

Simulation of components of mould board plough bottom using computer software

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■ **ABSTRACT :** The goal of the modern farming systems is to economize energy consumption and to reduce farming costs. In this study tractor drawn mouldboard plough of two bottoms was considered. Three main forces like draft force, side draft and vertical component were considered in plough bottom design software. Mouldboard plough is primary tillage implement, so that plough bottom has high magnitude reaction forces from the soil during tillage and these reaction forces effects on construction elements of plough bottom directly. If the construction elements cannot compensate reaction forces, they become useless due to plastic deformation or fracture. Therefore, structure must have been designed as stable durable enough to avoid undesirable failure cases. Proper selection and use of agricultural machines are important factors to achieve this end. Selection of appropriate tractor power and implement is more complex and tedious due to computational work involved in solving the equations for draft and working width and depth of ploughing of mouldboard plough bottom. Thus, a computer programme will be developed in visual basic language to compute width and the dimensions of the plough bottom by entering the essential inputs like tractor available power, soil type etc. for a particular farm situation. Results obtained by using this software were validated by comparing the simulated dimensions with some of the commercially available mouldboard plough. Hence, the developed software can be used as a tool for designing mouldboard plough bottom for different horsepower of tractor and soil conditions.

■ **KEY WORDS :** Simulation, Mouldboard, Force, Plough, Bottom

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Farm mechanization in agriculture leads to introduce many improved tillage implements in place of traditional implements. Requirement of farm mechanization for seedbed preparation has increased during recent years.

The first operation in production of crop is tillage. Tillage is the first and most important cultural practice undertaken to attain desired soil surface configuration and soil physical properties. Ploughing is one of the most power-consuming and expensive

processes in agricultural production. It is known that the draft resistance of ploughs, the energy requirement ploughing, the quantity of ploughing and expenses depend on the plough body design (Vilde, 2008).

Objectives :

- To develop a computer programme for optimum design of mouldboard plough bottom.
- To validate the computer programme with commercially mouldboard plough bottom.

METHODOLOGY

The software was designed by coding the equations of mouldboard plough bottom design in visual basic language.

Design consideration of mouldboard plough bottom (Sharma and Mukesh, 2010) :

Tractor mounted mouldboard plough bottom consists of share point, share, mouldboard, landside, frog, beam. The share point is of bar type and is made from high carbon steel or low alloy steel. The share is also made from high carbon steel or low alloy steel.

Drawbar horse power (DBHP) of tractor :

Drawbar horse power (DBHP) is given by DBHP=60 per cent of BHP.

Drawbar pull :

DBHP=Pull (kg) × speed (m/min)/4500
 Pull (kg) = DBHP × 4500/ speed (m/min).

Width of implement :

The width of an implement (W_i) can be calculated from the following formula:

$$W_i = D_i / (n \times d_p \times R) \text{ in cm}$$

where,

- D_i = Draft requirement of implement, kg
- n = Number of bottoms in mouldboard plough
- d_p = Depth of plowing, cm
- R = Specific resistance of soil, kg/cm².

Forces acting on mouldboard plough bottom :

Various forces acting on plough bottom are shown in Fig. A:

- Draft (D) = $P \times \cos\theta \times \cos\alpha$
- Side draft (S) = $P \times \cos\theta \times \sin\alpha$
- Vertical component (V) = $P \times \sin\theta \times \cos\alpha$.

where,

- P = Pull of plough, kg or N
- θ = Angle of pull with horizontal plane, degrees
- α = Angle of pull with vertical plane, degrees.

All the above forces are acting on plough since; the plough has two bottoms, So, draft, side draft, and vertical component on each bottom of plough are one half of its original value.

