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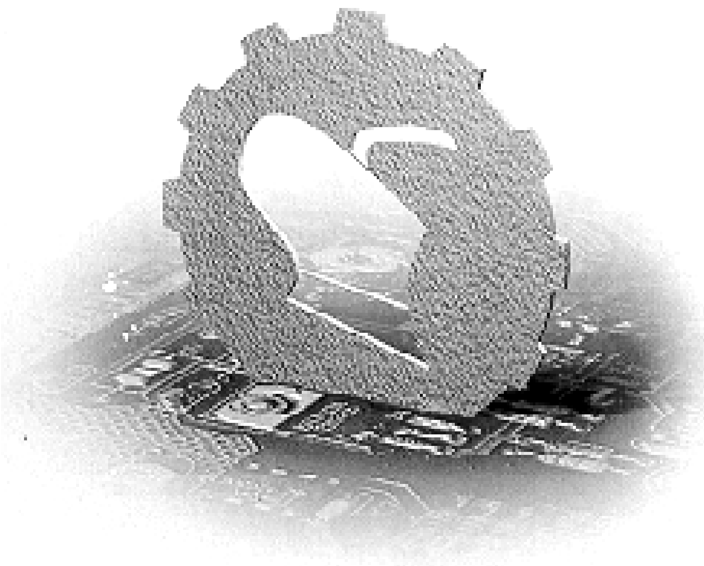

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SOCIO-ECONOMIC VIABILITY OF BALER FOR BALING PADDY STRAW: A CASE STUDY

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Abstract: The present study was conducted in south western district Mansa of Punjab during the year 2014-15. The main objective of the study was to study the socio-economic viability of the paddy straw baler technology. Farmers' opinion regarding baler technology was studied using interview schedules and economics was studied from case study of successful entrepreneur practicing baler technology for income generation. It was found that farmers were ready to adopt this technology due their concerns regarding removal of loose straw to prepare field for sowing of next season crop and their sensitivity towards environmental pollution from open field burning. The economic analysis revealed that total fixed cost for baler technology is Rs. 15.04 lac and total variable cost was Rs.4.17 lac. Total straw collection during 45 days period was 973 tons. The benefit cost ratio of this technology was 1.77 which indicated its economic viability.

Keywords: *baler, economic, harvesting, rake, saving, technology*

INTRODUCTION

Rice wheat system is important cropping system that has given assured income to the farmers of Punjab (India). About 2.8 million hectare area is under rice in the state. The area under rice has increased during last five decades. Farmers have promptly adopted rice wheat cropping system on large areas due to assured marketing and thus assured and high returns in comparison to other crops. Despite all these benefits, today the major problem State facing is that the farmers after combine harvesting paddy fields burning paddy straw in-situ in order to clear fields [1]. The Farmers are considering it as the easiest and cheapest way to dispose of straw in order to save time in field preparation

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for the sowing of next crop. Sometimes the straw burning is also linked to eliminate sources of pests, diseases and rat infestation. However, the practice of open-field burning is polluting air with a various gases especially carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); and fine particles which further effecting global climate and also impacting human in form of respiratory ailments [4].

Large number of sensitization programs is being organized by the State Department of Agriculture and Krishi Vigyan Kendras' to make the farmers aware of the consequences of open field burning, but despite all the farmers giving preferences to open field burning. In recent years, farmers have been compelled to burn crop residues due to shortage of human labor; high cost of removing the crop residues by conventional methods; use of combines for harvesting crops. The standing stubbles and loose straw in paddy harvested fields need to either incorporated into soil for enhancing soil fertility or removed from the field for other uses. Various technologies suggested by research scientists for straw in situ incorporation are still in trial phase from farmers' perspective. In situ rice straw incorporation as an alternate to burning has been adopted by only a few farmers because of high incorporation costs and energy and time intensive [5]. Further solution can be collection and removal of paddy straw from field and utilizing it for paper industry or feed for animals, mushroom production and electricity generation in biomass power plants. The State Government of Punjab also providing subsidies on machinery and technologies relating to rice straw management that could be more cost effective.

In the year 2011-12 a biomass plant was established for power generation in Khokhar Khurd village of Mansa district of Punjab State by Government. At same time Punjab Agricultural University, Ludhiana made the introduction of baler technology for collection of paddy straw in the district. In order to enhance the adoption rate of this technology among farmers Krishi Vigyan Kendra, Mansa conducted front line demonstrations in adjoining villages. The present study was conducted in operational area of the KVK to know the opinion of beneficiary farmers about the new technology and to analyze the economic viability of paddy straw baler-cum-knotter technology.

MATERIALS AND METHODS

For the purpose of the study the data were collected in form of a case study from successful entrepreneurial famer running paddy straw baler in the district on custom-hiring basis. Second set of data were collected by random sampling technique from 50 beneficiary farmers of 10 villages of the fields where paddy straw baler was operated.

Figure 1. View of rake machine, paddy straw baler in operation and bales transported from field for the sale

An interview schedule was developed to study the opinion of farmers regarding baler technology and reason for preferences/non-preference over open field burning. The view of bale and rake machine is shown in Fig. 1. For economic analysis of the paddy straw baler technology fixed costs regarding prices of baler, rake and stubble shaver was find out by interviewing entrepreneurial farmer. Empirical observation were also made on various aspects viz; working efficiency, twines required, diesel consumption during the baler machine was in operation at the farmers fields.

RESULTS AND DISCUSSION

The socio-personal characteristics of respondent farmers are given in Tab. 1 and the opinion of farmers regarding benefits of baler technology are given in Tab. 2.

Table 1. Socio-personal profile of respondents

Category	*Beneficiaries (n=50)*	
	Frequency	*Percentage*
Age		
Young	*8*	*16.00*
Middle	*35*	*70.00*
Old	*7*	*14.00*
Educational Qualification		
Below matriculation	*14*	*28.00*
Matriculation	*23*	*46.00*
10+2 and above	*13*	*26.00*
Land holding		
Small farmers	*14*	*28.00*
Medium farmers	*24*	*48.00*
Large farmers	*12*	*24.00*
Extension contacts		
Low	*4*	*8.00*
Medium	*29*	*58.00*
High	*17*	*34.00*

Table 2. Opinion of farmers regarding benefits of baler technology

S. No.	*Benefits*	*Beneficiary farmers* n_1*=50*	
		Average	*Rank*
1	*Cost saving*	*2.8*	*1*
2	*Timely sowing of next crop*	*2.4*	*2*
3	*Check on environmental pollution*	*2.3*	*3*
4	*Soil health conservation*	*2.0*	*4*
5	*Operation of new technology made easy*	*1.8*	*5*
6	*Reduction in risk to human life*	*1.75*	*6*
7	*Reduction in fire incidences*	*1.7*	*7*

*Multiple responses

Timely Sowing of Next Crop. Due to a short time, many farmers were forced to burn the straw immediately to clear the field for the next crop season. Major reason for adoption of baler technology was the short period of operation for next crop. Timely collection and removal of straw influenced the decision of farmers regarding management of paddy straw using baler technology. Interviews showed that both beneficiary and non-beneficiary farmers were willing to adopt baler technology due to timeliness parameter. [3] reported that due to a short time many farmers were also forced to burn the straw immediately to clear the field for the next crop season.

Check on Environment Pollution. The response showed that farmers were well-aware of the consequences of on-farm burning. In recent years, farmers have been compelled to burn crop residues due to shortage of human labor; high cost of removing the crop residues, and difficulties in operating straw incorporation technologies. Therefore, majority of the farmers were willing to use baler technology for straw collection and removal as open field burning resulted in environment pollution.

Cost Saving. The entrepreneurs working with baler were using chopper in paddy fields before the operation of baler. As, chopping operation was performed by the entrepreneurs, thus, there was a cost saving of Rs. 500 per hectare where baler was operated.

Soil Health Conservation. Burning of paddy straw resulted in soil compaction and loss of nutrients and results in soil compaction. Third major reason for adoption of baler technology by majority of the farmers were due to perceived benefits of non-burning on soil structure and soil fertility.

Operation of New Technology. Farmers of the area were facing problem in use of innovative technology viz; happy seeder and zero till drill for soil incorporation due chocking problem. Large amount of loose straw in the combine harvested paddy fields was resulting in decreased efficiency of paddy straw incorporation technologies. Respondent farmers revealed that removal of paddy straw using baler resulted in use of zero till drill technology feasible and enhanced its efficiency.

Reduction in Risk to Human Life. Burning of loose straw in paddy fields caused each year many accidents in the field as well as roads accidents due to smoke. Respondent farmers realized that use of baler resulted in check on accidents.

Reduction in Fire Incidences. Each year open field burning caused many fire incidences that led to loss of mature crops in farmer's field and neighboring farmers' fields. Beneficiary farmers realized reduction in fire incidences as a result of use of baler technology.

Field performance of paddy straw baler. The field performance of the baler is given in Tab. 3. The baler was evaluated for bale size of 36 x 46 x 90 cm. The baler was operated by using 50 hp tractors. The Operational time of the baler was 45 days (starting from 5th October-20th November, 2014). The baler was operated by the farmer on an average for 10 hours a day and its field capacity varied from 0.30-0.36 ha per hour. In an effective span of 45 days the farmers was able to collect the straw in form of bales from 144 ha. Operating the machine with forward speed of 2.7 km/h, the average number of twine tied bales of paddy straw obtained per ha was 287.5 with bale weight of 23.5 kg. The average straw recovery from one hectare field was worked out to be 6.75 ton. To tie the bales recovered from one ha area 6.25 kg of plastic twine was used.

Economic analysis of paddy straw baler technology. The data given in Tab. 4 depicts the cost incurred by the farmer on purchase various machineries along with rate of interest and their respective depreciation costs. The farmer except the 5 year old tractor had made fresh purchase all other machines such as baler, stubble shaver and rake. The present and depreciation value for the tractor was worked out to be rupees 3.28 lac and 4044, respectively. Fixed cost value of the machineries used was also worked out in order to find out the economics of the venture in 1st year of operation. The fixed cost value includes only rate of interest and depreciation costs.

Table 3. Performance of straw baler in combine harvested paddy fields

Parameter	*Observation recorded*
Machines operated	*Tractor, Baler (New Holland), Raker, Reaper*
Tractor (hp)	*50*
Operational time (days)	*45*
Forward Operating speed (km^{-hour})	*2.7*
Working hours^{-day}	*10*
Field capacity (ha)$^{-hour}$	*0.32 (Range 0.30-0.36)*
Area covered (ha) $^{-day}$	*3.2*
Total area covered by baler (ha)	*144*
Fuel consumption (liter)$^{-hour}$	*5*
Labour requirement	*2*
Size of the bales (cm)	*36×46×90 (H × W × L)*
Bale weight (kg)$^{-bale}$	*23.5*
No. of bales-ha	*287.5 (Rang 275-337.5)*
Total number of bales produced (NOS)	*41400*
Straw recovery (ton)$^{-ha}$	*6.75*
Total straw collected (ton)	*972.9*
Total twine used (kg)	900.0
Twine used (kg) $^{-ha}$	6.25
Twine used (kg) $^{-bale}$	0.022 (21.73g)

The findings given in Tab. 5 shows the economic analysis of paddy straw baler for the operational period of 45 days in season. The findings show that total fixed cost value and variable cost for a season was found to be rupees 2.79 lac and 4.17 lac, respectively. Variable cost include cost incurred on hiring the services of tractor operator, fuel charges, labor charges, transport cost, other expenses on purchase of twine and repair & maintenance of machinery. The net income of the farmers was worked out by subtracting total cost incurred (fixed cost value + total variable cost) from the Gross income generated from sale of straw. The net income of paddy straw baler for the season was found to be Rs. 5.38 lac. The benefit cost ratio of baler was 1.77. But, this income is only possible if the baler works in 20 km radius of biomass power plant.

Cost benefit analysis of paddy straw baler. The cost economics was worked out (Tab. 6) based on expenditure costs and income from sale of bales per hectare. The cost of producing one twine tied bale was Rs.16.84 and cost for twine used per hectare was Rs. 4.02. The cost of operation per ha was found to Rs. 2372.26 while, cost of baling per ha comes out to be 4841.75. The cost of twine used per hectare was Rs. 1156.25 and was almost one fourth of the total cost of bailing per hectare. The gross income from sale of collected straw was Rs. 8580.43 per hectare in addition to benefits to soil health and reduction in fire accidents by checking open field burning of straw.

