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Full Length Research Paper

Rock cutting with surface miner: A computational approach

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Surface miner is proved to be an efficient rock excavation technique in surface mines. However, till date, mining industry is facing a problem in selecting best surface miner model suitable to their conditions amongst the models available in the market. The readily available models are purchased by the mine authority and then, are deployed in the mines. This results into the increase in mining cost and reduction in performance. The field engineers are also unable to operate the surface miner in the optimum mode of operation. This paper has reported an investigation carried out to identify the factors affecting performance of surface miner. Computer software has also been developed to assist the mine management in selecting the most suitable surface miner. This also assists the field engineers to select the optimum mode of operation to arrive at the maximum possible production.

Key words: Surface miner, operating mode, software, cuttability.

INTRODUCTION

Surface miner was first used in mining sector in mid 70's. Indian mining industry introduced surface miner in the year 1996 in a limestone mines of Gujrat Ambuja Cement Ltd (Dey and Sen, 2001). Among the 400 surface miners working over the world, more than 100 are working in Indian coal and limestone mines (Dey and Ghose, 2008). Though surface miner was introduced as a technology to avoid the difficulties of blasting near the inhabitancy, but it became a cost-effective surface mining system. To reduce the cost of mining by surface miner, judicial planning and its proper implementations are essentially required. Deployment of surface miner in any surface mine requires three decisions to be made:

i) Whether the mine is suitable for deploying surface miner or not?
ii) If suitable, then which surface miner model should be used to achieve optimum production?
iii) How the selected model can be judicially deployed in the surface mine?

The first two decisions are taken by the mine planner and top management, where as the third decision is the responsibility of the field engineers. Performance of surface miner depends largely on the operating mode in which surface miner has to work and the cuttability index of the rock or material. Thus, it becomes a critical decision for the mine planner to adopt a suitable surface miner. Once the most suitable miner is decided, then it becomes a challenge for the field engineer to utilise the machine in appropriate operating mode. To assist the mine planner, a computer programme for selection of surface miner based on cuttability index is developed. To assist the field engineer, a computer programme for selection of optimum operating mode of surface miner is also developed. These computer programmes are combined to become a software.

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Factors affecting performance of surface miner

Performance of surface miner depends on cuttability index, as the cuttability index increases performance of surface miner decreases. If the cuttability index exceeds greater than 80 surface miner should not be deployed (Anon, 2008). "Cuttability" of a surface miner depends on a number of influencing parameters. These parameters can be categorized as rock/rockmass parameters, machine parameters and the type of application. The Parameters influencing performance of surface miner are detailed in Table 1.

Rockmass is a natural component in the earth's crust and is thus immutable. Machine configuration is the one

Table 1. Parameters influencing performance of surface miner (Pradhan and Dey, 2009).

Rock/rockmass parameters	Machine configuration	Type of application
Moisture content, density, brittleness, unconfined compressive strength, point load index, Young's modulus, fracture energy, toughness index, Brazilian tensile strength, sonic velocity, abrasivity (Schimazek-F, Cerchar) volumetric joint count, stickiness of material, specific energy of cuttability .	Cutting tool configuration (rake angle, attack angle, clearance angle and tip angle, pick lacing, type of pick (point attack) number of picks, (tip material), drum weight, engine power, nature of coolant for tips.	Mode of operation (windrowing/ conveyor loading), length and width of operating area (select machine travel method), operator skill, specific requirements (dry/wet, fragmentation desired and output).

