Computers and Electronics in Agriculture 135 (2017) 252–259

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Soft simulator for redesigning of a chickpea harvester header

Hiwa Golpira [a,*], Hêmin Golpîra [b]

[a] Department of Biosystems Engineering, University of Kurdistan, Sanandaj, Iran
[b] Department of Electrical and Computer Engineering, University of Kurdistan, Sanandaj, Iran

ARTICLE INFO

Article history:
Received 26 March 2015
Received in revised form 10 February 2017
Accepted 17 February 2017
Available online 24 February 2017

Keywords:
Chickpea
Design
Fuzzy modeling
Genetic algorithm
Harvesting losses
Model-based engineering
Structural optimization

ABSTRACT

This paper proposes a new framework to tackle computer-aided modeling and evolutionary algorithms into conventional design phase of a machine, which, in turn, significantly reduces time and cost of structural optimization. The model-based engineering approach overcomes the crudity of hard modeling, field experiments and statistical analysis for finding the optimum structure of a design. Genetic algorithm incorporated with fuzzy modeling established a hybrid computational algorithm which predicts optimal sizing of a platform, developed for a chickpea harvester header. The harvesting losses of the platform's configurations in field trials were fed to the metaheuristic approach to develop a soft simulator for redesigning of the machine. Acceptable harvesting performance of the optimized harvester in field trials confirmed the robustness feature of the experiments based simulator. Further the results validated the virtual model and verified the reliability of the automatically generated harvester. The methodology can be employed for structural optimization of mechanical systems.

1. Introduction

Time-consuming and costly development of the conventional design methodology are difficulties for prototyping a concept and reaching optimal solution. During last decades, conceptually designed headers and harvesters were tried for chickpea (*Cicer arietinum* L.) harvesting (Bansal and Sakr, 1992; Behroozi-Lar and Huang, 2002; Konak et al., 2002; Siemens, 2006), but acceptable performance has not been achieved yet. The problem becomes more acute when mechanical harvesters applied for harvesting rainfed chickpeas cultivated in fallow fields.

In 2006, available information on the physical, mechanical, and aerodynamic properties of chickpea seeds was reviewed for designing of a chickpea harvester. Terminal velocity, Reynolds number, sphericity, dimensions, densities, mass, volume hardness, impact velocity, coefficient of friction and drag force were surveyed for designing of a concept. For instance, length, width, thickness and geometric mean diameter of chickpeas seed were determined 9.34, 7.72, 7.75 and 8.5 mm, respectively. Later, the gathered information was published by (Golpira, 2015). In 2009, a tractor-pulled harvester with modified stripper header was conceptually designed and fabricated for chickpea harvesting. A platform, with 1 m working width, was accompanied by a batted reel to develop a modified stripper harvester header. The platform with forward-opening fingers produced a harvester header, in which the plants move through the V-shaped slots and are stripped. The platform supports the passive fingers and delivers the harvested material. Reel with three bats sweeps the pods across the platform and pushes the top of the chickpeas over the header. A conveyor with an endless chain sweeps the harvested material which falls onto the header (Golpira et al., 2013). In 2011, the tractor-pulled harvester was redesigned to a tractor-mounted harvester which benefits from advantages of pneumatic conveyors (Golpira, 2013). In addition to adaptability of the floating header with ground unevenness, field environmental impacts have moderated by two tire wheels located on both sides of the header. This causes the performance of the harvester is kept acceptable in different fields. Field experiments results confirmed that the structural optimization of the platform can reduce losses. However, hard modeling, field experiments, and statistical analysis are time and cost-consuming tools for decision-making in conventional design of a concept.

Nature of computer-based design models and evolutionary algorithms provides some opportunities that cannot be obtained through conventional approaches. Fuzzy Modeling (FM), Genetic Algorithm (GA), differential evolution, harmony search, particle swarm and ant colony optimizations, bee, bat and firefly algo-

Abbreviations: FM, fuzzy model; GA, genetic algorithm; MF, membership function.

* Corresponding author.
E-mail address: h.golpira@uok.ac.ir (H. Golpira).