Table 4. Machinery required along with costs and depreciation

Particulars	Baler	Stubble shaver	Tractor (5 year old)	Rake
Cost incurred (Rs)	1025000	50000	328050	150000
Interest (12.75%)	128125	6250	0	18750
Depreciation cost @ 10 %	102500	5000	4044*	15000
Fixed cost value	1255625	61250	4044	183750
Grand Total	1504669			

*Depreciation value for tractor was worked out only 45 days due to its other uses

Table 5. Economic analysis of paddy straw baler technology

Parameter	Per Season (45 Days)
Fixed cost value	
Interest on fixed costs value	153125
Depreciation cost of machinery used (Other than tractor)	122500
Depreciation on tractor (For 45 days)	4044
Total Fixed Cost value	279669
Variable cost	
Tractor operator	18000
Fuel charges, l/h (12 liters)	130500
Twine (Rs. 185/Kg)	166500
Repair and maintenance	3025
Labor cost (2 men days @ Rs. 262 per day)	23580
Transportation cost @ Rs 25 $^{-quintal}$ (With in radius of 20 kms)	75937.5
Total variable cost	417542.5
Total costs	
Fixed +variable	697211.5
Income from straw sale	
Total area covered (ha)	144
Total yield of paddy Straw , t/ha	6.76
Total straw collection during season (t)	973
Gross income from sale of straw @ Rs 1270 per ton	1235583
Net income from sale of paddy straw	538371.5
Benefit cost ratio	1.77

Table 6. Cost benefit analysis of paddy straw baler

Parameter	Observation recorded
Cost of operation (baler-cum-tractor) Rs^{-ha}	2372.26
Cost of bailing Rs^{-ha}	4841.75
Cost of bailing Rs-^{bale}	16.84
Cost of twine used Rs^{-ha}	1156.25
Cost of twine used Rs^{-bale}	4.02
Gross Income Rs $^{-ha}$	8580.43
Gross Income Rs $^{-bale}$	29.84
Net Income Rs $^{-bale}$	13.00
Net Income (Rs^{-ha})	3738.69
Relative income^{-bale}	1.77

Gross income per bale was Rs. 29.84 and net income per bale was Rs. 13.0. Net income from sale of twined bales from one acre was Rs. 3783.69. The relative income from sale of bale was Rs. 1.77. Thus, making it a viable option for removal of paddy straw from field. [2] also concluded that straw management in the combine harvested fields by straw collection and baling in the field is an appropriate and economically viable option for timely use of the field for subsequent sowing.

CONCLUSIONS

There is immense need to check the open field burning of paddy straw to avoid environmental pollution, soil degradation, health problems and other problems. From the findings of the study it can be concluded that baler technology is socially and economically viable in removal of paddy straw from the combine harvested paddy fields. Short window for sowing of next season crop, risk to human lives, environmental pollution and soil health are the sensitive issues for farmers. The baler technology is economically viable with relative income per bale of 1.77. But, it is mandatory that there should be proper market for bulk purchase of paddy straw and if operational area of technology is within 20 kilometers radius of the demand area. Moreover, entrepreneur needs to work extra hours to make this enterprise a viable one.

BIBLIOGRAPHY

[1] Erenstein, O. 2011. Cropping systems and crop residue management in the Trans-Gangetic Plains: Issues and challenges for conservation agriculture from village surveys. Agricultural Systems, 104, 54-62. Available at: https://ideas.repec.org/a/eee/agisys/v104y2011i1p54-62.html.

[2] Mangaraj, S., Kulkarni, S.D. 2011- Field Straw Management - A Techno Economic Perspectives. *Journal of the Institute of Engineering*, 8 (1), 153–159.

[3] Rosmiza, M.Z., Davies, W.P., Rosniza Aznie, C.R., Mazdi, M., Jabil, M.J., Wan Toren, W.Y., Che Rosmawati, C.M. 2014- Farmers' Participation in Rice Straw-Utilisation in the MADA Region of Kedah, Malaysia *Mediterranean Journal of Social Sciences,* 5 (23), 229-237.

[4] Singh B, Shan, Y.H., Johnson-Beebout, S.E., Yadvinder Singh, Buresh, R.J. 2008. Crop residue management for lowland rice-based cropping systems in Asia. *Advances in Agronomy*, 98, 117-187.

[5] Singh, Y., Sidhu, H.S. 2014. Management of Cereal Crop Residues for Sustainable Rice-Wheat Production System in the Indo-Gangetic Plains of India. *Proc Indian Natn Sci Acad* 80 (1), March 2014, 95-114.

SOCIO-EKONOMSKA ODRŽIVOST BALERA ZA BALIRANJE SLAME PIRINČA: STUDIJA SLUČAJA

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Sažetak: Predstavljena studija je provedena u jugozapadnoj oblasti Mansa u Punjabu tokom 2014-15 godine. Glavni cilj studije bilo je proučavanje socioekonomske održivosti tehnologije baliranja slame pirinča. Istraživana su mišljenja farmera o tehnologiji baliranja kroz upitnike, a ekonomičnost je ocenjivana iz studije slučaja uspešnog preduzimača koji uslužno primenjuje tehnologiju baliranja. Zaključeno je da su farmeri bili spremni da primene ovu tehnologiju umesto uklanjanja slame u rasutom stanju radi pripreme parcela za setvu sledećeg sezonskog useva i spaljivanja slame na parceli. Ekonomska analiza je otkrila da su ukupni fiksni troškovi baliranja Rs. 15.04 lac i ukupni varijabilni troškovi Rs.4.17 lac. Ukupna količina pokupljene slame tokom 45 dana iznosila je 973 tone. Analiza odnosa troškova ove tehnologije pokazala je vrednost 1.77 što pokazuje ekonomsku održivost.

Ključne reči: *baler, ekonomičnost, žetva, grablje, ušteda, tehnologija*

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MACHINE VISION BASED CLASSIFICATION OF RICE (*Oryza sativa l.)* CULTIVARS USING MORPHOLOGICAL, CHROMATIC AND TEXTURAL FEATURES OF SEED IMAGES

V. Bhushana Babu[*], Madhvi Tiwari, Nachiket Kotwaliwale, Karan Singh, Rajendra Hamad

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Abstract: Variety identification is an important task for plant breeders, farmers and traders. DUS (Distinctness, Uniformity, Stability) protocol is generally carried out for identification of plant variety which is time consuming and laborious. An attempt was made to quantify 28 rice varieties based on seed images by digital image analysis. Rice seed images were captured using Canon-LiDE110 flatbed scanner at 600 dpi resolutions. An algorithm was developed using Matlab 2012B to capture and extract seven morphological, 18 textural features and seven chromatic features. Discriminant analysis was carried out to identify critical parameters and classified them into similar groups. The study identified 14 best features out of 32 features that has capability to discriminate between rice cultivars. Eccentricity, awn length, major axis, equivalent diameter, kernel area, kernel perimeter and minor axis were found to be most critical among morphological features while standard deviation (STD) and Energy were found to be most critical among textural features while Hue, Red and Green were found to be most critical among chromatic features. Thus the present study indicated that morphological, chromatic as well as textural features play a vital role in identification of new varieties and distinguishing them to classify into similar groups.

Key words*: color features, discriminant analysis, morphological features, rice seed image analysis, textural features*

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INTRODUCTION

Rice is the most important food crop in India. It plays a vital role in primary food source for millions of people in the country. A rich and wide range of genetic wealth of rice exists in India. Further in various surveys, it is estimated that around 50,000 rice cultivars are stillbeing grown in the country. The varietal identification is becoming a very difficult task for breeders, seed quality testing experts, farmers and traders as the number of new varieties released every year is increasing. Though crops are classified based on morphology, color and texture of various plant parts, identification and classification of varieties is difficult and complex task. Thus, identification of varieties based on morphological, chromatic and textural features is essential for improving the quality of seed production. According to the International Union for the Protection of New Varieties of Plants (UPOV), several characteristics are described for different crop varieties.

In DUS protocol, color and morphological features play a vital role in classification of cultivars. Morphological or chromatic or textural features alone may not be sufficient to identify new cultivars or help in classification of cultivars into similar groups. Thus machine vision plays a key role in using morphological, chromatic and textural features in combination to identification and classification of varieties instantly with more accuracy and at low cost by extracting more number of parameters that couldn't be visible by naked eye. The machine vision is a powerful tool of automation and they highlighted its potential for the inspection and evaluation of grain quality and food products [1]. Texture is the most efficient feature utilized in machine vision to distribute images into groups [2]. Several researchers have used flatbed scanner for classification of Indian wheat varieties using kernel and shape features. Vision system composed of two stereoscopic cameras and a matrix of laser diodes were used to distinguish fruits that grow in bunches [3].Color and textural features were used for distinguish among quality categories of potato chips [4]. Barley kernel images were used to evaluate cereal grain quality and perform grain classification [5]. Seed shape and seed color were extracted from digital flax seed images to categorize similar flax cultivars into clusters [6].Three grasses (wheat, ryegrass and brome grass) were classified using combination of texture, color and shape features [7]. Wheat grain kernels were classified using discriminant analysis to extract features and obtained 100 % accuracy [8]. Four paddy varieties were classified (Karjat-6, Ratnagiri-2, Ratnagiri-4 and Ratnagiri-24) using texture, shape and texture-shape features and found that 82.61%, 88% and 87.27% accuracy [9]. Engineering properties of rice namely, size, shape, thousand grains mass, aspect ratio, surface area, volume, bulk density, true density and porosity were also used for development of storage bin studies [10].Therefore, the present study is carried out to identify best morphological, chromatic and textural features of seeds that critically contribute to classification of rice cultivars. Discriminant analysis was carried out to identify critical parameters and classified them into similar groups.

MATERIAL AND METHODS

Twenty eight rice varieties (Tab. 1) were grown at ICAR-Central Institute of Agricultural Engineering, Bhopal in RBD experimental layout to ensure authenticity of the varieties. After harvesting, rice seeds were threshed manually. Seed samples were obtained after harvesting which were used as input for image analysis.

Table 1. Varieties of rice (Oryza Sativa L.) cultivars

S. No.	Variety	Code	S. No.	Variety	Code
1	Basmati 370	B370	15	PR 113	P113
2	CSR 27	CS27	16	Pusa Basmati 1	PBT1
3	Improved PB1	IPB1	17	Pusa Basmati 6	PBT6
4	Jaya	JAYA	18	PusaSugandh 2	PS02
5	Jyothi	JYTH	19	PusaSugandh 3	PS03
6	Kasturi	KSTR	20	PusaSugandh 4	PS04
7	Kranthi	KRNT	21	PusaSugandh 5	PS05
8	Makom	MKOM	22	Ravi	RAVI
9	MandyaVijaya	MDVJ	23	Tulasi	TLSI
10	NDR 359	ND59	24	Vasumati	VSMT
11	Pant Dhan 11	PD11	25	Vijetha	VJTH
12	Pant Dhan 12	PD12	26	Vikash	VKSH
13	Pant Dhan 4	PD04	27	Vikarmarya	VKMY
14	Phalguna	PHGN	28	VL Dhan 81	VL81

Image Acquisition. A flatbed scanner (LiDe110 Canon Make) with Canon solution menu GUI- based software was used for image acquisition. Seeds of each variety were scanned at 600 dpi resolutions. The images were stored in JPEG format for further analysis. All images were analyzed by Matlab 2012 B software. Seven morphological, seven chromatic and 18 textural features were extracted from segmented images. The flowchart of image acquisition and features analysis algorithm sequence for classification of rice cultivars were shown in Fig. 1.