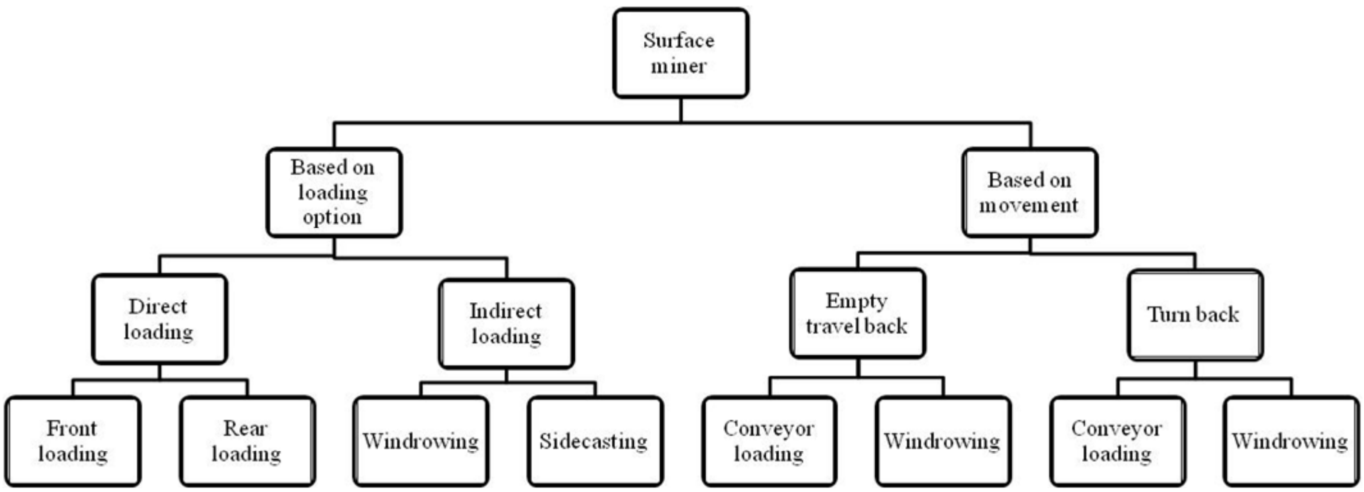

Figure 1. Possible modes of operation of a surface miner.

(a) Windrowing (b) Conveyor loading

Figure 2. Loading modes of surface miner.

time decision of the mine management. Thus, performance of a surface miner, generally, depends on cutting in edges, curves, turning radius and length of working area, truck changing time, which can be controlled by the field engineers. Field engineer can choose operating modes of surface miner to achieve the maximum production based on the onsite requirement. The operating modes can be classified based on the travelling and loading options. The possible modes of operation are depicted in Figures 1 and 2.

User of the surface miners always finds difficulty in selecting suitable machines (for a mine) and also in choosing their operating mode in short term (day to day operation) and long term basis (for a particular face). For the ready guidance to them, surface miner manufacturers provide performance graphs (Performance vs. compressive strength) derived based on their experience. Though, the reliability of these charts varies due to two main reasons: (a) manufacturer assumes ideal conditions (b) geo-mining differences in applications. Further, these

Table 2. Rating of the parameters of new rockmass cuttability classification (Dey and Ghose, 2008).

Class	I	II	III	IV	V
Point load index (I_s50)	< 0.5	0.5 – 1.5	1.5 – 2.0	2.0 – 3.5	> 3.5
Rating (I_s)	5	10	15	20	25
Volumetric joint coun (no/m^3)	> 30	30– 10	10 – 3	3 – 1	1
Rating (J_v)	5	10	15	20	25
Abrasivity	< 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	> 3.0
Rating (A_w)	3	6	9	12	15
Direction of cutting respect to major joint direction	720 - 900	540 - 720	360 - 540	180 - 360	00 - 180
Rating (J_s)	3	6	9	12	15
Machine power (kW)	> 1000	800 – 1000	600 – 800	400 – 600	< 400
Rating (M)	4	8	12	16	20

charts are also not available for all the manufacturers. To overcome this problem, software has been developed to select the suitable surface miner and their operating mode.

THE SOFTWARE

"Cuttability index" developed by Dey and Ghose (2008) had been utilised in selection of surface miner model. The model has been considered the key influencing parameters, namely; point load strength index, rock abrasivity, volumetric joint count, direction of machine operation with respect to joint direction and the cutting power of surface miner. The ratings of these parameters are tabulated in Table 2.

Utilising this theory, software has been developed in C language to select the suitable surface miner model. The flow sheet of the software is given in Figure 3. Similarly, the mathematical relationship proposed for computation of surface miner performance in different operating mode is utilised for selecting the optimum operating mode of surface miner. The flow sheet for this module is given in Figure 4.

Thus, the cuttability index (CI) is the sum of the rating of above five parameters

$$CI = I_S + J_V + A_W + J_S + M \quad (1)$$

Utilising this cuttability index production rate of a surface miner can be estimated as follow –

$$L^* = \left(1 - \frac{CI}{100}\right) k M_C \quad (2)$$

Where;

L^* = production or cutting performance (bcm/h).

M_c = Rated capacity of the machine (bcm/h).