Design of share of mouldboard plough bottom :

The best throat angle (share angle) of the share

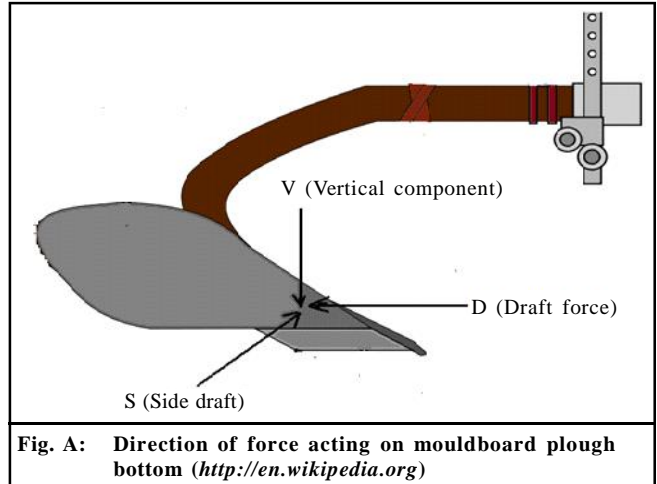


Fig. A: Direction of force acting on mouldboard plough bottom (<http://en.wikipedia.org>)

should be an angle along which soil rupture takes place.

$$\text{Soil shear angle } (\theta_s) = 45^\circ - \Phi$$

where,

Φ = angle of friction between metal and soil.

Now, the share may be assumed like a rectangular plate of area ($\Delta ABC + \Delta BCD$) subjected to bending. Refer Fig. B.

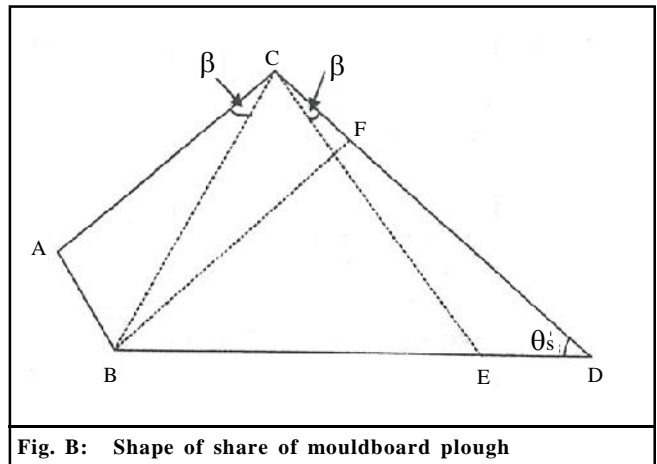


Fig. B: Shape of share of mouldboard plough

The equivalent rectangular dimensions of share can be taken as CE and BF, calculated as:

$$\text{From the similar triangles ABC and BCF} \\ AC/BC = BC/BF \text{ or } BF = BC^2/AC$$

Also in triangles ABC, $AB/BC = \sin\beta$. So, find angle beta

$$\text{Also from triangle CED, } \angle \beta + \angle \theta_s + \angle CED = 180^\circ \\ \angle CED = 180^\circ - \angle \beta - \angle \theta_s$$

Find value of CE by using sine theorem.

$$CD/\sin \angle CED = CE/\sin \angle \theta_s$$

Unit draft of share = unit draft of soil \times factor of safety

Total design draft of mouldboard plough bottom = width \times depth \times unit draft

The total draft force will act on entire area of share. It is assumed that the soil pressure is uniformly distributed on share.

Total area of share = area of BCD + area of ABC
Therefore, soil pressure on share =

$$\frac{\text{Total design draft of plough bottom}}{\text{Total area of share}}$$

This pressure is acting on the share at $\Psi=20^\circ$

Therefore, uniformly distributed load = Soil pressure on share $\times \sin\Psi$

Length breadth ratio of share = L/b

Share thickness (t):

In the design of plough share law of bending of rectangular plate with one side fixed and three sides freely supported may be applied. For uniformly distributed loads on rectangular plate.

$$S_{\max} = B \times F \times b^2 / t^2$$

where,

S_{\max} = Maximum stress developed load, kg/cm^2

F = Uniformly distributed load, kg/cm^2

b = Width of share, cm

t = Thickness of share, cm

B = A constant, depends on length-breadth ratio of share.

Design of landside of mouldboard plough bottom :

Landside is a long flat metal piece bolted to the side of frog and acts as one side of the wedge formed with the share of mouldboard plough bottom (Fig. C).