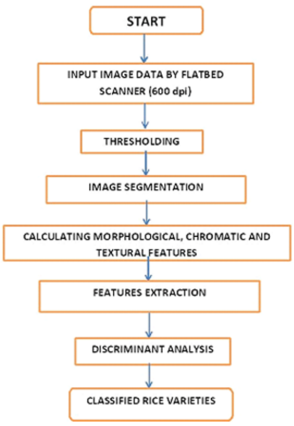

Figure 1. Flow diagram of image acquisition and procedure for classification of rice cultivars

Extraction Morphological features. Morphological features play a vital role in image segmentation. These features were extracted by developing an algorithm to generate values corresponding to awn length, kernel area, kernel perimeter, major axis, minor axis, eccentricity and equivalent diameter.

ExtractionChromatic features. Chromatic features were extracted to generate values corresponding to red, green, blue, saturation, hue, huestd and saturation. Hue, saturation and value of an object is classified into red, blue, and green. Saturation refers to how much of the light is concentrated on its wavelength and is independent of intensity and value represents the brightness of a reflecting object.

ExtractionTextural features. Textural features are the most significant feature for distinguishing among images. The values of contrast, correlation, energy and homogeneity were extracted using grey level co-occurrence matrix (GLCM). Short run emphasis (SRE), long run emphasis (LRE), grey level non uniformity (GLN), run percentage (RP), run length non uniformity (RLN), low grey level run emphasis(LGRE), high grey level run emphasis (HGRE) were extracted and defined as:

$$Contrast = \sum_{i,j} |i-j|^2 \, p(i,j) \tag{1}$$

$$Correlation = \sum_{i,j} \left[(i-\mu_i)(j-\mu_j)p(i,j)/\sigma_i\sigma_j\right] \tag{2}$$

$$Energy = \sum_{i,j} p(i,j)^2 \tag{3}$$

$$Homogeheity = \sum_{i,j} [p(i,j)^2/(1+|i-j|)] \tag{4}$$

Where μ_i,μ_j,σ_i and σ_j are the mean and standard deviation of p_i and p_j.

$$ShortRunEmphasis(SRE) = \frac{1}{n_r}\sum_{j=1}^{N}\frac{p_r(\mathrm{j})}{j^2} \tag{5}$$

$$Long\ Run\ Emphasis(LRE) = \frac{1}{n_r}\sum_{j=1}^{N} p_r(\mathrm{j}).j^2 \tag{6}$$

$$Gray-Lavel\ Nonunifomity(GLN) = \frac{1}{n_r}\sum_{i=1}^{M} p_g(\mathrm{i})^2 \tag{7}$$

$$Run\ Percentage(RP) = \frac{\mathrm{n_r}}{n_p} \tag{8}$$

$$Run\ Length\ Non-uniformity\ (RLN) = \frac{1}{n_r}\sum_{j=1}^{N}\left(\sum_{i=1}^{M} p(i,j)\right)^2 \tag{9}$$

$$Low\ Gray-levelRunEmphasis(LGRE) = \frac{1}{n_r}\sum_{i=1}^{M}\frac{p_g(\mathrm{i})}{i^2} \tag{10}$$

$$High\ Gray-levelRunEmphasis(HGRE) = \frac{1}{n_r}\sum_{i=1}^{M} p_r(\mathrm{j}).i^2 \tag{11}$$

where $p_{(i,j)}$ is a run length metric, i is pixel of grey level and run length j, n_r and n_p are total numbers of runs and total numbers of pixels in the image respectively.

Statistical analysis. Discriminant analysis was carried out using SAS STEPDISC procedure to reduce the number of variables. The procedure evaluated the seven morphological features, seven chromatic and 18 textural features using the stepwise test procedure for entering and removing variables from the model. The stepwise procedure begins with no entries in the model. At each step of the process, if the variable within the model, which contributes least to the models determined by the Wilk's lambda method, does not pass the test to stay, it is removed from the model. The variable outside the model which contributes most to the model and passes the test to be admitted is added. When no more steps can be taken the model is reduced to its final form.

Five reduced models were created using STEPDISC on various combination of the morphological, chromatic and textural features of seeds. The training data set consisted of 28 classes with 20 replications per class. Each of the unreduced models used different combination of the original 20 features per image. The unreduced variables consisted of seven morphological, seven chromatic and 18 textural features. The aim of the model was to minimize the computational requirement, while maintaining high classification accuracy of varieties based on these properties.

The SAS DISCRIM procedure evaluated the ability of the four models to determine classification capabilities between the rice cultivars. Four models were used from the previous STEPDISC variables reduction study, and a fifth model was added which was an unreduced model containing all 32 features. The discriminant function is established using a measure of the generalized squared distance between a specific test image texture variable input set and the class texture variable means, with an additional criteria being the posterior probability of the classification groups (SAS 9.3 version). Each test observation is placed in the class for which it has the smallest generalized square distance between the test observation and the selected class, or the largest posterior probability of being in the selected class. The DISCRIM procedure utilized a likelihood ratio test for homogeneity of the within-group covariance matrices, at 0.1 test significance level. A training data set consisting of 28 varieties and 32 properties replicated 20 times were used in analysis and a random test data set consisting of few classes with 20 replications per class were created for each of the STEPDISC reduced model described above. The training set was used to train DISCRIM function for classification of rice cultivars and the test data set was used to evaluate different model's classification accuracy.

RESULTS AND DISCUSSION

The data from the cultivars were collected and analysed. The replicated data of morphological, chromatic and texture features of all the cultivars were divided into training and test data sets. These features provided the data to generate five models viz. model1, 2, 3, 4 and 5.Stepwise discriminant analysis was carried out that selects a subset of the quantitative variables for use in discriminating among the classes.

Morphological features. The results indicated that all the seven morphological features having discriminatory power used in the classification are shown in Tab. 2. The probability of F value indicates all the parameters are significant at 1% level of significance. None of the features were dropped in the model. The partial R square indicates the amount of variation caused by each parameter indicating the level of discriminatory power. i.e. eccentricity (0.806), awn length (0.619), major axis (0.439) and equivalent diameter (0.447) have more discriminatory power than minor axis (0.161) which had the least partial R square value.

Table 2. Summary of morphological features

Code	*Features*	*Partial R-Square*	*Pr> F*	*Wilks' Lambda*	*Pr<Lambda*	*Average Squared Canonical Correlation*	*Pr> ASCC*
M6	*Eccentricity*	*0.806*	*<.0001*	*0.194*	*<.0001*	*0.03*	*<.0001*
M1	*Awn length*	*0.619*	*<.0001*	*0.074*	*<.0001*	*0.05*	*<.0001*
M4	*Major axis*	*0.439*	*<.0001*	*0.041*	*<.0001*	*0.07*	*<.0001*
M7	*Equivalent diameter*	*0.447*	*<.0001*	*0.023*	*<.0001*	*0.08*	*<.0001*
M2	*Kernel area*	*0.223*	*<.0001*	*0.010*	*<.0001*	*0.10*	*<.0001*
M3	*Kernel perimeter*	*0.197*	*<.0001*	*0.006*	*<.0001*	*0.11*	*<.0001*
M5	*Minor axis*	*0.161*	*<.0001*	*0.003*	*<.0001*	*0.13*	*<.0001*

Chromatic features. The output of the chromatic properties indicated that all the seven chromatic features are having discriminatory power to classify rice cultivars (Table3).The probability of F value indicated that all the features are significant at 1% level of significance (<0.01) except Hue std value which was found to be non-significant, therefore, it was dropped. The partial R square values of Blue (0.450), Red (0.190) and Green (0.281) were found to be having more discriminatory power than Hue (0.063) which had the least partial R square value. The value of Wilk's Lambda (close to zero) indicates that the two groups are well separated. Wilk's Lambda indicated that all the parameters were significant inferring that all the cultivars were well separated for parameter under study.

Table 3. Summary of chromatic features

Code	*Features*	*Partial R-Square*	*Pr> F*	*Wilks' Lambda*	*Pr<Lambda*	*Average Squared Canonical Correlation*	*Pr> ASCC*
C3	*Blue*	*0.450*	*<.0001*	*0.550*	*<.0001*	*0.02*	*<.0001*
C1	*Red*	*0.190*	*<.0001*	*0.446*	*<.0001*	*0.02*	*<.0001*
C2	*Green*	*0.281*	*<.0001*	*0.321*	*<.0001*	*0.03*	*<.0001*
C5	*Saturation*	*0.156*	*<.0001*	*0.271*	*<.0001*	*0.04*	*<.0001*
C7	*Hue Std*	*0.078*	*0.065*	*0.249*	*<.0001*	*0.04*	*<.0001*
C4	*Hue*	*0.063*	*<.0001*	*0.234*	*<.0001*	*0.04*	*<.0001*

Textural features. The analysis indicated that as shown in Table 4, all the eighteen textural features were significant at 1% level of significance (<0.01). The partial R square indicates that Offset0 (0.625), Offset90 (0.468), Entropy (0.295), GLN (0.249), LRE (0.189) and Contrast (0.161) have more discriminatory power than Homogeneity (0.047) which had the least partial R square value. This showed that all the varieties are well separated for the parameters under study.

Table 4. Summary of textural features

Code	*Features*	*Partial R-Square*	*Pr> F*	*Wilks' Lambda*	*Pr<Lambda*	*Average Squared Canonical Correlation*	*Pr> ASCC*
T8	*Offset0*	*0.625*	*<.0001*	*0.375*	*<.0001*	*0.03*	*<.0001*
T10	*Offset90*	*0.468*	*<.0001*	*0.200*	*<.0001*	*0.03*	*<.0001*
T3	*Entropy*	*0.295*	*<.0001*	*0.141*	*<.0001*	*0.04*	*<.0001*
T14	*GLN*	*0.249*	*<.0001*	*0.106*	*<.0001*	*0.05*	*<.0001*
T13	*LRE*	*0.189*	*<.0001*	*0.086*	*<.0001*	*0.06*	*<.0001*
T5	*Contrast*	*0.161*	*<.0001*	*0.072*	*<.0001*	*0.06*	*<.0001*
T4	*Correlation*	*0.120*	*<.0001*	*0.063*	*<.0001*	*0.05*	*<.0001*
T9	*Offset45*	*0.112*	*0.0013*	*0.056*	*<.0001*	*0.07*	*<.0001*
T2	*STD*	*0.089*	*<.0001*	*0.512*	*<.0001*	*0.07*	*<.0001*
T1	*Range*	*0.163*	*<.0001*	*0.043*	*<.0001*	*0.08*	*<.0001*
T11	*Offset135*	*0.096*	*0.0001*	*0.039*	*<.0001*	*0.08*	*<.0001*
T18	*HGRE*	*0.090*	*<.0001*	*0.035*	*<.0001*	*0.08*	*<.0001*
T16	*RLN*	*0.107*	*<.0001*	*0.032*	*<.0001*	*0.09*	*<.0001*
T12	*SRE*	*0.096*	*0.0024*	*0.028*	*<.0001*	*0.09*	*<.0001*
T17	*LGRE*	*0.068*	*0.0537*	*0.027*	*<.0001*	*0.09*	*<.0001*
T15	*RP*	*0.065*	*<.0001*	*0.025*	*<.0001*	*0.09*	*<.0001*
T6	*Energy*	*0.065*	*<.0001*	*0.023*	*<.0001*	*0.09*	*<.0001*
T7	*Homogeneity*	*0.047*	*0.0066*	*0.022*	*<.0001*	*0.10*	*<.0001*

Five statistical models were analysed using the SAS STEPDISC procedure to determine a reduced variable set with the greatest discriminant power. The STEPDISC results for each model are shown in Tab. 5. The number of variables in the original model is dependent upon the properties considered. For instance, model1 had 32 variables in the original model. The STEPDISC selected variables are listed in the order in which they were added to the model, and are therefore, listed from the highest to the lowest significance based on partial R square. In the case of model 2, the number of textural properties selected to classify the varieties were reduced from the original 18 properties to eight properties. All the variable names are coded using a single letter and a numeric extension. Table 5 describes the interpretation of these statistics. Almost the all variables were found to be significant except value and entropy were found to be non-significant therefore, they were dropped from the model 1 for discrimination. However, based on the partial R-square value (> 0.10), the variables were arranged in the order of importance as shown below.

