CHAPTER 4

ANALYTICAL COMPUTATIONS TO EVALUATE LOAD, RESISTIVE FORCE AND OPTIMIZATION FUNCTION

4.1 Evaluation of load on bucket under static conditions

The present analysis is done in the static conditions in which hitch element and arc anchors have been considered to be fixed. The load has been applied at the base of the bucket. Two conditions have been taken into consideration for the load calculation (i)empty bucket (ii) and filled bucket condition. The load computations are given as:

4.1.1 Empty bucket condition

The self-weight of the bucket for $62m^3$ size in mine A is 70 ton approx.

$F_1 = 70 \times 10^3 \times g$ N

$F_1 = 7 \times 10^5$ N

Where,

F_1= Applied load

g= acceleration due to gravity taken as 10 m/s^2

4.1.2 Loaded bucket condition

In this condition bucket is filled with material. Material has been taken as sandstone having density 2.40 ton/m^3.

$m = \rho \times V$

$m = 2400 \times 62$

$m = 148800$ kg

Total mass =mass of bucket+ mass of sandstone

=70000+148800

=218800 kg

Total load = m x g x f

F_2 =218800x10x0.85

F_2 =18.59800x10^5N

Where,

m= mass in kg

ρ= density of sandstone ton/m^3

V= volume of the bucket in m^3

f= bucket fill factor

4.2 Evaluation of resistive force in dynamic condition

Cutting equipment vary according to their contact widths from wide to narrow. For instance, a tillage machine makes use of a narrow width cutting blade to transport the formation. A dozer earthmover on the other hand makes use of its extensive width of the blade. Cutting force varies in accordance with the width of the cutting element. If the cutting blade isn't very huge, a large quantity of material moves to the edges of the plane, which causes the side effect. Two-dimensional cutting methods exhibit approaches for wide-blade operations without considering the side effect. These methods assume that the operation is done at the infinitely huge plate. On the opposite hand, three-dimensional techniques consist of the side impact for slender blade cutting. However, a bucket does no longer show side-impact conduct like a blade even though the bucket cutting edge is not infinitely wide (Blouin et al., 2001; McKyes, 1985). Since, bucket sides cause the cutting material to move them inside and two-dimensional approach become convenient for this situation (McKyes, 1985), two-dimensional models had been utilized to calculate the resistive forces on the bucket teeth.

As indicated in the Equation (2.8), the total resistive force on the teeth can be estimated from the forces related to the weight of broken rock material, cohesion in the broken rock material, adhesion between tool and rock, surface surcharge pressure and inertia within the broken rock. The resistive forces such as adhesion, surcharge, and inertia forces were neglected in the calculation of total resistive force. In this study, the overload pressure due to additional load on the formation surface, leading to increased compaction of the formation, has been neglected. Moreover, the adhesion force can be described as the force of attraction between different materials. In the study, rock and the bucket teeth are two distinct materials and adhesion between them was assumed as zero. Also, the impact of inertia has been observed when the formation is elevated from a resting state at a selected speed (Abo-Elnor et al., 2004). Since constant speed bucket movement was applied in the study, the inertial force was also neglected.

In the observation, bucket teeth depth is 0.512 m depth. Therefore, the weight of the formation body was included in the earth passive pressure system. Thus, cohesion force was taken into consideration of resistive force calculation. Therefore, weight and cohesion force have been taken for computation of resistive forces.

Accordingly, the cutting force equation from the given model, Equation (2.8), is re-arranged as follows:

$$T = w(\gamma g d^2 N_\gamma + \; c d N_c) \tag{4.1}$$

Where

w = cutting width in (m)

γ = density of overburden (t/m^3)

g = gravitational acceleration (m/s^2)

d = teeth depth (m)

c = cohesion strength of overburden (kPa)

N_y = weight factor

N_c = cohesion factor

In equation (4.1), the value of Nc and Nγ , taken from the charts generated by Hettiaratchi and Reece (1974). McKyes (1985) states that, Hettiaratchi's charts for N-factors can be used efficiently for the fast solution of passive earth pressure formula. Charts only give N-factors for the situations of δ=0 and δ= φ.

$$N = \; N_0 \; + \; (N_\varphi \; - \; N_0)\frac{\delta}{\varphi} \tag{4.2}$$

In equation (4.2):

δ = external friction angle

ϕ = internal friction angle

N = N factor for a specific external friction angle

N_0 = N factor where external friction angle is zero

$N_{\phi} =$ N factor where external friction angle equal to internal friction angle

Calculation for N_y and N_c

if δ = 0

ϕ = 40^0, α = 45^0 From Table 3.1

Then $N_0 = 1.1$ and $N_\phi = 2.8$ From Figure A.1 and Figure A.2 (see Appendix A)

These values put in equation (5.11) and find the value of N_y

$N_y = 1.1 + (2.8-1.1)30/40$

$N_y = 2.375$

Similarly, for N_c

When $\delta = \phi$

Then $N_0 = 0.8$ and $N_\phi = 4.2$ From Figure A.3 and Figure A.4 (see Appendix A)

$N_c = 0.8+(4.2-0.8)30/40$

$N_c = 3.4$

w = 4 m , c = 25 kPa, d =0.512 m, and $\gamma = 2$ ton/m^3

Putting these values in equation (4.1), we get, the total cutting force

$T= 4x\,[2x9.81x0.512^2\, x2.375+ 25x0.512x3.4]$ KN

T = 222.94 KN

Surface area of tooth (A)= 0.24749 m^2

Unit force for each tooth (F)= 222.94 / 6 =37.1566 KN

Pressure on each tooth (P_1) = force / area

$P_1 = 37.1566$ KN / 0.24749m^2

$P_1 = 150.13374$ KN/m^2

Normal pressure on tooth $P_t = P \times \cos\delta$

$= 150.13374x \cos30$ [$\delta = 30^0$ From Table 3.1]

$P_t = 0.1300$ MPa

Total pressure on teeth (P) = 6 x 0.130

= 0.78 MPa

4.3 Determination of optimization function between resistive force and teeth angles

During the cutting action various forces act on the bucket teeth, and these forces depend upon the different angle of bucket teeth. To develop a relationship between the resistive force and different angles of bucket the equation 4.1 has been used.

The resistive force is usually affected by the characteristic of the medium under excavation. We know that the equation of the N_y and N_c in terms of angle.

$$N_y = \frac{cot\alpha + cot\beta}{2[cos(\alpha+\delta) + sin(\alpha+\delta)cot(\beta+\varphi)]} \tag{4.3}$$

$$N_c = \frac{[1 + cot\beta cot(\beta+\varphi)]}{[cos(\alpha+\delta) + sin(\alpha+\delta)cot(\beta+\varphi)]} \tag{4.4}$$

In equation (4.1) put the value of N_y and N_c we get

$$T = \frac{w[\{\gamma g d^2(cot\alpha + cot\beta)\}}{2\{cos(\alpha+\delta) + sin(\alpha+\delta)cot(\beta+\varphi)\}} + \frac{cd\{1 + cot\beta cot(\beta+\varphi)\}]}{\{cos(\alpha+\delta) + sin(\alpha+\delta)cot(\beta+\varphi)\}} \tag{4.5}$$

This equation (4.5) is a fitness function equation which is used in MATLAB and optimise the function.