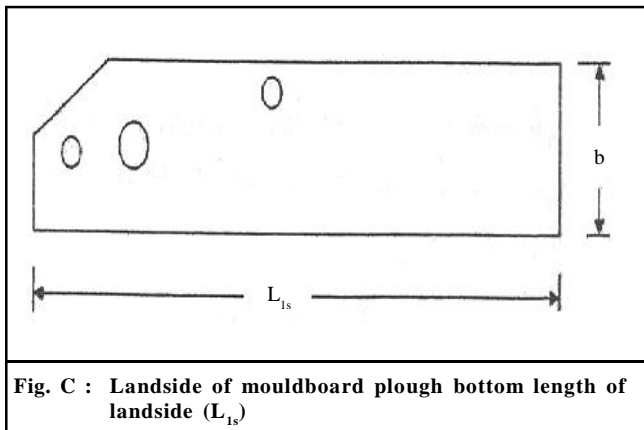


Fig. C : Landside of mouldboard plough bottom length of landside (L_{ls})

Length of landside is calculated by using following expression:

$$L_{ls} = 1/2 \times [b \times \cos W / \sin r \times \cos (W + r)]$$

where,

L_{ls} = Length of landside from the point of share to landside, cm

b = Width of landside, cm

Φ = Angle of soil granular friction, degrees

α = Inclination of pull with vertical plane, degrees.

Width of landside (b) :

Usually width of landside is taken as one third of share width of mouldboard plough bottom.

Thickness of landside (t) :

$$f_t = W \times L_{ls}^2 / 3 \times t^2$$

where,

f_t = Permissible stress in the landside, kg/cm^2 or N/mm^2 = Yield strength of material/factor of safety

W = Uniformly distributed load on landside surface, kg/cm^2 or N/mm^2

t = Thickness of landside, cm or mm.

Design of beam of mouldboard plough bottom :

The Mouldboard plough bottom of tractor drawn plough is attached to a curved beam. As the beam is curved therefore, theory of bending of curved beams is applied (Fig. D). According to theory of curved beams of rectangular section, the bending stress is given by,

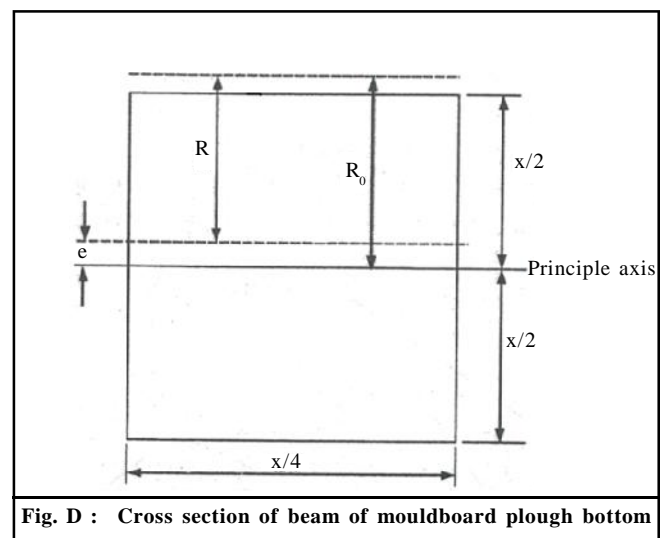


Fig. D : Cross section of beam of mouldboard plough bottom

$$F = M \times y/A \times e \times (R_0 + y)$$

$$y = X/2 \pm e \quad (X=\text{assume})$$

where,

F= Bending stress at any point from neutral axis

=Yield strength of material/Factor of safety

M=Maximum bending moment induced in the beam

= maximum draft \times distance

R_0 = The initial radius of neutral surface, cm = R – e

R= Radius of curvature of beam (assume)

e =Distance between the neutral axis and the principle axis through centroid, cm

A=Area of cross section of beam, cm²

If the beam is assumed to be of square section, each side measuring X cm, then the value of 'e' can be determined by using the relationship,

$$e = R - X/\text{Log} [(R + X/2)/(R - X/2)]$$

The stress produced in the beam can be calculated by using above equation and the value of X can be determined by using allowable stress in the beam based on material of the beam.

$$F=450000 \times (X/2 \pm e) / \{X^2 \times e \times (20 + X/2 \pm e)\}$$

Formulation of software for components of designing plough bottom :

To design the mouldboard plough bottom a computer programme was written in visual basic 6 language. The equations used for programming are selected as given in the above section. All the required equations were coded in visual basic language and its parameters were simulated using this software. Input parameters for the software are given below.