The training data set for each model was presented to SAS DISCRIM to train the data and then the test data set for the corresponding model was evaluated using

DISCRIM classification test. The procedure was repeated for all the five models. The results presented in Table 6 illustrate the classification accuracy of the models. Model 5 had an average classification accuracy of 80%, model 2 had shown the poorest average classification accuracy of 0 percent indicating that classification based only on textural properties has poor classification ability. The results indicated that model 5 with 14 parameters had shown better classification accuracy with 80% while model 1 with 31 parameters had shown classification accuracy of 40%, model 3 and 4 had shown an accuracy of 20% each. The models which used only one set of parameters showed a loss of classification accuracy as might be expected. This demonstrates the superior discrimination capability of mixture of parameters to either morphological or chromatic or textural features alone.

Table-5Identified best features using Discriminant analysis by STEPDISC procedure

Model	*Features*	*STEPDISC reduced variable list*
1	*All features*	*M6, M1, M4, M7, C3, M2, T2, M3, C4, C1, T1, M5, T6, C2, C5, T8, T3, T4, T10, T16, T5, T15, T14, T17, T13, T9, T11, T12, T7, T17, C7.*
2	*Texture*	*T8, T10, T3, T14, T13, T5, T4, T9, T2, T1, T11, T18, T16, T12, T17, T15, T6, T7.*
3	*Chromatic*	*C3, C1, C2, C5, C7, C4.*
4	*Morphological*	*M6, M1, M4, M7, M2, M3, M5.*
5	*Best features*	*M6, M1, M4, M7, C3, M2, T2, M3, C4, C1, T1, M5, T6, C2.*

Table 6 PROC DISCRIM classification accuracy in percentage

Model	*Features*	*Classification Accuracy percentage*
1	*All features*	*40*
2	*Texture*	*0*
3	*Chromatic*	*20*
4	*Morphological*	*20*
5	*Best features*	*80*

CONCLUSIONS

A set of 1109 data from 28 rice cultivars based on seed images were analysed. Rice seed images were captured using flatbed scanner at 600 dpi resolutions. An algorithm was developed using Matlab2012B to capture and extract seven morphological features, 18 textural features and seven chromatic features. Discriminant analysis were carried out to identify critical parameters and classified them into similar groups. It was found that mixture of parameters classifier was capable of classifying rice varieties with high degree of accuracy (80 %) compared to only one set of parameters i.e. either morphological or chromatic or texture alone. The use of SAS procedure STEPDISC proved beneficial for reducing the number of variables in the data models. Model 1 was reduced from 32 to 14 while all the other models were unreduced. It can be concluded eccentricity, awn length, major axis, equivalent diameter, blueness, kernel area, STD, kernel perimeter, hue, red color, range, minor axis, energy and green color in this order are the major factor that contribute to discrimination. Also morphological features along with chromatic and textural features will improve the classification accuracy.

BIBLIOGRAPHY

[1] Patel, K.K., Kar, A., Jha, S.N., Khan, M.A. 2012. Machine vision system: a tool for quality inspection of food and agricultural products. *Journal Food Science Technology* 49(2): 123-141.

[2] Selvarajah, S., Kodituwakku, S.R. 2011.Analysis and Comparison of Texture Features for Content Based Image Retrieval. *International Journal of Latest Trends in Computing* 2:108-113.

[3] Tarrio, P., Bernardos, A., Casar, J., Portillo, J. 2006. A Vision System to Efficiently HarvestFruits Which Grow in Clusters. Agricultural Engineering (Serbia), 2006 (3), 43-48.

[4] Mendoza, F., Dejmek, P., Aguilera, J.M. 2007. Colour and image texture analysis in classification of commercial potato chips. *Food Research International*40: 1146–1154.

[5] Szczypinski, P.M., Zapotoczny, P. 2012. Computer vision algorithm for barley kernel identification, orientation estimation and surface structure assessment. *Computers and Electronics in Agriculture* 87: 32–38.

[6] Wiesnerova, D.W., Wiesner, I. 2008. Computer image analysis of seed shape and seed color for flax cultivar description. *Computers and Electronics in Agriculture* 61:126–135.

[7] Golzarian, M.R., Frick, R.A. 2011.Classification of images of wheat, ryegrass and brome grass species at early growth stages using principal component analysis. *Plant Methods*7 (28): 2-11.

[8] Choudhary, R., Paliwal, J., Jayas, D.S. 2008. Classification of cereals grains using wavelet, morphological, colour, and textural features of non-touching kernel image. *BiosystemEngineering*99: 330-337.

[9] Chaugle, A., Mali, S.N. 2014. Evaluation of texture and shape features for classification of four paddy varieties.*Journal of Agricultural Engineering,* 1-8.

[10] Ravi, P., Venkatachalam,T., Mohan, S. 2015. Engineering Properties of Rice. Agricultural Engineering (Serbia), 2015 (3), 69-78.

MAŠINSKA VIZUELNA KLASIFIKACIJA SORTI PIRINČA (*Oryza sativa l.)* UPOTREBOM MORFOLOŠKIH, HROMATSKIH I TEKSTURALNIH OSOBINA SLIKA SEMENA

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Sažetak: Identifikacija vrste je važna za odgajivače, farmere i trgovce. DUS (Rastojanja, Ujednačenost, Stabilnost) protokol je generalno izveden za identifikaciju biljne vrste koja zahteva mnogo vremena i rada. Pokušali smo da kvantifikujemo 28 sorti pirinča na osnovu slika semena digitalnom analizom slike. Semena pirinča su snimljena skenerom Canon-LiDE110 u rezoluciji 600 dpi. Razvijen je algoritam upotrebom Matlab 2012B za hvatanje i izvođenje 7 morfoloških, 18 teksturalnih i 7 hromatskih osobina. Diskriminaciona analiza je izvedena radi identifikacije kritičnih parametara i njihove klasifikacije u slične grupe. Studija je identifikovala 14 najboljih od 32 osobine koje imaju mogućnost razlikovanja sorti pirinča. Ekscentričnost, dužina pleve, glavna osa, ekvivalentni prečnik, površina zrna, obim zrna i mala osa su definisane kao kritične među morfološkim osobinama dok su standardna devijacija i energija izdvojene kao najkritičnije među osobinama teksture. Crvena i zelena boja su bile najkritičnije među hromatskim osobinama. Tako je ova studija pokazala da morfološke, hromatske i osobine teksture igraju odlučujuću ulogu u identifikaciji novih sorti i mkihovog razlikovanja radi klasifikacije u slične grupe.

Ključne reči: *boja, diskriminaciona analiza, morfološke osobine, analiza slike semena, tekstura*

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A VISUAL BASIC PROGRAM FOR DESIGNING OF GEAR PAIR FOR FRONT POWER TAKE-OFF UNIT OF HIGHER HP TRACTORS

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Abstract: With a view to fully utilize the available power, reduce soil compaction and for timeliness of tillage operations, now-a-days, front three point linkages are used in higher power tractors. So, front power take-off (PTO) also desirable with front three point linkages to operate passive implements like rotavator, mower etc. With this requirement in view, a program was developed in visual basic for design of a front PTO gear pair of higher hp tractors. In this design, the drive was taken from engine crankshaft running at rated speed of 2200 rpm and was reduced to 1000 rpm using helical gear pair. For validation of developed Visual Basic program, contact stresses and bending stresses analysis of gear and pinion was done in KISS software. The maximum bending root stress on pinion and gear was 330 N/mm^2 and 300 N/mm^2 against limiting stress value of 430 N/mm^2 where contact stresses are 1000 N/mm^2 against limiting value of 1500 N/mm^2 and therefore, designed gear pair was safe against bending and pitting. The output results of KISS software was used for validation of developed visual basic program. Developed program shows approximately the same results as in KISS software. Developed VB program is cheap, simple and can be used to design and for analysis of single gear pair.

Key words: *front power take-off, gear pair, bearings, contact stress, Visual Basic*

INTRODUCTION

The biggest challenge before the agricultural sector of India is to meet the growing demands of food for its increasing population from 1.22 billion in the year 2010 to 1.46 billion by the year 2030 [1]. This can be achieved by increasing cropping intensity and

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reducing turnaround time through increased mechanization. Tractors form an integral part of farm mechanization and have a crucial role to play in increasing agricultural productivity. As a result of different programmes implemented by the Government of India over the years, the total farm power availability is estimated to have been increased from 0.47 kW/ha in 1981-82 to 1.5 kW/ha in 2005-06 having a 46.75% contribution of tractor power [2]. India is the largest producer of tractors with 5.45 lakh of tractors in 2011 increased from 3.46 lakh in 2008 [3]. The tractor population of 41-60 hp segment has increased from 54,685 (22.8% of total number of tractors in a year) in 2000-2001 to 91,741 (31.5%) in 2005-2006. Usage of higher hp tractors (> 60 hp) has also increased from 265 tractors in 2000-2001 to 2068 in 2003-2004 [4]. To fully utilize the available power and for timeliness of tillage operations, now-a-days, front three point linkages are used in higher hp power tractors. Hence, there is need of front power take-off (PTO) drive with front three point linkages to operate passive implements like rotavator, mower etc. Therefore, a front PTO was designed which include the design of helical gear pair, selection of roller bearings and needle roller bearings, design of transmission shaft and gear as well as pinion shafts. PTO required the greatest amount of power among the major components during rotary tillage operations [3]. So, gear pair should design precisely to avoid breakage of PTO during operation.

So, by keeping the above facts in mind present study was undertaken with the objectives of designing the front PTO for higher power range tractors, analysis of bending and contact stresses of gear and pinion, development of a visual basic program and validate it with the results of KISS software.

MATERIAL AND METHODS

Front PTO design includes design of helical gear pair, selection of roller bearings, design of transmission shaft and gear as well as pinion shafts. To operate front PTO, the drive was taken from engine crankshaft in front side running at rated speed of 2200 rpm and was reduced to 1000 rpm using single gear pair. A visual basic program was developed in Visual Basic 6.0 for designing and selection of gears.

Design of gear pair: The gears are the central element in the transmission. Helical gear pair was designed as helical gears have more bending strength than spur gears. Front PTO output speed should be 1000 rpm at rated speed in anticlockwise direction as seen from front side [5]. Therefore, the gear reduction required will be the ratio of rated rpm to the 1000 rpm.

Geometry of gear: Geometry of any gear basically contains the module, pressure angle, face width, helix angle for helical gear, addendum, circular pitch diameter, root circle diameter, axial pitch, tooth height etc. Two standard pressure angles used in gear design are 14.5° and 20°.

Calculation of safety factor against bending: Failure by bending will occur when the tooth bending stress equals or exceed the yield strength [4]. The actual tooth root stress σ_F and the permissible (tooth root) bending stress σ_{FP} should be calculated separately for pinion and gear. Tooth root stress σ_F is the maximum tensile stress at the surface in the root, so it should be less than σ_{FP}. The ratio of σ_{FP} to σ_F is called safety factor against bending.

Calculation of safety factor against pitting: The calculation of surface durability is based on the contact stress, σ_H, at the pitch point or at the inner point of single pair tooth contact. The higher of the two values obtained is used to determine the load capacity. σ_H and the permissible contact stress, σ_{HP}, shall be calculated separately for wheel and pinion. σ_H shall be less than σ_{HP}. This comparison will be expressed in safety factors S_H which is the ratio of permissible contact stress, σ_{HP} and contact stress, σ_H. Fig. 1 shows the Pro-e model of designed front PTO drive.

Development of program in Visual Basic: The rapid progress in developing new software and programming languages always tend to facilitate the interaction between users and computers. As a result, many computer modeling and simulation programs have been developed. Recently, a computer program is developed in Visual Basic environment to determine the all types of machinery costs in hour and hectare basis [5]. Presently Visual Basic and Visual C++ are widely used to develop such software. In this paper, a program was developed for designing gear pair which gives the complete geometry of gear and pinion, analysis of the gear and pinion against the bending and contact stresses. This program was developed by using empirical equations of gear parameters given in ISO 6336-1, ISO 6336-2, ISO 6336-3, ISO 6336-5, ISO 6336-6 and written in Visual Basic programming language. Fig. 2 shows the flowchart used to design the program.

