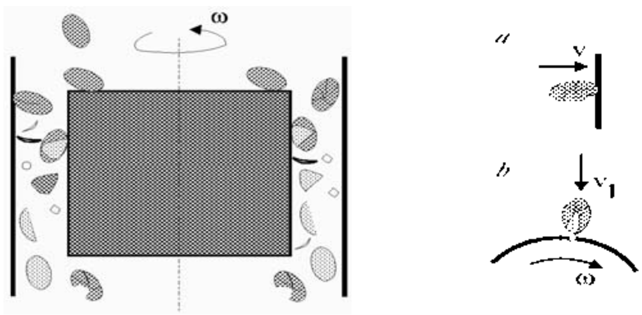

FIGURE 2. The concept of the huller working unit: a – impact of the seed against the casing, b – impact of the seed against the grinding wheel (own elaboration)

wheel, at the points of contact, local stress concentration can be observed in the seed coat. After the admissible stress level has been exceeded, the coat cracks. As the seed hits the grinding wheel again, the grinding wheel grits around the point of contact result in deformation of the cracked coat, and the edge, visible in Figure 5, emerges [Mieszkalski 2015]. At the time of contact of the seed with the grinding wheel, the seed is pressed against the grinding wheel, and the force of inertia creates resistance for the grinding wheel grit, which, leaning against the edge resulting from cracking of the coat, tears off the first fragment, as illustrated by Figure 7 (part I). The process of cracking and tearing of fragments of the cover takes place during the subsequent hits of the seed against the grinding wheel and the casing. Further cracks emerge and new fragments of the seed coat are torn off. After the cover has been removed from 0.62 of the surface, and torn off from the remaining part, the seed should leave the working space of the huller.

The huller design concept has been presented as a diagram in Figure 3. Seeds from the container get into the

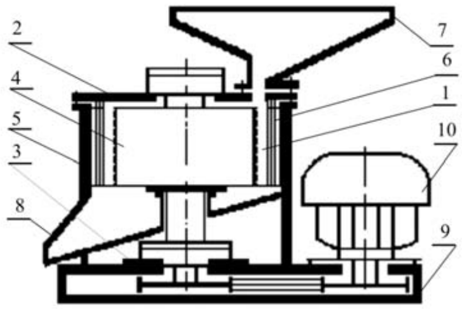

FIGURE 3. Diagram of a huller for broad bean seeds according to patent 285095: 1 – working space, 2, 3 – covers, 4 – head with the grinding wheel mounted, 5 – cylindrical casing, 6 – cylindrical spacers, 7 – container, 8 – chute, 9 – body, 10 – electrical engine (own elaboration)

working space between the grinding wheel and the cylindrical casing. In the working space, the process of seed hulling takes place. A mix of seed leaves, seed coat fragments and fine parts resulting from cutting of seed leaves and the coat, is discharged outside via the chute. The vertical shaft, on which the grinding wheel is mounted, is powered by an electrical engine. The casing with the container and the chute, the vertical shaft with the grinding wheel and the electrical engine are fixed to the base.

Numerical modeling of the huller, according to the concept developed earlier, was conducted using the Solid Edge V19 software tool.

The huller has been divided into the following units: base with an electrical engine, stretcher of the V-belt, casing, charging hopper, head. The huller consists of 118 parts. Individual solid models of the huller parts (Fig. 4) were made in the Solid Edge V19 environment for modeling of separate parts. After making sketches of individual parts, depending on the needs, the following Solid Edge V19 modeling tools were used: extrusion, revolved extrusion, opening, rounding. In the huller being modelled, the base unit, the charging hopper unit, the chute unit and many stretcher components were made of cut metal sheets. For modeling of individual metal sheet parts, Solid Edge V19 environment was used. In this environment, diagrams were prepared, specifying the metal sheet thickness and bending radiuses, the rounded undercut on the bend and undercut of the corner. Appropriate bends were made on the profile cut from the meatal sheet. The edges of the profiled metal sheet part were welded in the "welded structures environment" of Solid Edge V19, defining welds to the indicated edge. Structural material was defined for individual parts. Solid Edge V19 assigned such physical property values to 3D solid models as: mass,