Parameters of bottom :

- Rated engine power (hp)
- Number of bottom
- Drawbar pull (kg)
- Line of pull (degree)
- Direction of motion (degree).

Parameters of share :

- Factor of safety of share
- Angle ϕ_i (degree)
- Angle ϕ_{hi} (degree)
- Length-breadth ratio
- Throat width of share (cm)
- Maximum stress in share (kg/cm²).

Parameters of landside :

- Factor of safety landside
- Yield strength of landside (kg/cm²)
- Area of landside (cm²).

Parameters of beam :

- Factor of safety of beam
- Square section of beam (cm)
- Radius of beam (cm)
- Unit draft of soil (kg/cm²)
- Ground clearance of beam (cm).

Operating parameters :

- Speed of operation (km/h)
- Depth of operation (cm)
- Width of operation (cm).

Type of soil :

- Light soil
- Medium soil
- Heavy soil
- Very heavy soil.

Output parameters simulated by the software are given below.

Parameters of bottom :

- Drawbar horse power (DBHP)
- Width of one bottom (cm)
- Draft (kg)
- Side draft (kg)
- Vertical component (kg).

Parameters of share :

- Total design draft of mouldboard plough bottom (kg)
- Total area of share (cm²)
- Thickness of share (mm).

Parameters of landside :

- Area of landside (cm²)
- Permissible stress in landside (kg/cm²)
- Thickness of landside (mm).

Computer simulation is commonly used to visualize and to investigate a particular system without going through practical measurement. A computer simulation also contains the flexibility to choose the design

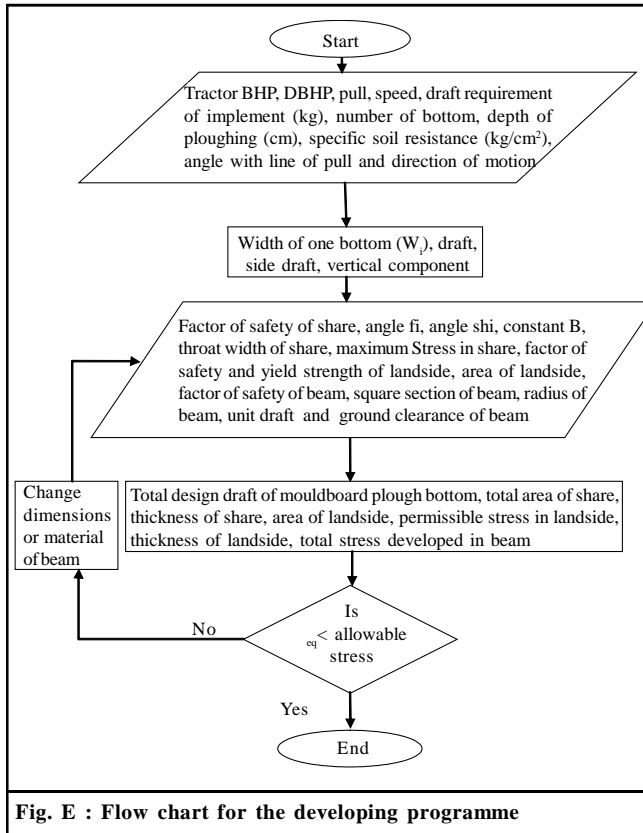


Fig. E : Flow chart for the developing programme

parameters we want to incorporate. The programme was based on the algorithm as shown in Fig. E.