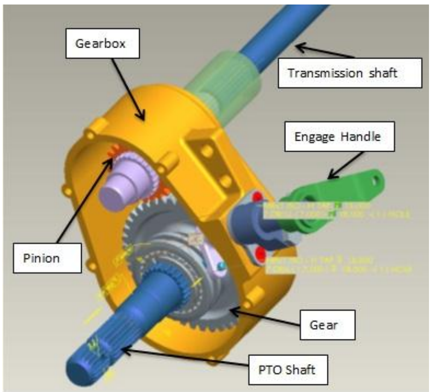

Figure 1. Pro-e model of front PTO

The program starts with an opening screen as shown in Fig. 3 which consist input parameters like power to be transmitted through gear pair, input and output speed, module, pressure angle and helix angle. Output parameters box consists center distance, number of computed teeth of gear and pinion. In choose teeth box, user should choose the integer number of teeth on the basis of computed number of teeth of gear and pinion. On the basis of chose teeth, VB program compute the center distance and computed gear ratio. User required to filled standard center distance while referring computed center distance.

Second screen as shown in Fig. 4 is opened which consists of gear and pinion geometry parameters like base circle diameter, pitch circle diameter, addendum, dedendum, base pitch etc. Third screen as shown in Fig. 5 used to select the material properties of gears. Using drop down menu, user can choose material type like normalized low carbon steel, through hardened wrought steel etc. Similarly, user can also choose reference profile of tooth for gear using drop down menu. Main output parameters on this screen will be nominal stress number, σ_{Flim} and allowable stress number σ_{Hlim} in N/mm^2. Fourth screen as shown in Fig. 6 consist of input box in which user have to fill required service life, application factor and life factor. On clicking on load cycle pushbutton, number of load cycles (in millions) will be calculated by VB program. The major output of this screen will be tooth root stress and tooth root safety factor against bending.

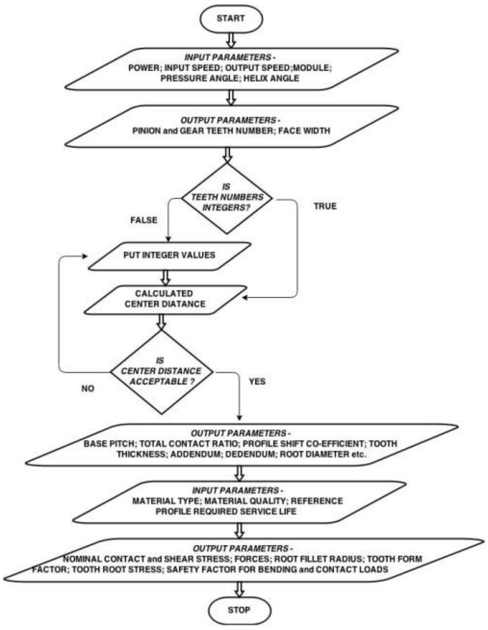

Figure 2. Flow chart for gear design in Visual Basic

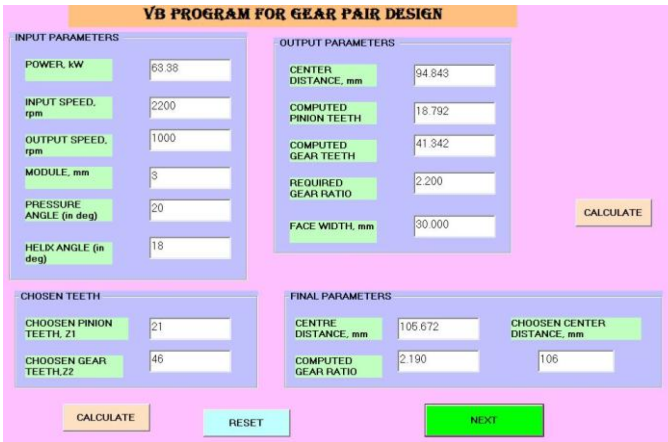

Figure 3. Input screen of VB program

Figure 4. Geometry of gear and pinion in software

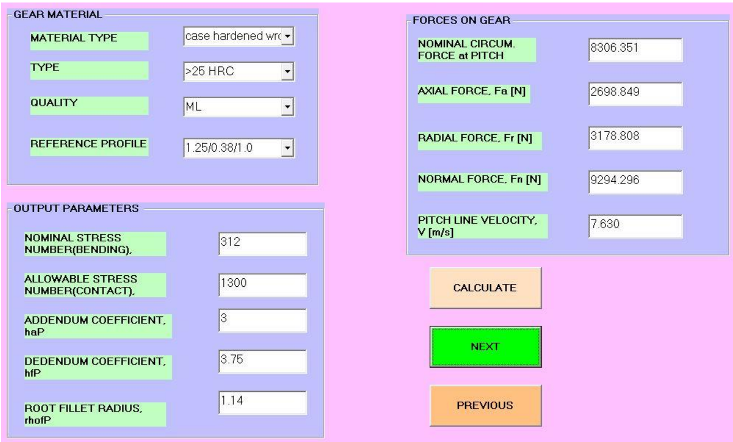

Figure 5. Mechanical properties and forces on gear pairs

Figure 6. Screen showing tooth root stress and other factors

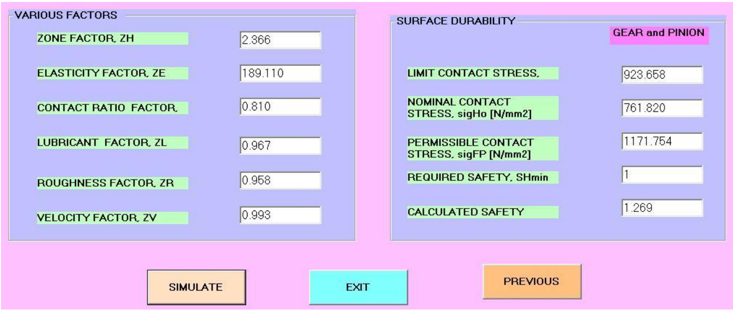

Figure 7. Screen showing contact stresses and other factors

Fifth screen as shown in Fig. 7 shows the nominal contact stress, σ_{Ho}, permissible contact stress, σ_{FP} and safety factor of gear and pinion against pitting. The minimum required safety factor against bending is 1.4 while for pitting it is 1. Value of safety factor against bending is more than safety factor for pitting because tooth breakage usually ends the service life of a transmission. Sometimes, the destruction of gear transmission can be a consequence of the breakage of one tooth. Therefore, the chosen value of safety factor against tooth breakage should be larger than the safety factor against pitting.

RESULTS AND DISCUSSION

Front PTO gear pair was designed and strength analysis was done in KISS software. Fig. 8 shows the tooth root stress on pinion which causes breakage of tooth and Fig. 9 shows the contact stress on gear which causes the pitting of tooth.

Fig. 10 and Fig. 11 show the tooth root stress on pinion and gear graphically. In this x-axis represent the middle axis of tooth and y-axis represent tooth root stress. As distance increased from middle of tooth to the side of tooth, tooth root stress increases. Initially, it increases slowly but as approaches to root of tooth it increases rapidly because at root thickness of tooth is less. For pinion, tooth root stress value reaches to 315 N/mm^2 while for gear its value is 300 N/mm^2. 3-D view of tooth root stress on pinion and gear are shown in Fig. 12 and Fig. 13. Root diameter is represented along x-axis, y-axis represent tooth root stress while z-axis represents width of tooth. In Fig. 12, up to root diameter 62 mm, there is no stress, so represented by blue color. Below 62 mm diameter, it starts increases and attains maximum value of 315 N/mm^2 at 59 mm diameter which is represented by red color. In Fig. 13, up to diameter 140 mm, there is no stress but at 138 mm diameter it reaches 300 N/mm^2. Fig. 14 shows the 3-D view of contact stresses on tooth of gear. At periphery of tooth, the contact stresses are nearly zero while at middle of face width contact stresses are higher which value is 1000 N/mm^2 and represented by red color. The results based on the graph and 3-D views presented in Figs. 11 - 15 are given in Table 1. The bending strength factor for gear is 1.955 and 1.876 for pinion. The contact stress factor for gear and pinion is 1.269. The minimum required value for bending strength factor and contact stress factor are 1.4 and 1 respectively. Hence, gear pair is safe against bending and pitting stresses.

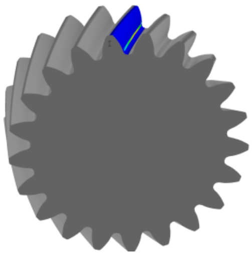

Figure 8. Tooth root stress on pinion

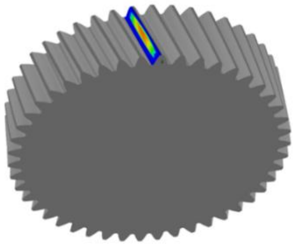

Figure 9. Contact stress on gear

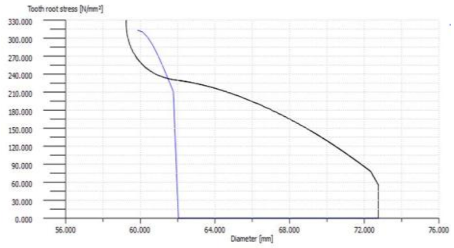

Figure 10. Graphical representation of tooth root stress on pinion

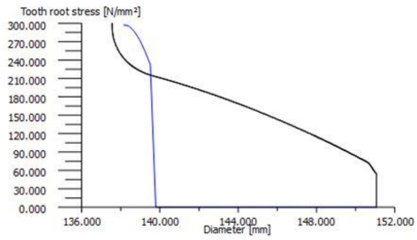

Figure 11. Graphical representation of tooth root stress on gear

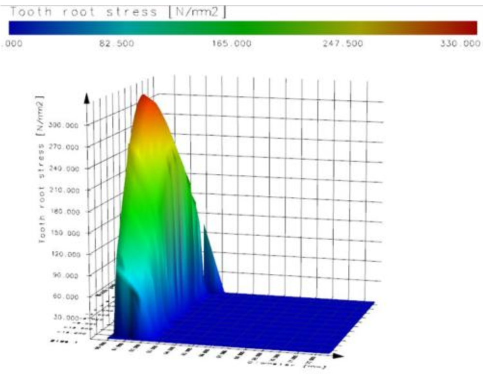

Figure 12. 3-D view of tooth root stress on pinion

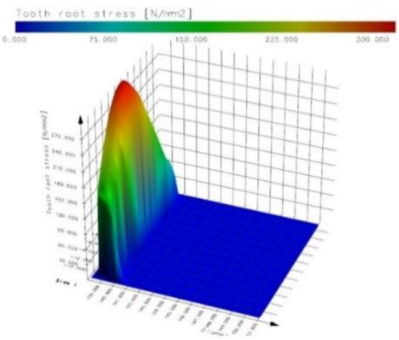

Figure 13. 3-D view of tooth root stress on gear

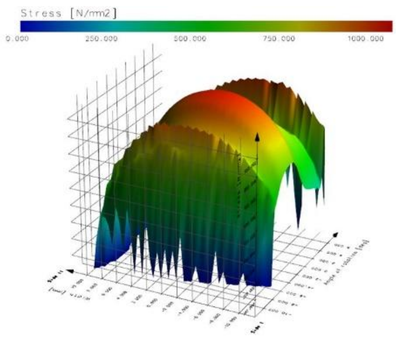

Figure 14. 3-D view of contact stress on gear

Table1. Results of stress analysis of gear and pinion

Parameter	*Maximum stress (N/mm^2)*	*Permissible stress value (N/mm^2)*	*Bending strength factor*	*Contact stress factor*	*Remarks*
Root stress on pinion	*310.522*	*582.53*	*1.876*	*NA*	*Safe against bending*
Root stress on gear	*324.010*	*633.29*	*1.955*	*NA*	*Safe against bending*
Contact stress	*923.658*	*1171.75*	*NA*	*1.269*	*Safe against pitting*