CI = Cuttability index.

k = A factor for consideration of influence of specific cutting condition and is a function of pick lacing (array), pick shape, atmospheric condition etc. and varies from 0.5 – 1.0.

Thus, the flow sheet of the software can be established as given below (Pradhan, 2008).

Theoretical production formulae for surface miner (Dey, 1999) are utilised to find out performance of a surface miner for different mode of operations. The operating mode gives the maximum production is selected as the optimum mode of operation. Thus, the flow sheet of the software can be established as given below (Dey and Sen, 2001).

The software is being developed to select suitable surface miner and its operating mode. The software is presently under development in Visual Basic but it is completed in C language and is presented in this section. The developed module can select the suitable surface miner for a particular condition from the available models and also the operating mode for the surface miner to achieve optimum production under following geo mining conditions:-

i) Compressive strength of the rock is less than 120 MPa,
ii) Abrasivity should be less than 3.
iii) The effect of gradient of the working bench on the production is not considered, thus it is considered to be flat or gently inclined.
iv) Special applications like, selective mining of thin seams/dirt bands, ramp construction etc., are not considered.
v) No financial calculation has been incorporated presently.

The step by step procedure to use the software is as follows –

Step 1: The basic information like rock properties and

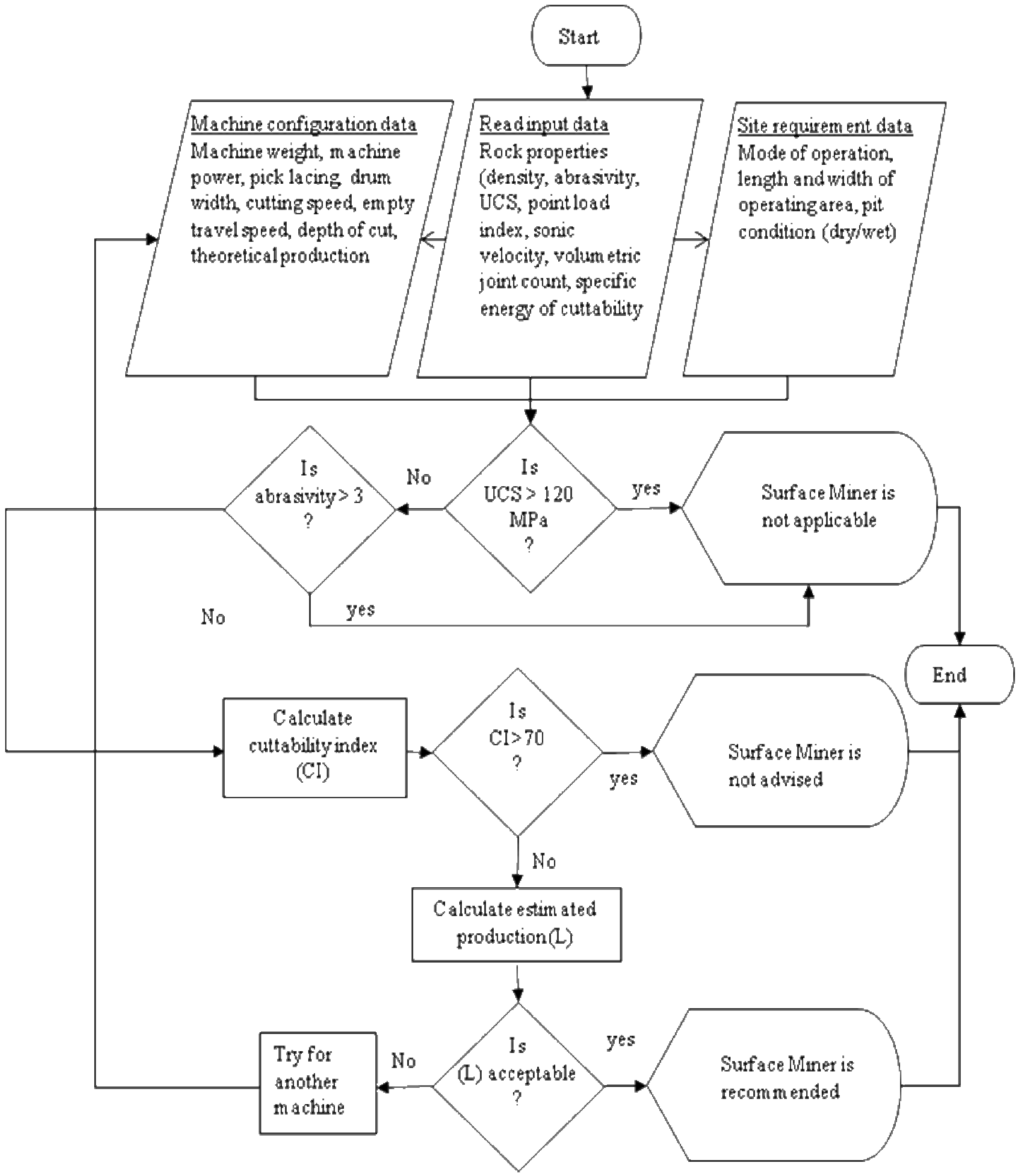

Figure 3. Flow sheet for selection of surface miner based on cuttability index.

machine configuration has to give.

Step 2: Check the UCS and abrasivity of rock than calculate the cuttability index.

Step 3: Calculate the estimated production than check whether the production is acceptable or not. If not go for other model otherwise show the production.

Step 4: To choose operating mode the basic inputs like machine parameters has to give and the calculation option for travel and loading combinations mode has to select.

Step 5: Check the mode of travel and loading combinations inserted.

Step 6: Read the relevant input parameters required for production analysis.

Step 7: Calculate the production for the selected mode of travel and loading combination.

Step 8: Check and calculate for other modes.