Development of software for designing tractor drawn mouldboard plough bottom :

The software for designing tractor drawn mouldboard plough bottom was developed in visual basic environment. The coding of this software is given in APPENDIX. The opening screen, input and output screen of software for mouldboard plough bottom is presented in Fig. F and G. Provisions were made to change these input parameters depending on the requirement and thus making the software users friendly.

APPENDIX

Program in visual basic 6 (coding) :

– Program of components of mouldboard plough bottom design :

Dim bhp As Double, dbhp As Double, pull As Double, n As Double, dp As Double, R As Double, Wi As Double, Wp as Double, lop As Double, d As Double, s As Double, v As Double, dom As Double, a1 As Double,

a2 As Double, fi As Double, ssa As Double, cd As Double, bc As Double, X1 As Double, BD As Double, AB As Double, ac As Double, bf As Double, beta As Double, ced As Double, ce As Double, fos As Double, uds As Double, dpb As Double, tas As Double, sps As Double, shi As Double, f As Double, lbr As Double, Smax As Double, b As Double, t As Double, fosL As Double, ys As Double, gs As Double, fosB As Double, xo As Double, e1 As Double, R1 As Double, tw As Double, wop As Double, Lls As Double, Al As Double, W As Double, ft As Double, T1 As Double, bmb As Double, psb As Double, fo As Double, dbs As Double, tsd As Double

Dim Design, PASS, FAIL As Integer

Private Sub Command1_Click()

bhp = Text1.Text

n = Text4.Text

dp = Text5.Text

dbhp = bhp * 0.6

R = Text6.Text

pull = ((dbhp * 4500 * 60) / 5000) / 2

Wi = (pull * 2) / (dp * R)

Wp = Wi / 2

Text2.Text = Format(dbhp, "standard")

Text3.Text = Format(pull, "standard")

Text7.Text = Format(Wi, "standard")

lop = Text11.Text

dom = Text12.Text

pi = 22 / 7

a1 = lop * (pi / 180)

a2 = dom * (pi / 180)

d = pull * (Math.Cos(a1) * Math.Cos(a2))

s = pull * (Math.Cos(a1) * Math.Sin(a2))

v = pull * (Math.Sin(a1) * Math.Cos(a2))

Text8.Text = Format(d, "standard")

Text9.Text = Format(s, "standard")

Text10.Text = Format(v, "standard")

fi = Text13.Text

bc = Text14.Text

shi = Text15.Text

fos = Text29.Text

b = Text30.Text

Smax = Text31.Text

ssa = (45 - (fi / 2))

angle = ssa * (pi / 180)

cd = bc / Math.Tan(angle)

BD = ((bc ^ 2) + (cd ^ 2)) ^ (1 / 2)

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AB = 12
ac = ((bc ^ 2) - (AB ^ 2)) ^ (1 / 2)
bf = (bc ^ 2) / ac
X1 = AB / bc
beta = (Math.Atn(X1 / Math.Sqr(-X1 * X1 + 1)) *
(180 / pi))
ced = 180 - beta - ssa
e = ced * (pi / 180)
ce = cd * (Math.Sin(angle) / Math.Sin(e))
uds = R * fos
dpb = bc * dp * uds
tas = (bc * cd + AB * bc) * (1 / 2)
sps = dpb / tas
shi = 20 * (pi / 180)
f = sps * (Math.Sin(shi))
lbr = ce / bf
t = (((b * f * (Wi ^ 2) / Smax) ^ (1 / 2)) * 10)
Text16.Text = Format(ssa, "standard")
Text17.Text = Format(cd, "standard")
Text18.Text = Format(BD, "standard")
Text19.Text = Format(ac, "standard")
Text20.Text = Format(bf, "standard")
Text21.Text = Format(beta, "standard")
Text22.Text = Format(ced, "standard")
Text32.Text = Format(ce, "standard")
Text23.Text = Format(uds, "standard")
Text24.Text = Format(dpb, "standard")
Text25.Text = Format(tas, "standard")
Text26.Text = Format(sps, "standard")
Text27.Text = Format(f, "standard")
Text28.Text = Format(lbr, "standard")
Text33.Text = Format(t, "standard")
Text41.Text = Format(Wp, "standard")
ys = Text35.Text
fosL = Text34(1).Text
BL = bc / 3
Lls = (1 / 2) * BL * Math.Cos(a1) / (Math.Sin(a2)
* Math.Cos(a1 + a2))
A1 = Lls * BL
W = s / A1
ft1 = ys / fosL
T1 = (W * (BL ^ 2) / (3 * ft1)) ^ (1 / 2)
Text46.Text = Format(Lls, "standard")
Text47.Text = Format(A1, "standard")
Text48.Text = Format(W, "standard")
Text49.Text = Format(ft1, "standard")
Text50.Text = Format(T1, "standard")