Table 2. Validation of gear design Visual Basic program for front PTO drive

Parameters	*KISS Software values*		*VB program values*	
	Pinion	*Gear*	*Pinion*	*Gear*
Dedendum, mm	*3.45*	*3.71*	*3.481*	*3.688*
Addendum, mm	*3.3*	*3.041*	*3.269*	*3.062*
Root diameter, mm	*59.342*	*137.665*	*59.281*	*137.726*
Tip diameter, mm	*72.842*	*151.165*	*72.781*	*151.226*
Tooth thickness, mm	*4.92*	*4.81*	*4.908*	*4.758*
Working angle (°)	*20.07*	*20.19*	*19.048*	*19.868*
Bending lever arm, mm	*3.01*	*3.18*	*2.837*	*3.088*
Tooth root stress, $N\ mm^{-2}$	*324.43*	*332.19*	*310.522*	*324.010*
Pressure angle at pitch circle (°)	*20.942*		*20.942*	
Base helix angle (°)	*16.881*		*16.881*	
Center distance, mm	*105.672*		*105.672*	
Axial pitch, mm	*30.499*		*30.5*	
Overlap ratio	*0.971*		*0.984*	

Table 3 - Difference between VB program and KISS software values

Parameters	*Pinion*	*Gear*
Dedendum, mm	*-0.031*	*0.022*
Addendum, mm	*0.031*	*-0.021*
Root diameter, mm	*0.061*	*-0.061*
Tip diameter, mm	*0.061*	*-0.061*
Tooth thickness, mm	*0.012*	*0.052*
Working angle (°)	*1.652°*	*0.322°*
Bending lever arm, mm	*0.173*	*0.092*
Tooth root stress, $N\ mm^{-2}$	*13.908*	*8.18*

To validate the developed Visual Basic program, the output parameters of VB program were compared with the KISS software output values. As shown in Tab. 2 the parameters which computed using VB program and necessary for manufacturing a gear pair, are not much differ from the results obtained from KISS software. Some parameters like pressure angle at pitch circle, base helix angle, center distance etc. are perfectly same and in other parameters like dedendum, addendum, tooth root stress etc. an insignificant difference is present between VB program and KISS software results as shown in Tab. 3. There is a slightly difference because in designed VB program the values of trigonometric functions like tanβ etc. and other constant values like pi (π) are taken up to three decimal places only and output of one equation was the input of next equation, so the error was cumulative in nature.

CONCLUSIONS

A computer based user-friendly simulation program for designing gear pair for front PTO developed in Visual Basic software. This program was validated with output values of KISS software. The program has been found to give very close prediction of various gear parameters. Contact stress and bending stress analysis of designed gears was done and the designed pair was found safe against contact stresses and bending stresses. The calculated life of bearings using KISS software is found greater than the required service life. The advantage of developed VB program over KISS software is that KISS software is very costly and complicated one where developed VB program is cheap, simple and can be alternative of KISS software for designing and do analysis of single gear pair.

BIBLIOGRAPHY

[1] Anonymous. 2013. *Demographic overview-India, International database*, United States Census Bureau, http://www.census.gov. (Last accessed on August 17, 2016).

[2] Bector V., Singh S., Sharda A., Bansal A. 2008. Status and recent trends of tractor power in Indian agriculture, *Agri. Engg. Today* 32(1), 16-26.

[3] Lee, D., Kim, Y., Chung, S., Choi, C., Lee, K., Shin, B. 2015. Analysis of the PTO load of a 75 kW agricultural tractor during rotary tillage and baller operation in Korean upland fields. *Journal of Terramechanics*, 60, 75-83.

[4] Kamandar, M.R. 2011. The selection, designing and analysis of heavy duty tractor gearox, *Applied Mechanics and Materials*, 110, 2948-2957.

[5] Pranav, P.K., Phukan, Y., Saha, B. 2016. Computer program for cost estimation of agricultural machines. *Scientific Journal Agricultural Engineering*, XL(1), 1-10.

VISUAL BASIC PROGRAM ZA KONSTRUISANJE ZUPČASTOG PRENOSNIKA PREDNJEG PRIKLJUČNOG VRATILA KOD TRAKTORA VEĆE SNAGE

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Sažetak: Kod traktora veće snage se danas koriste prednji hidraulični uređaji radi potpunog iskorišćenja raspoložive snage, smanjenja sabijanja zemljišta i rokova za obradu zemljišta. Tako je i prednje priključno vratilo potrebno sa podiznim uređajem, za pogon gonjenih priključaka kao što su freza, kosačica i sl. Imajući u vidu ovaj zahtev, razvijen je program u visual basic za konstrukciju zupčastog prenosnika prednjeg priključnog vratila kod traktora veće snage. U ovoj konstrukciji korišćen je pogon sa kolenastog vratila motora brzine 2200 min^{-1}, redukovane na 1000 min^{-1} spiralnim zupčastim parom. Za ocenu razvijenog programa i analizu kontaktknog opterećenja i opterećenja na savijanje zupčanika i vratila korišćen je KISS softver. Maksimalno opterećenje na savijanje vratila i zupčanika bilo je 330 N/mm^2 i 300 N/mm^2 u odnosu na graničnu vrednost od 430 N/mm^2, a kontaktno opterećenje 1000 N/mm^2 u odnosu na hgraničnu vrednost od 1500 N/mm^2, tako da je konstruisani zupčasti par bio bezbedan pri udaru i savijanju. Izlazni rezultati programa KISS su korišćeni za ocenu razvijenog visual basic programa. Razvijeni program je pokazao približno iste rezultate kao i program KISS. Razvijeni program je je jevtin, jednostavan i može da se upotrebi pri konstruisanju i analizi pojedinačnih zupčastih parova.

Ključne reči: *prednje vratilo, zupčasti par, ležajevi, kontaktno opterećenje, Visual Basic*

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Original scientific paper

COMPUTER PROGRAM FOR ENERGY REQUIREMENT OF SUGARCANE PRODUCTION

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Abstract: A user-friendly computer program is developed in Visual Basic environment to determine the energy requirement for sugarcane production and other related terms such as energy ratio, specific energy and output energy. Program is also capable to compute renewable / non-renewable and commercial / non-commercial source of energy. The input parameters of the developed program are mainly human (h), diesel (lit.), electricity (kWh), seed (kg), farm yard manure (kg), fertilizer (kg), chemical (kg), machinery (h), number of human labours and yield (kg/ha). The total energy is being calculated with the help of energy equivalents which are already fed in programme for sugarcane crop. The developed program successfully calculates the energy consumption in MJ/ha. The program could prove to be a useful tool for suggesting sugarcane growing farmers the future need of energy input by analysing season to season data.

Key words*: computer program, energy requirement, sugarcane*

INTRODUCTION

Agriculture is both a producer and consumer of energy. It uses large quantity of locally available non-commercial energy (seed, manure, animate energy etc.) as well as commercial energy (diesel, electricity, fertilizers, plant protection chemicals, machinery etc.) directly and indirectly, Efficient use of these energies help to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living [1].

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Sugarcane (*Saccharum officinarum*) is a widely grown crop in India having 5.03 million-hectare area under cultivation during the year 2013-14. It is an energy intensive crop requiring high input of natural resources especially fossil energy and irrigation water. Earlier studies showed that major energy inputs on farms were derived through farm machinery and equipment, use of petroleum products (directly as diesel or indirectly through fertilizers), tube well irrigation using electricity [2]. About 60% of the world's sugar is supplied from sugarcane production and the rest is produced from sugar beet [3].

To propagate sugarcane crop, stem cuttings (setts) are planted. The first crop, called plant cane, is harvested after 12-16 months. Ratooning is a method where the lower parts of the plants along with the roots are left uncut at the time of harvesting gives sprouting of ratoon. In ratoon crops, there is a saving in cost of cultivation in terms of land preparation, seed canes, etc. The first ratoon crop is harvested after 10-12 months and five to six ratoon crops are common [2].

Singh et al. [4] evaluated the energy requirements of rice, maize, wheat, groundnut, sugarcane, cotton and gram in Indian conditions. The study deals with energy consumption for production of these crops in different states of India. It also highlights the future energy needs to achieve desired yield levels and production targets. Finally, it was concluded that as the energy input increased, the production also increased. Several other studies on energy utilization, energy input–output analysis and their relationships, mostly concentrated on field crops, have been conducted on agricultural production.

Punjab is one of the most important agricultural production province in India. Different geographical and climatic characteristics increase the variety of crop patterns, and irrigated farms have an important economic value in the province. Sugarcane is one of the energy intensive crops of Punjab region. The main objective of the present research was to develop a computer program for calculating energy requirement, to investigate the energy use patterns and to analyze energy input–output in the production of sugarcane. Keeping these facts in mind, the present study helps in keeping record of energy requirement season by season which is easily calculated by the developed program.

MATERIAL AND METHODS

Theoretical consideration. All inputs were converted to energy units using the energy equivalents reported in Tab. 1. These coefficients were adapted from several literature sources that best fit in the Indian conditions.

Table 1. Energy equivalents of inputs in sugarcane production

required quantity in sugarcane production			
Input	*Units*	*MJ/unit*	*References*
Human	*hour*	*1.96*	[1]
Diesel	*litre*	*56.31*	[5]
Electricity	*kWh*	*11.93*	[5]
Seed	*kilogram*	*5.3*	[3]
Farmyard manure	*kilogram*	*60.6*	[7]
Chemical	*kilogram*	*20.9*	[6]

Machinery	*hour*	*68.4*	[6]

Energy sources grouped under different categories of energy in which direct energy include human, diesel, electricity, etc. and in indirect energy include seed, FYM, chemicals, machinery etc. Renewable source of energy is the energy source, which can be subsequently replenished and vice-versa for non-renewable energy source. The energy source which are available cheaply are called non-commercial source of energy whereas the others which are capital intensive are called commercial energy source.

$$Output\ Energy\ (MJ/ha) = Y \times E \tag{1}$$

where:
Y (kg) - Yield of sugarcane,
E (MJ/unit) - Energy equivalent of sugarcane,

$$Energy\ Ratio = OE\ /\ IE \tag{2}$$

where:
OE (kg) - Yield of sugarcane,
IE (MJ/ha) - Input energy,

$$Specific\ Energy\ (MJ/kg) = Y\ /\ TE \tag{3}$$

where:
Y (kg) - Yield of sugarcane,
TE (MJ/ha) - Total Energy or Input Energy,

$$Renewable\ energy\ (MJ/ha) = H + S + FYM \tag{4}$$
$$Non\text{-}renewable\ energy\ (MJ/ha) = D + E + F + C + M \tag{5}$$
$$Commercial\ energy\ (MJ/ha) = D + E + F + C + M + S \tag{6}$$
$$Non\text{-}commercial\ energy\ (MJ/ha) = H + FYM \tag{7}$$

where:
H (MJ/ha) - Energy from human labour,
S (MJ/ha) - Energy from sugarcane stem or seed,
FYM (MJ/ha) - Energy from farm yard manure,
D (MJ/ha) - Energy from diesel consume in sugarcane production,
E (MJ/ha) - Energy from electricity,
F (MJ/ha) - Energy from fertilizer,
C (MJ/ha) - Energy from chemical,
M (MJ/ha) - Energy from machinery like tractor etc.,

Input Parameters. The input parameters for the developed computer program are mainly divided in two parts, namely energy equivalents and required quantity in sugarcane production per hectare. The quantity in sugarcane production inputs include human (h), diesel (lit.), electricity (kWh), seed (kg), FYM (kg), fertilizer (kg), chemical (kg), machinery (h), number of human labours and yield (kg/ha). Beside the input group, the energy equivalents are displayed which was used in the program. The program window for input parameter is shown in Fig. 1. The input data as per parameters discussed was taken only for indication purpose. Sugarcane production system include operations like, seedbed preparation, planting, bund making, irrigation, weeding, fertilizer application, spraying, cutting and cleaning, transportation, post-harvest activities etc. For energy calculation i.e. source wise energy including direct and indirect energy, subtotal of energy (MJ/ha), total energy requirement (MJ/ha), output energy (MJ/ha), energy ratio and specific energy (MJ/ha), a separate output table is created which is shown in Fig. 2. The flow chart of the developed program is shown in the Fig. 3.