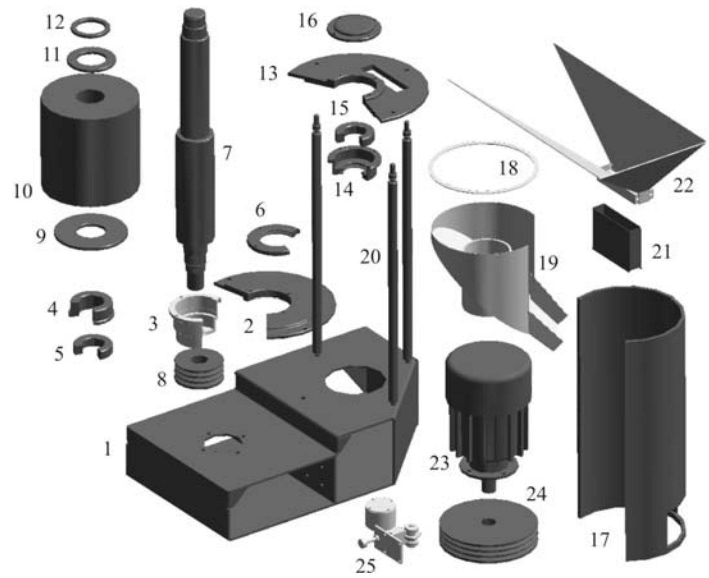

FIGURE 4. Broad bean seed huller components: 1 – base, 2 – lower cover, 3 – lower bearing casing, 4 – self-aligning bearing I, 5 – thrust ball bearing, 6 – lower cover of the bearing casing, 7 – shaft, 8 – shaft pulley, 9 – grinding wheel ring, 10 – grinding wheel, 11 – nut, 12 – positive locknut, 13 – top cover, 14 – top bearing casing, 15 – self-aligning bearing II, 16 – top cover of the bearing casing, 17 – cylindrical casing, 18 – ring, 19 – chute unit, 21 – inlet channel, 22 – charging hopper unit, 23 – electrical engine, 24 – engine pulley, 25 – stretcher unit (own materials)

volume, area, inertial moments, inertial radiuses, mass center and volume center coordinates.

The individual solid models of the huller parts were integrated in Solid Edge V19, using the unit design environment (Fig. 5). When attaching individual parts to the unit, the following relationships were applied: fastening, adherence, leveling of surfaces and coaxiality.

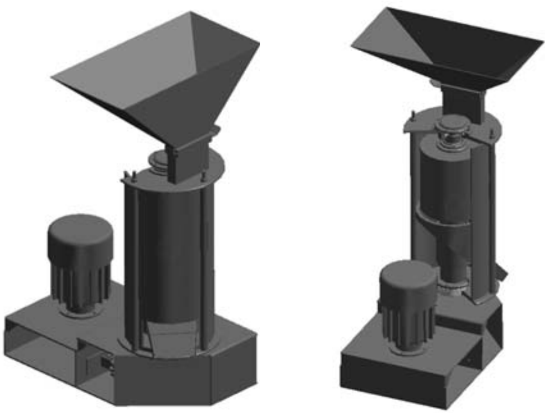

FIGURE 5. Vertical broad bean seed huller (own materials), (own materials)

On the basis of research conducted in Olsztyn, at the Agricultural and Technical Academy (presently – the University of Warmia and Mazury, in Olsztyn), the hulling process parameters were defined, and then – the technical parameters of the huller [Mieszkalski 1993]. The basic technical parameters of the huller include: diameter of the grinding wheel 400 mm, grinding wheel height 200 mm, width of the working space slot 10–16 mm, grinding wheel peripheral velocity 40 $m\cdot s^{-1}$, effective performance 1,200 $kg\cdot h^{-1}$, unit energy consumption $15\cdot 10^{-3}$ $MJ\cdot kg^{-1}$, hulling efficiency 95%. After hulling of the broad bean seeds and pneumatic separation, broad bean seed leaves and hulls were obtained (Fig. 6).

CONCLUSIONS

The broad bean seed huller design method can be applied to designing of hullers equipped with grinding wheels for hulling of leguminous plant seeds of morphological structure similar to broad bean seeds. Analysis of internal structure of the cross-section of the seed coat provides information necessary when searching for the concept of the hulling process and the concept of the huller structural solution. Solid 3D modeling of components and units using CAD software, such as Solid Edge, is the basic tool in modern design of technical objects. The 3D solid models of the huller can be used to create database of geometric and material data, as well as for the purpose of resistance analyses.

FIGURE 6. Hulled broad bean seeds (seed leaves) and seed coats (own materials)

Development of a numerical model of a broad bean seed huller allows for creation of a database, containing the physical parameter values associated with geometric and material properties. Further research works will be associated with dynamic and resistance analysis using Femap software.

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Streszczenie: *Metodyczne aspekty tworzenia modelu bryłowego 3D obłuskiwacza do nasion bobiku. Część II. Model bryłowy 3D obłuskiwacza do nasion bobiku.* W artykule przedstawiono metodyczne aspekty opracowania koncepcji konstrukcji obłuskiwacza. Numeryczny model 3D obłuskiwacza powstał w środowisku Solid Edge V19. Modelowano poszczególne części obłuskiwacza, które następnie złożono w funkcjonalną całość. Bryłowy model 3D jest wstępem do dalszych analiz dynamicznych pracy obłuskiwacza.

Author's address:
Leszek Mieszkalski
Wydział Inżynierii Produkcji SGGW
Katedra Organizacji i Inżynierii Produkcji
02-787 Warszawa, ul. Nowoursynowska 164
Poland
e-mail: leszek_mieszkalski@sggw.pl