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gc = Text36.Text
fosB = Text37.Text
xo = Text38.Text
R1 = Text70.Text
tw = Text40.Text
bmb = dpb * gc
psb = ys / fosB
e1 = R1 - xo / Math.Log((R1 + (xo / 2)) / (R1 - (xo
/ 2)))
fo = 45000 * ((xo / 2) + e1) / ((xo * xo) * e1 * (20
+ (xo / 2) + e1))
If fo>psb Then
Design = "FAIL"
ElseIf fo<= psb Then
Design = "PASS"
End If
If Combo1.ListIndex = 0 Then
ud = 0.39
End If
If Combo1.ListIndex = 1 Then
ud = 0.49
End If
If Combo1.ListIndex = 2 Then
ud = 0.79
End If
If Combo1.ListIndex = 3 Then
ud = 1.2
End If
dbs = tw * R1 * ud / (xo ^ 2)
tsd = fo + dbs
Text79.Text = Design
Text39.Text = Format(e1, "standard")
Text51.Text = Format(bmb, "standard")
Text52.Text = Format(psb, "standard")
Text53.Text = Format(fo, "standard")
Text54.Text = Format(dbs, "standard")

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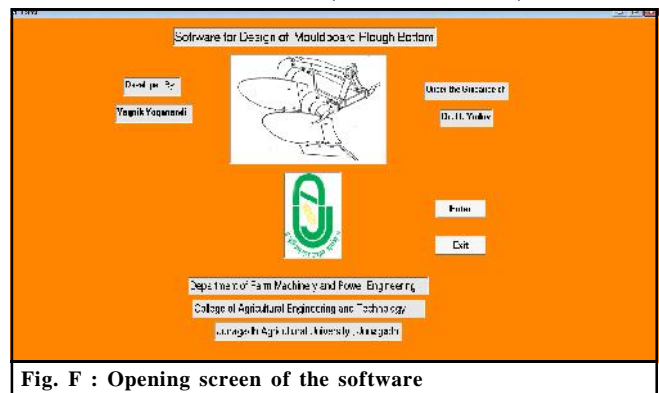


Fig. F : Opening screen of the software

Input parameters of DBIP, Pull, Implement width, Forces on plough bottom

BHP: 30, n (No. of bottom): 2, Unit draft (kg/cm²): 0.49, dp (depth in cm): 20, lop (Line of pull): 20, dom (direction of motion): 15

Output parameters of DBIP, Pull, Implement width, Forces on plough bottom

DBHP: 18.00, Width of implement (cm): 99.18, pull (kg): 486.00, Width of plough bottom (cm): 49.59, Draft (kg): 441.09, Side draft (kg): 118.24, Vertical component (kg): 160.62

Input parameters of Share design

fi: 20, BC (cm): 45, shi: 20, Smax (kg/cm²): 800, Factor of safety of Share: 2.0, B: 0.520

Output parameters of Share design

Soil shear angle: 35.00, Beta: 15.46, Total area of share: 1.7152, CD (cm): 64.23, Angle CED: 129.54, Soil pressure on share (kg/cm²): 0.51, BD (cm): 73.43, Length CE (cm): 47.83, Uniformly distributed load F (kg/cm²): 0.18, AC (cm): 43.37, Unit draft of share (kg/cm²): 0.98, Length-Breadth ratio: 1.02, Breadth BF (cm): 46.69, Design draft of plough bottom (kg): 882.00, Thickness of share (mm): 10.61