Figure 1. Program window for the input parameters

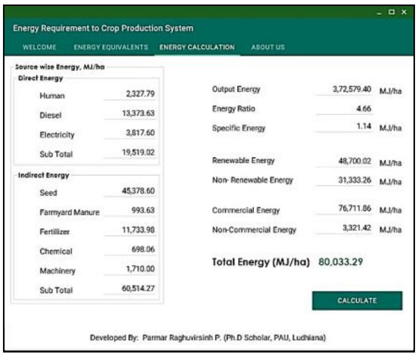

Figure 2. Program window for the output parameters

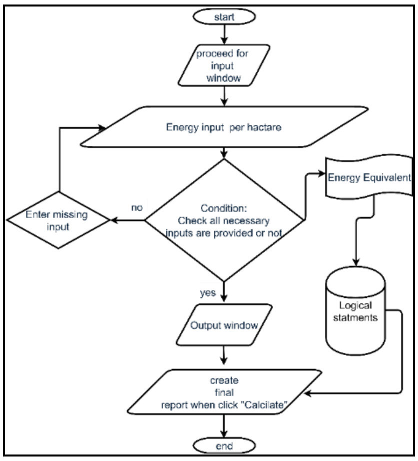

Figure 3. Flow chart of the developed program

RESULTS AND DISCUSSION

General Inputs of Software. Staring from the sugarcane season, input data is to be taken. In the present study, the indicative data per hectare is tabulated in Table 2.

General Outputs of Software. The software output for these runs is given in Table 3. Table indicates that the developed program is capable of calculating all components of energy requirement for sugarcane production.

Table 2. Input parameters

Quantity for sugarcane production(Indicative)	
Input	*Quantity per unit area (unit/ha)*
Human (h)	*237.53*
Diesel (L)	*237.50*
Electricity (kWh)	*320.00*
Seed (kg)	*8562.00*
Farmyard Manure (kg)	*3312.10*
Fertilizer (kg)	*193.63*
Chemical (kg)	*33.40*
Machinery (h)	*25.00*
Number of human labor	*5.00*
Yield(kg/ha)	*70298*

Table 3. Output results as calculated by software

Source wise energy, MJ/ha	
Direct Energy	
Human	*2327.79*
Diesel	*13373.63*
Electricity	*3817.60*
Sub-total	*19519.02*
Indirect Energy	
Seed	*45378.60*

Farmyard Manure	*993.63*
Fertilizer	*11733.98*
Chemical	*698.06*
Machinery	*1710.00*
Sub-total	*60514.27*
Total Energy required = 80033.29	
Output Energy (MJ/ha)	*372579.40*
Energy Ratio	*4.66*
Specific Energy (MJ/kg)	*1.14*
Renewable Energy (MJ/ha)	*48700.02*
Non-renewable Energy (MJ/ha)	*31333.26*
Commercial Energy (MJ/ha)	*76711.86*
Non-commercial Energy (MJ/ha)	*3321.42*

Source wise percentage share energy for sugarcane is presented in Fig. 4. From the chart, it is clearly indicated that seed (57%) is major source of energy followed by diesel (17%) and fertilizer (14%). Rest is electricity (5%), human (3%), machinery (2%), chemical (1%) and farm yard manure (1%). Fig. 5 shows percentage share by renewable (61%) and non-renewable source of energy (39%) and Fig. 6 shows that share of commercial and non-commercial source of energy is 61% and 39% respectively.

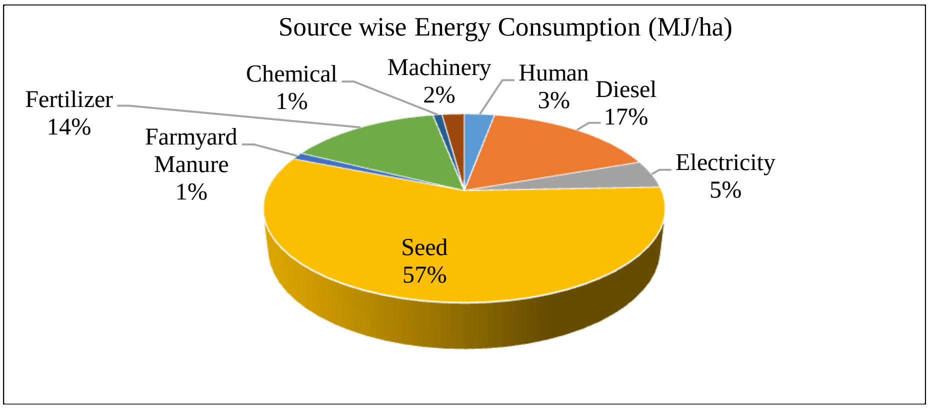

Figure 4. Source wise energy consumption in sugarcane production system

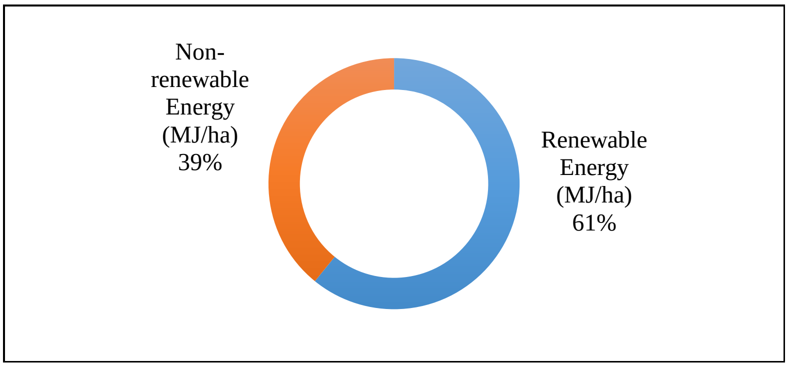

Figure 5. Share of renewable and non-renewable energy sources

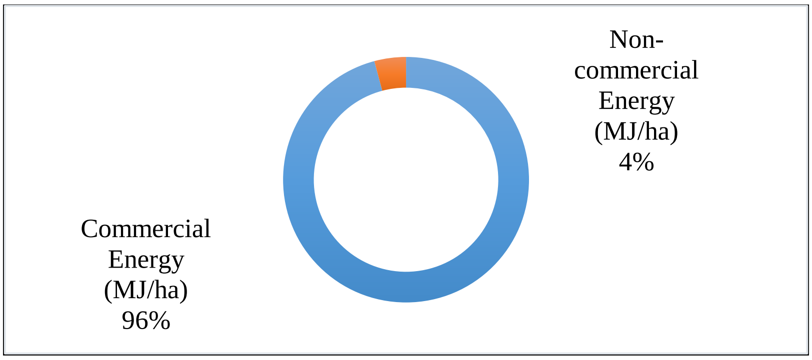

Figure 6. Share of commercial and non-commercial energy sources

CONCLUSION

The developed software is capable to calculate energy requirement in MJ/ha of different source of energy and also calculate output energy, energy ratio and specific energy. This program could prove to be useful to track record of energy use season by season and on the basis of that one can estimate future energy requirement which would help farmer in decision making.

BIBLIOGRAPHY

[1] Singh, H., Mishra, D., Nahar, N.M. 2002. Energy use pattern in production agriculture of atypical village in arid zone, India - part I. *Energy Conversion and Management*, 43(16), 2275–2286.

[2] Karimi, M., Rajabi, P.A., Tabatabaeefar, A., Borghei, A. 2008. Energy Analysis of Sugarcane Production in Plant Farms A Case Study in Debel Khazai Agro-industry in Iran. *American-Eurasian J. Agric. &Environ. Science*, 4(2), 165–171.

[3] Asoodar, M.A., Marzban, A. 2013. Energy use and economical analysis of sugarcane production in Iran a case study: *Debel Khazaeei*, 1, 249–252.

[4] Singh S, Mittal J.P., Verma S.R. 1997. Energy requirements for production of major crops in

India. *Agricultural Mechanization in Asia, Africa and Latin America (AMA)*, 28(4), 13-17.

[5] Ozkan, B., Akcaoz, H., Karadeniz, F. 2004. Energy requirement and economic analysis of citrus production in Turkey. *Energy Conversion and Management*, 45 (11–12), 1821–1830.

[6] Hamedani, S.R., Shabani, Z., Rafiee, S. 2011. Energy inputs and crop yield relationship in potato production in Hamadan province of Iran. *Energy*, 36(5), 2367–2371.

[7] Ishii, Y., Hamano, K., Kang, D.J., Kannika, R., Idota, S., Fukuyama, K., Nishiwaki, A. 2013. C4-Napier Grass Cultivation for Cadmium Phytoremediation Activity and Organic Livestock Farming in Kyushu, Japan. *Journal of Agricultural Science and Technology*, 3, 321–330.

RAČUNARSKI PROGRAM ZA ENERGETSKE POTREBE PROIZVODNJE ŠEĆERNE TRSKE

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Sažetak: Računarski program prilagođen korisnicima je razvijen u Visual Basic okruženju, za određivanje energetskih potreba proizvodnje šećerne trske i pripadajućih vrednosti kao što su: odnos energije, specifična energija i izlazna energija. Program takođe može da izračuna i obnovljive / ne-obnovljive i komercijalne / ne-komercijalne izvore energije. Ulazni parametri razvijenog programa su ljudi (h), diesel gorivo (lit.), električna energija (kWh), seme (kg), stajnjak (kg), đubrivo (kg), hemikalije (kg), mašine (h), ljudski rad i prinos (kg/ha). Ukupna energija se proračunava pomoću energetskih ekvivalenata koji su već uneti u program. Razvijeni program uspešno računa potrošnju energije u MJ/ha. Program može da se pokaže kao koristan alat farmerima za predviđanje energetskih potreba u proizvodnji šećerne trske analizom sezonskih podataka.

Ključne reči*: program, energetske potrebe, šećerna trska*

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ELECTROSPARK COATING FROM NANOCRYSTALLINE ALLOY

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Abstract: The article describes the properties of wear resistant electrospark coating made of nanocrystalline alloy of type 5БДСР (Finemet). It is proved that electrospark coating has nanocrystalline structure which is like amorphous matrix with nanocrystals α – Fe. Coating thickness is 33 µm, micro-hardness is 8461 - 11357 MPa, wear resistance is 0,55×104 s/g. Coating of nanocrystalline alloy of type 5БДСР can be used to increase wear resistance of machinery working surfaces.

Key words*: electrospark deposition, electrospark coating, nanocrystalline alloy, microhardness, wear resistance.*

INTRODUCTION

One of the promising trends of wear resistance increase of elements working surfaces is their hardening at the expense of formation of surface coating with high physical mechanical properties. Scientific and technical information analysis displayed that among widely-accepted methods of working surfaces hardening it is possible to differentiate thermal treatment, thermochemical treatment, laser and plasma hardening, etc. The promising method of hardening of working surfaces with complicated geometric form is electrospark treatment (EST) [1]. There are many different ways of development of EST method. One of them is usage of new materials with nanocrystalline structure. These materials usage allows to obtain multifunctional coatings that are able to increase elements working surfaces wear resistance [2-16].

Purpose of the work is to investigate the properties of hardening electrospark coating of nanocrystalline alloy (NCA).

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MATERIAL AND METHODS

Nanocrystalline alloy of type 5БДСР (Finemet) (Fe–70%, B – 9,2%, Si– 6,3%, Nb–2,21%, Cu– 0,8%, Mo– 0,2%) was chosen as electrode material. The obtained coatings structure was investigated by means of scanning electron microscope Hitachi TM – 1000. Hardening coating was applied on steel samples 65Г by installation EST of type БИГ – 4 (mode: №2, K=0,8). The experimental electrospark coating thickness was measured at the sections. Measurements were done by microscope МИМ-8. The reference surface was the boundary of coating and base. Microhardness was measured at loading of 50 g by the diamond point pressing-in method using computerized microhardness tester ПМТ-3М-01. Mass transfer process was studied, investigated by geometric measuring of single erosive traces left by electrode the measurements were done with microhardness tester ПМТ-3М. The microhardness tester was equipped with ocular screw micrometer МОВ-1-16Х, and also with lens ОЭ-25 (epilens-plan-achromatic F=25,0 mm, A=0,17). Tribotechnical tests were done using, friction machine МТУ-01, at external loading 2,5 N, with resultant sliding velocity – 1,0 m/s. Steel of type 65Г tempered to HRC 58…60 was used as a material for counter-sample production. The wear was determined according to gravimetric method using balance Sartorius Competence CP64 with accuracy 0,0001 g.