http://dx.doi.org/10.1016/j.compag.2017.02.018
0168-1699/

Nomenclature

W	slot width	l	total losses, %
L	finger length	L_p	weight of remained pods on the plant, kg
D	keyhole diameter	L_s	weight of shattered pods on the ground, kg
E	entrance width		
H_p	weight of harvested pods on the header, kg		

rithms, cuckoo search, charged system search and krill herd are utilized for modeling and optimization (Babuska, 2001; Gandomi et al., 2011, 2013; Saridakis and Dentsoras, 2008). While modeling approaches are employed to visualize performance of a system, bio-inspired algorithm attains the required knowledge to converge at optimum solution from the fitness function in the evolutionary process. Two types of rule-based fuzzy models are Mamdani and Takagi–Sugeno. While the early one is determined by linguistic description of both antecedent and consequent, the later, known as Takagi–Sugeno (Takagi and Sugeno, 1985), is described by linguistic antecedent and crisp consequent. The linguistic fuzzy model, introduced by (Mamdani, 1977; Zadeh, 1973), is appropriate for structural optimization problems (Kicinger et al., 2005). GA is a powerful optimization technique, capable of being applied to a wide range of optimization problems that enables to perform randomized global search in a solution space. GA produces an exhaustive set of variables that covers all the search space of possible solutions in an optimal way. Combination of two or more above mentioned metaheuristic approaches produces hybrid algorithms for model-based engineering solutions. It should be noted that while evolutionary algorithms and hybrid models are common tools to deal with control systems (Jamshidi, 1996), their ability in designing a concept is neglected in literature.

In this research, a soft simulator was developed to optimize performance of a platform, designed for chickpea harvesting. FM incorporated with GA provides an experiment-based hybrid model for structural optimization of the machine. The virtual harvester reduces design cost and time through mimics the behavior of the machine to predict harvesting losses.

The rest of this paper is organized as follows. Section 2 presents the harvesters, models and design variables. Section 3 describes real and virtual field evaluations. Section 4 develops the soft simulator. Section 5 validates the hybrid model, and finally Section 6 compromises a framework for structural optimization of concepts.

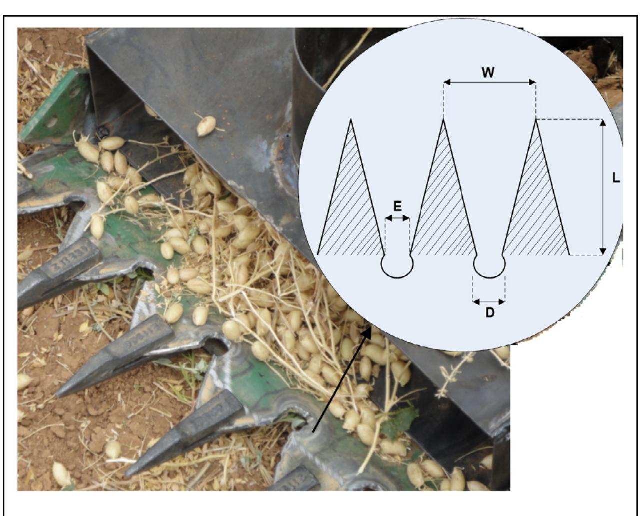

Fig. 1. Platform with design variables of D: Keyhole diameter; E: Entrance width; L: Finger length; W: Slot width.

2. Machine design

2.1. Platform configurations

Platform variables of slot width, finger length, keyhole diameter and entrance width would be modified in order to minimize the harvesting losses (Fig. 1). The sizing optimization problem is formulated as:

$$Minimize\ Losses = F(W, L, D, E) \quad (1)$$

where $W, L, D,$ and E are slot width, finger length, keyhole diameter, and entrance width, respectively.

Eighteen steel platforms were built and evaluated in field trials. The design variables of the fabricated platforms are illustrated in Table 1. Platform with slot widths of 40- and 70-mm and finger lengths of 150- and 200-mm were the preliminary models (Nos. 1, 2 and 3). The width of these platforms was 100 cm. These models were tried during year 2009 on the tractor-pulled harvester (Fig. 2). The optimal design included a slot width of 40 mm and finger lengths of 200 mm. As the long fingers produce high losses, the finger lengths were reduced to 95-mm. Further, Keyhole, a hole at the base of the fingers, was added to the platform structure. Platform with the slot width of 72-mm, finger length of 95-mm, keyhole diameter of 16-mm and entrance width of 10-mm (No. 4) was the baseline for the redesigned harvester (Fig. 3). The width of this platform was 140 cm.

To reduce cost and time, a simple harvester was fabricated for testing the platform configurations (Fig. 4). An adjustable screw adjusts height of platforms above the ground. This human-handled harvester is utilized to test ten fabricated platforms, i.e. configuration Nos. 5–14 in Table 1. The width of theses platforms

Table 1
Platform configurations fabricated for chickpea harvesting.

Platforms	Design variables (mm)			
	Slot width	Finger length	Entrance width	Keyhole diameter
1	70	150	–	–
2	40	200	–	–
3	40	150	–	–
4	72	95	10	16
5	72	95	13	16
6	40	40	6	6
7	58	95	12	13
8	58	95	10	17
9	58	40	12	13
10	58	40	10	17
11	40	40	7	10
12	40	40	14	15
13	40	40	8	11
14	72	95	6	12
15	–	–	13.5	15.5
16	–	–	6.5	9
17	–	–	5.5	13.5
18	–	–	12.5	16