Input parameters of Landside design

Factor of safety of Landside: 4.0, Yield strength of landside (kg/cm²): 2000

Output parameters of Landside design

Length of landside (cm): 33.23, Permissible stress (kg/cm²): 500.00, Uniformly distributed load W (kg/cm²): 0.24, Area of landside: 498.49, Thickness of landside (mm): 0.19

Input parameters of Beam design

Ground clearance (cm): 40, Radius of curvature R1 (cm): 20, Factor of safety of Beam: 3.5, Unit draft of soil (kg/cm²): Medium soil, Side of beam Xo (cm): 8.0, Throat width (cm): 45

Output parameters of Beam design

Bending moment of beam (kg cm): 35,280.0, e (cm): 0.27, Design: PASS, Bending stress in beam f (kg/cm²): 458.86, Direct stress (kg/cm²): 6.89, Permissible stress of beam: 571.43, Total stress developed (kg/cm²): 465.75

Fig. G : Screen of software for components of mouldboard plough bottom

Text55.Text = Format(tsd, "standard")
End Sub

RESULTS AND DISCUSSION

This chapter deals with analysis, interpretation of results obtained from software simulation and validation of the software for mouldboard plough bottom.

Validation of software developed for components of mouldboard plough bottom design :

For validating the developed software, the simulated dimensions of mouldboard plough bottom were compared with the commercially available mouldboard plough. For

| Soil condition | Unit draft, kg/cm ² |
|-----------------|--------------------------------|
| Light soil | 0.39 |
| Medium soil | 0.49 |
| Heavy soil | 0.79 |
| Very heavy soil | 1.2 |

validation purpose, mouldboard plough bottom parameters were simulated at 5 km/h traveling speed for 30 hp tractor shown in Table 1.

The minor variations between simulated and available data were found (Table 2). Hence, the developed software can be used as a tool for designing mouldboard plough bottom for different horsepower ranges of tractor and soil conditions.

Based on the results simulated by visual basic

| Parameters | Mouldboard plough for 30 hp tractor | |
|-----------------------------------|-------------------------------------|------------------|
| | Simulated values | Available values |
| Implementwidth, cm | 99.18 | 98.50 |
| Number of bottoms | 2 | 2 |
| Thickness of share, mm | 10.61 | 10.00 |
| Length of share, cm | 47.83 | 48.50 |
| Breadth of share, cm | 46.69 | 45.00 |
| Length of landside, cm | 33.23 | 33.00 |
| Area of landside, cm ² | 498.49 | 497.00 |
| Thickness of landside, mm | 0.27 | 0.26 |

software, the following comparisons were carried out with available and simulated values of mouldboard plough bottom proportionate 30 hp tractor.

- An overall width of mouldboard plough bottom was 98.50 cm as analyzed to the simulated value of 99.18cm (Table 2).
- A thickness of share of mouldboard plough bottom was 10 cm against the simulated value of 10.61 cm.
- A length of share of mouldboard plough bottom was 48.50 cm as compared to the simulated value of 47.83 cm.
- A breadth of share was 45.00 cm whereas the simulated value of 46.69 cm.
- A length of landside was 33.00 cm while the simulated value as 33.23 cm.
- An area of landside was 497.00 cm² while the simulated value as 498.49 cm².
- A thickness of landside was 0.26 mm while the simulated value as 0.27 mm.
- The variation observed was within the range of 5 per cent. Hence, the software could be effectively used for predicting various dimensions for a matching mouldboard plough bottom.

Conclusion :

This study was focused on developing of software for designing mouldboard plough bottom for tractor and soil conditions.

- The developed software can be used as a tool for

matching and designing mouldboard plough for different horsepower range and soil conditions.

- The minor variation between simulated and available data were found.
- The software reduces lots of manual calculations and directly gives resultant dimensions related to design of mouldboard plough bottom.
- The software can be used to find out change in forces with change in horsepower of tractor and other input parameters.

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