RESULTS AND DISCUSSION

Scanning electronic microscopy allowed stating that electrospark coating, obtained by steel base treatment with the electrode made of nanocrystalline alloy (NCA) of type 5БДСР, has homogenious structure to level of 1 μm. However, there are microcrystalline inclusions of base material in transition section between coating and base (Fig. 1). X-ray tests displayed that the coating from alloy 5БДСР has nanocrystalline structure, which is like amorphous matrix with nanocrystals α – Fe. It is seen from Figure 2, wich presents the reflection from crystalline phases α–Fe [10].

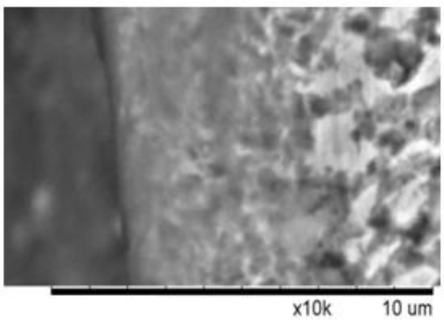

Figure1. Electrospark coating structure

Electrospark coating thickness varies nonlinearly. Experimental dependence of thickness from specific treatment time is presented in Fig. 3. Thereon fracture failure threshold equal to 2,1 min/cm^2 and fracture failure critical threshold equal to 5,2 min/cm^2 were set. At electrospark treatment (EST) with mode №2, К=0,8 maximum coating thickness from nanocrystalline alloy (NCA) of type 5БДСР is h = 33 µm, which is about 1,5 times more, than thickness of coating from alloy of type ВК6-ОМ, obtained with the analogous mode.

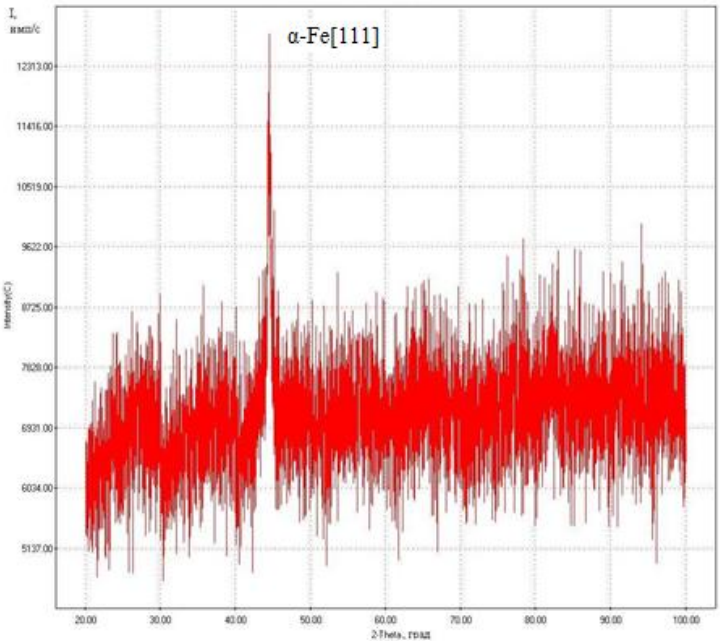

Figure 2. Electrospark coating diffractogram

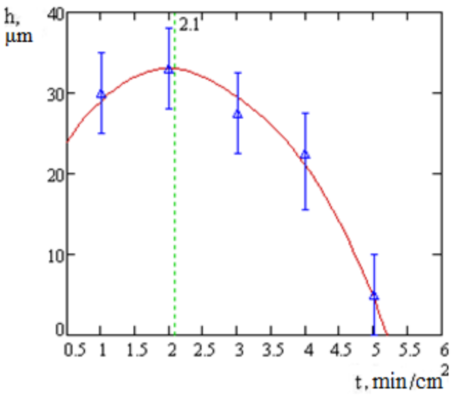

Figure 3. Coating thickness dependence from specific treatment time

Microhardness of hardening coating has dispersion in magnitude. Maximum value of coating microhardness from nanocrystalline alloy (NCA) of type 5БДСР is $H_{\mu max}$ = 11357 MPa, minimum is $H_{\mu min}$ = 8461 MPa. The distinctive feature indicating the coating plastic deformation is that there is a “crown” on indenter impresses [1, 8].

While mass-transfer investigations we determined the electrode material mass dependence being transferred from anode to cathode from initial potential – one of the main technological parameters of electrospark treatment (EST). Fig. 4 presents regressive power dependence which can be used to develop the technological process of elements hardness. By means of gravimetric method the mass-transfer direction and electrospark treatment (EST) efficiency were determined in whole. This method allowed determination of some parameters of mass-transfer which are essential for engineering support of electrospark treatment (EST) process (Tab. 1).

Table 1. Mass-transfer parameters

Mass-transfer average ratio	*Fracture failure threshold of coatings (t_x, min/cm^2)*	*Fracture failure critical threshold of coatings ($t_{кр}$, min/cm^2)*
0,54	*4,0*	*6,5*

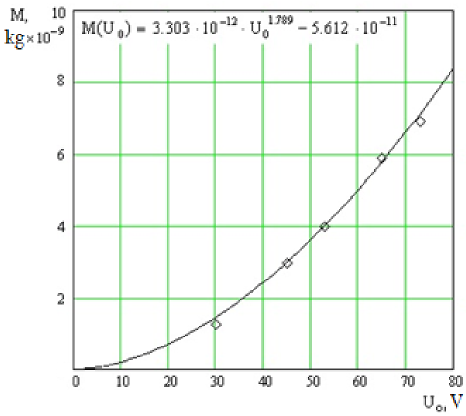

Figure 4. Mass dependence of electrode material being transferred from anode to cathode from initial potential at electrospark treatment (EST)

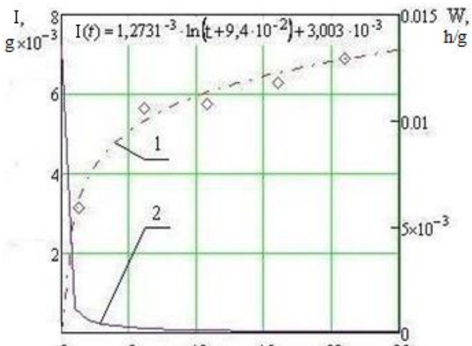

Figure 5. Dependence of wear (1) and u wear rate (2) of electrospark coating from test duration

Wear tests allowed obtaining the wear dependence from tests duration presented in the form of logarithmic regression function. After its differentiation the wear rate dependence from time was obtained (Fig. 5).

By means of tribotechnical tests it is proved that hardening electrospark coating from nanocrystalline alloy (NCA) of type 5БДСР has wear rate $W_{average} = 18\times10^{-5}$ g/s and wear resistance $U = 0{,}55\times10^{4}$ s/g. Low wear rate and high wear resistance testify that the examined electrospark coating should be reasonably used at hardening of machinery working surfaces.

CONCLUSIONS

Wear resistant electrospark coating from nanocrystalline alloy (NCA) of type 5БДСР has nanocrystalline structure, thickness 33 µm, maximum microhardness 11357 MPa, wear resistance 0,55×104 s/g. The coating from this alloy can be used to increase the wear resistance of machinery working surfaces.

BIBLIOGRAPHY

[1] Kolomeichenko A.V., Kuznetsov, I.S. 2015. *Theory and practice of electrospark hardening of cutting machine elements using amorphous and nanocrystalline alloys*: educational monograph. Orel. Orel State Agrarian University Publishing house. 2015. - 174. p.

[2] Ageev E., Mizobata K., Nakajima T., Zen H., Kii T., Ohgaki H. 2015. *Time-resolved detection of structural change in polyethylene films using mid-infrared laser pulses.* Applied Physics Letters. 2015. Vol. 107. No 4. p.p. 041904.

[3] Ageeva E.V., Khor'yakova N.M., Ageev E.V. 2015. *Morphology and composition of copper electrospark powder suitable for sintering*. Russian Engineering Research. 2015. Vol. 35. No 1. p.p. 33–35.

[4] Cadney S., Brochu M. 2008. Formation of amorphous Zr41.2Ti13.8Ni10Cu12.5Be22.5 coatings via the electrospark deposition process. *Intermetallics*. Vol.16. No 4. p.p. 518–523.

[5] Brochu M., Heard D.W., Milligan J., Cadney S. 2010. Bulk nanostructure and amorphous metallic components using the electrospark welding process. *Assembly automation*. 2010. Vol. 30. No 3. p.p. 248–256.

[6] Milligan J., Heard D.W., Brochu M. 2010. Formation of nanostructured weldments in the Al-Si system using electrospark welding. *Applied surface science*. 2010. Vol. 256. No 12. p.p. 4009–4016.

[7] Cadney S., Goodall G., Kim G., Moran A., Brochu M. 2009. The transformation of an al-based crystalline electrode material to an amorphous deposit via the electrospark welding process. *Journal of alloys and compounds*. 2009. Vol. 476. No 1-2. p.p. 147–151.

[8] Kolomeichenko A.V., Kuznetsov I.S., Kravchenko I.N. 2015. Investigation of the thickness and microhardness of electrospark coatings of amorphous and nanocrystalline alloys. *Welding International*. 2015. Vol. 29. № 10. p.p. 823–825.

[9] Kolomeichenko A.V., Kuznetsov I.S. 2014. Tribotechnical properties the electrospark coating of amorphous and nanocrystalline alloys based on iron. *Friction and wear*. 2014. Vol. 35. No 6. p.p. 501–504.

[10] Kolomeichenko A.V., Kuznetsov I.S., Rodichev A.Yu., Penyashky T.G. 2015. On the question of obtaining amorphous and nanocrystalline structures in electrospark coatings. *Repair. Reconditioning. Modernization*. 2015. No 5. p.p. 33–36.

[11] Mileusnić, I.Z., Petrović, V.D., Miodragović, M.R., Dimitrijević, Aleksandra. 2010. U uslova eksploatacije traktora na njegovu pouzdanost i radni vek. *Poljoprivredna tehnika*, vol. XXXV, No. 1, p.p. 59-67.

[12] Ašonja, N.A., Pastuhov, G.A. 2014. Uticaj dijagnostike stanja na pouzdanost dvostr poljoprivrednih kardanskih vrtaila. *Poljoprivredna tehnika*, vol. XXXIX, No. 1. p.p. 21-30.

[13] Kravchenko, I., Kuznetsov, Y., Bobryashov, E., Kolomeichenko, A. 2014. Plasma restoration and hardening of elements of tillage tools**.** *Poljoprivredna tehnika,* vol. XXXIX, No. 4. p.p. 91-99.

[14] Kuznetsov, Y., Kossenko, A., Lugovskoy, A. 2011. Studies on corrosion resistance of coatings formed by plasma electrolytic oxidation on aluminum alloys. *Proceedings of the tenth Israeli-Russian Bi-National Workshop,* No. 307. p.p. 297-303.

[15] Kuznetsov, Y.A. 2013. Investigation of internal stresses in thin layer oxide ceramic coating. *Traktori i pogonske masine*, Vol. 18, No. 2. p.p. 42-49.

[16] Kuznetsov, Y,A., Kosenko, A.V., Kazansky, V.A. 2011. Влияние модуля силиката на технологические свойства покрытий. *Vestnik of Orel State Agrarian University*, No. 2. p.p. 97-101.

ELEKTROLUČNO PREMAZIVANJE NANOKRISTALNOM LEGUROM

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Sažetak: U radu su prikazane osobine otpornosti na habanje elektrolučnog premaza od nanokristalne legure tipa 5БДСР (Finemet). Dokazano je da elektrolučni premaz ima nanokristalnu strukturu koja izgleda kao amorfna matrica sa nanokristalima α – Fe. Debljina premaza iznosi 33 µm, mikrotvrdoća 8461 - 11357 MPa, otpornost na habanje 0,55×104 s/g. Premaz od nanokristalne legure tipa 5БДСР se može koristiti za povećanje otpornosti na habanje radnih površina mašina.

Ključne reči: *elektrolučna depozicija, elektrolučno premazivanje, nanokristalna legura, mikrotvrdoća, otpor habanju.*

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