Step 9: Compare the productions and find out the mode

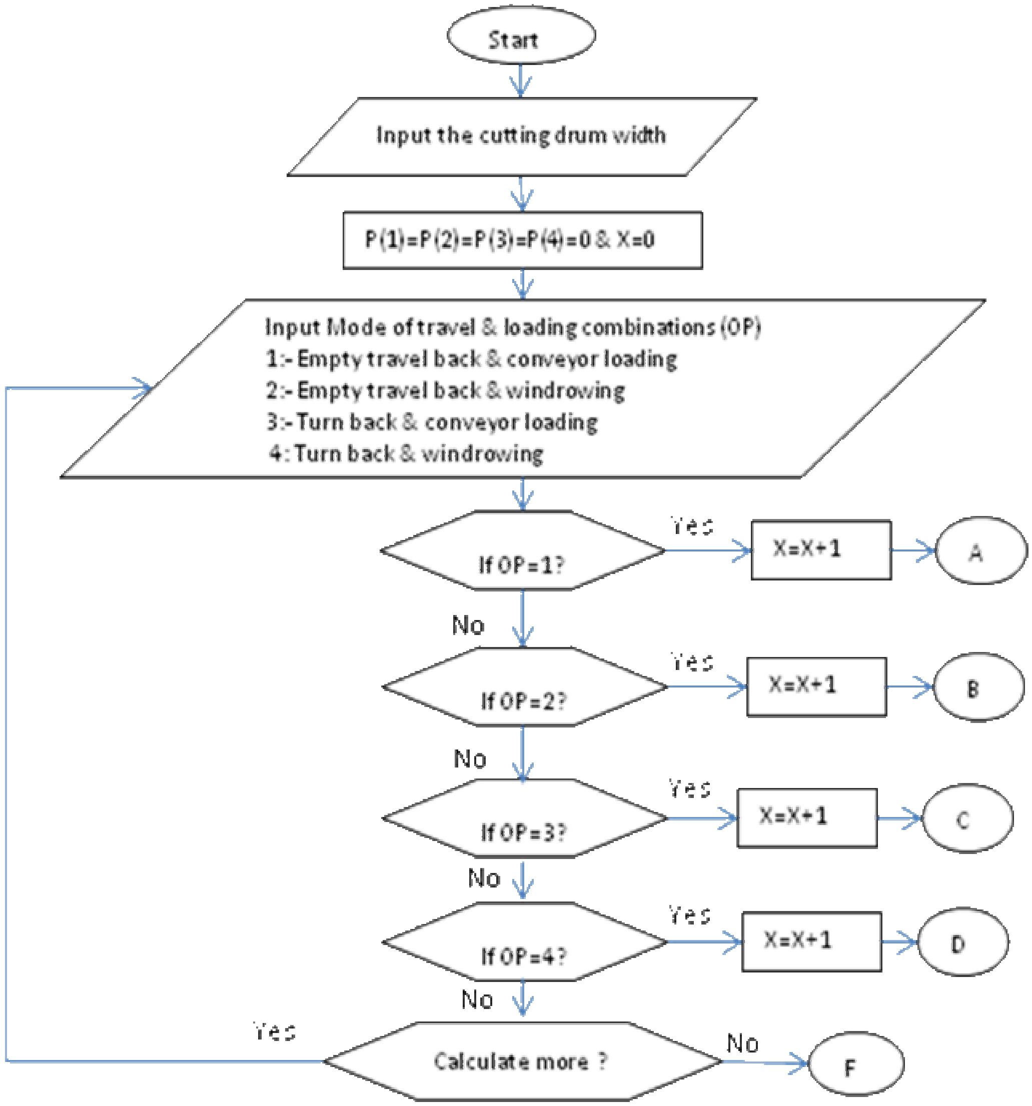

Figure 4a. Reading the inputs to determine optimum mode of operation

of maximum production and print.

The software has the feature to give the output in text format.

A trial of the software

The software has been tested for a case of coal mines of MCL. The data are taken from Lakhanpur Opencast Project of Mahanadi Coal Fields Limited.

Point load index = 1.1 that is rating $I_s = 10$
Surface Miner used == 2100 SM
Rated machine capacity = 400 m^3/h
Machine power = 448 kW that is rating $M_c = 16$
Volumetric joint count = 32 that is rating $J_v = 5$
Abrasivity = 0.4 that is rating $A_w = 3$
Direction of machine operation with respect to joint plane = 800 that is rating $J_s = 3$
Thus, cuttability index (CI) = 37 (thus very easy cutting condition for surface miner)
Expected production (for k = 0.6) = (1 – 37/100) × 400 × 0.6 = 151 m^3/h
Density = 1.4 t/m^3
Expected production achieved = 210 t/h
Truck exchange time=24 s
Length required to fill a truck = 51 m
Drum width = 2.1 m
Cutting depth = 160 mm

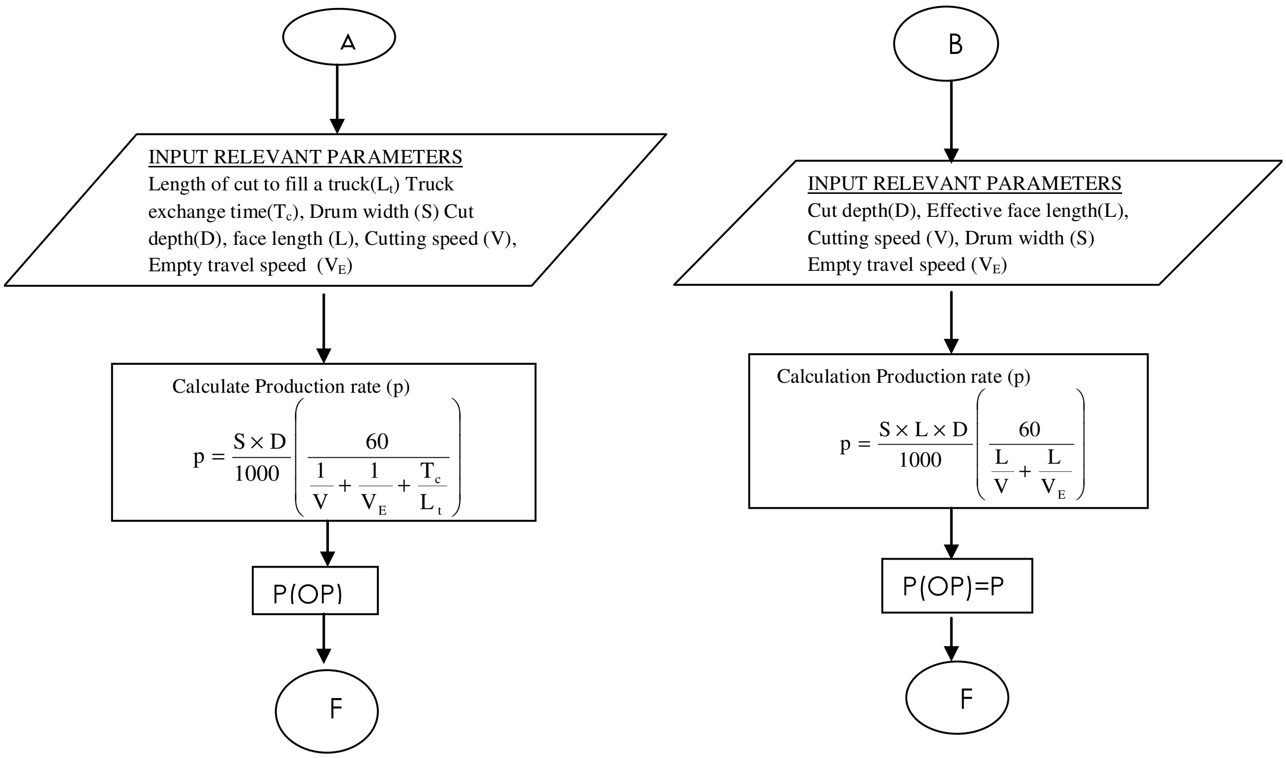

Figure 4b. Calculation for empty travel back - conveyor loading and widrowing mode

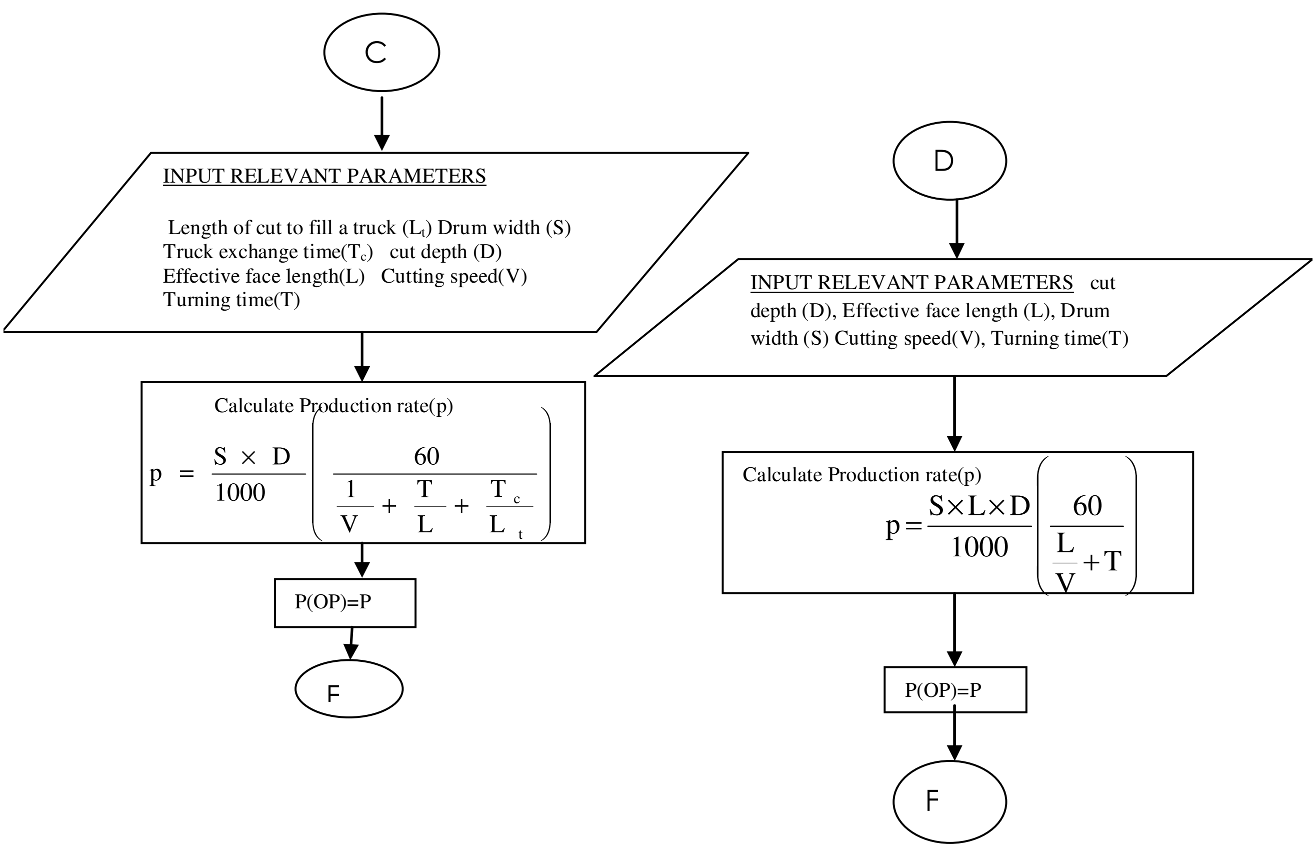

Figure 4c. Calculation for turn back - conveyor loading and widrowing mode

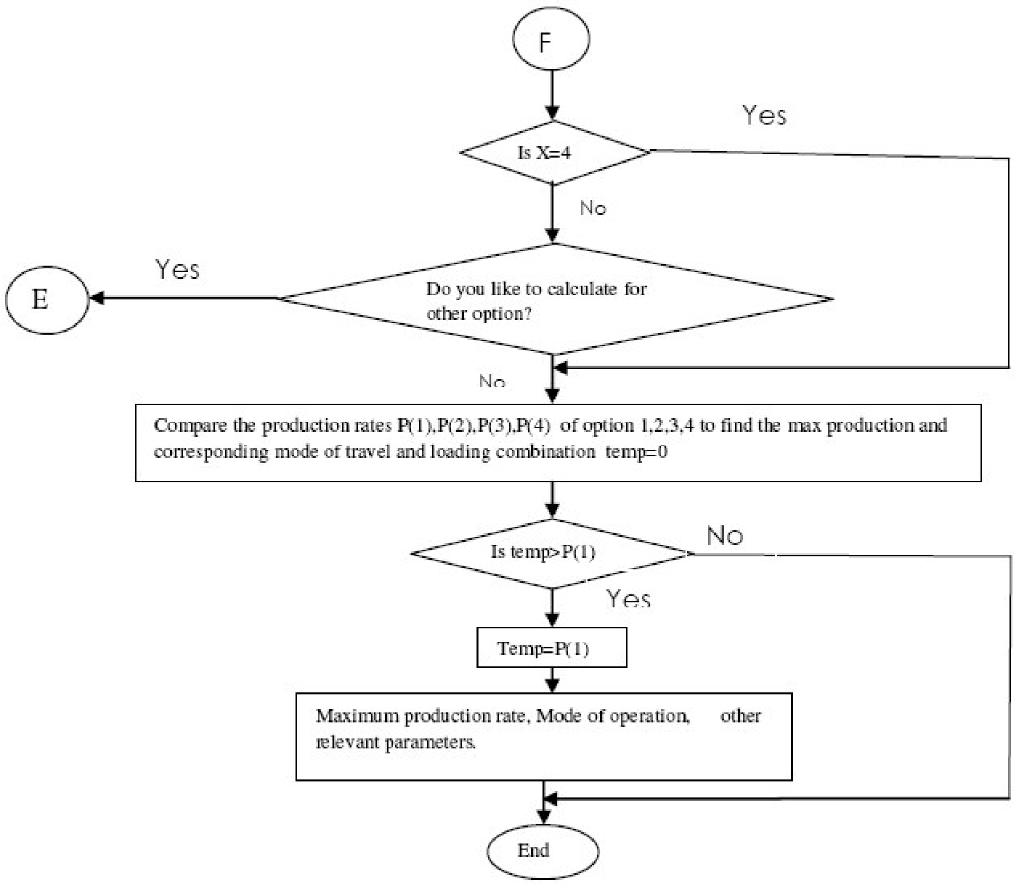

Figure 4d. Selection of optimum mode of operation and computation of optimum production

Figure 4. Flow sheet of the software used for developing the programme.

Cutting speed = 22 m/min
Empty travel speed = 25 m/min
Turning time = 4.6 min
Length of face = 212 m
Production for empty travel back and conveyor loading is=216.08 tonnes/h
Production for empty travel back and windrowing is = 235.91 tonnes/h
Production for turn back and conveyor loading is = 268.81 tonnes/h
Production for turn back and windrowing is = 300.21 tonnes/h.

Conclusion

The developed software is user-friendly and easily to operate. Thus, it can be used to select the suitable surface miner model and also the optimum mode of operation. Software may suggest a mode of operation as the optimum (windrowing in this case). The software is tested successfully for a case of coal mine, where a SM2100 Surface miner has been introduced successfully. The estimated production and actual productions are also quite similar. However, it is strongly recommended to carry out financial analysis prior to deployment of surface miner. In future, all those (including financial assessment) would be given in a nutshell in the software.

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