Developing Codes For Rock Cutting Process

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Abstract—In any Rock cutting process knowledge on rupture is necessary for tool wear estimation. Tool wear is a rupture process which is obtained by rubbing action either between tool and rock . So this paper shows Cutting Codes for rock cutting process. Usually in a Rock cutting process cutting temperatures, strains and stresses will be generated. The main objective of this paper is to develop codes for solving mathematical values of rock cutting process.

Index Terms—MATLAB Codes, Tool wear appliances, Chip Propagation.

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1 INTRODUCTION

In India, agriculture plays a predominant role especially for hill cultivation rock cutting help in farming, when cutting a rock under high pressure the cultivator or tool gets high pressure which causes frequent or regular failure of tool [1].Various Metal addition process came in market of India, in zones of Bangalore where tools are manufactured using CAD software's and Vacuum Casting techniques [2]. For metal reduction process a thorough study of Metal Cutting is required because of temperature rise at the tip of tool/ workpiece interface which leads to plastic flow and dimensional deformation. Machining process is consistent on dimensional accuracy and surface finish [3]. A thorough optimization of cutting process is required because the tool breaks down due to friction. For a designer the profile of tool and its wear are the basic areas of interest. Flexible Manufacturing plays a vital role in change of tool geometry and design of experiments [4]. Finite Element Method, Finite Difference Method, Finite Element Analysis with Analysis software's are widely used in product design and development[5-23]. FEM have even become a vital tool in analysis of cutting process. This paper focuses on developing Machining codes for chip and tool rock interface using MATLAB

2 TOOL WEAR APPLIANCES

The exact rock cutting is subdivided into scientific wear mechanisms such as Abrasive, Adhesion, Diffusion, Oxidation & Fatigue. Throughout cutting process tougher materials acts as grinding wheel and confiscates softer materials due to sliding which is Abrasive wear. Fragments of softer materials sticks to the metal throughout sliding which is Adhesion. Diffusion is a phenomenon in which particles of hard materials disperses into softer. Oxidation is the outcome of reaction amongst tool surface and oxygen. Fatigue is the roughness of single surface affected due to sliding which knits the other surface.The standards for tool life is eminence of machined surface, degree of cutting force & cutting temperature.Tool wear is due to the rupture between rock and the cutting tool. It is predicted by various models. Gray, Markov Chain, tool wear by state division. Secondly wear prediction of tool is dueto chip propagation, temperature generation, wear rate at nodal points; flank face and on rake. This paper introduces MATLAB as a simulation programming language to develop engineering analysis through programming. The main moto is to solve mathematical analysis through MATLAB programming language. Gray mode is a forecasting time related model. This technique uses differential equations which can be implemented to cutting process.

Program to predict rock cutting process value at a particular cutting time.

1.Goal: Compute $x^{(0)}_{(k+1)}$ at time (k+1)

2.Analysis:

$$X^{(0)}_{x0} = \{ x^{(0)}(1), x^{(0)}(2)--- x^{(0)}(i)--- x^{(0)}(n) \} \quad (1)$$

Where $x^{(0)}(i)$ is the time series data at time i, and n must be equal to or larger than 4.

On the basis of the initial sequence $X^{(0)}$, a new sequence $X^{(1)}$ is set up through the accumulated generating operation in order to provide the middle message of building a model and to weaken the variation tendency.

$$X^{(1)}_{x1} = \{ x^{(1)}(1), x^{(1)}(2)--- x^{(1)}(i)--- x^{(1)}(n) \} \quad (2)$$

Where

$$x^{(1)}(k) = \sum_{1=1}^{k} x^{(0)}(i \quad (3)$$

k = 1,2---n

Mean Sequence is

$$Z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1) \quad (k= 2,3,---n) \quad (4)$$

That is

$$Z^{(1)}_{z1} = (z^{(1)}(2), z^{(1)}(3), --- z^{(1)}(n)) \quad (5)$$

This is expressed as

$$x^{(0)}(k)+az^{(1)}(k) = b \quad (k= 2,3,---n) \quad (6)$$

Equations can be expressed as

$$\begin{bmatrix} x(0)(2 \\ --- \\ x(0)(n \end{bmatrix} = \begin{bmatrix} -z(1)(2) \\ --- \\ -z(1)(n) \end{bmatrix} \times [\quad (7)$$

a & b are coefficients.

$$Yn = [x^{(0)}(2), x^{(0)}(3)---x^{(0)}(n)]^T \quad (8)$$

$$B = \begin{bmatrix} -z(1)(2) \\ --- \\ -z(1)(n) \end{bmatrix} \quad (9)$$

$$Z_{z1}^{(1)}(k+1) = 1/2(x^{(1)}(k)+x^{(1)}(k+1)) \quad k= 1,2---(n-1) \quad (10)$$

$$A = [a,b]^T \quad (11)$$

By Least Square Method to Eq. (7) throughEqs. (8) to (11) A is

$$A = (B^T B)^{-1} B^T Y_n \quad (12)$$

Inserting A in Eq.(7) along Eq. (12) then

$$x^{(0)}_{x\_hat\_0}(k+1) = x^{(1)}(k+1) - x^{(1)}(k) \quad (k=0,1,2,3----,n) \quad (13)$$

3.Algorithm:

- Sequence of calculating for each term
- To get final term combined with individual terms

4. MATLAB Code:

```
%3.1 Prediction theory of gray model
X0 = [0,2,3,4,3]; % columns should not be less that 4
n = size(X0)(2);
X1=[ ];
for k=1:n
x=0;
for i=1:k
 x=x+X0(i);
end
X1=[X1,x];
end
 Z1=[ ];
for k=2:n
 z=0.5*X1(k)+0.5*X1(k-1);
 Z1=[Z1,z];
end
Yn = X0(2:end)';
B=[-Z1',ones(size(Z1')(1),1)];
A=((inv(B'*B))*B')*Yn; % A=[a,b]'
a=A(1);
b=A(2);
 x_hat_1=[ ];
for k=0:n
x_k1= (X0(1)-b/a)*exp(-a*k)+b/a;
x_hat_1=[x_hat_1,x_k1]; %predicted value
end
x_hat_0=[];
for k=1:n
x0_k1=x_hat_1(k+1)-x_hat_1(k);
x_hat_0=[x_hat_0,x0_k1];
end
 x_hat_0
```

In Monitoring machine tool recognition Hidden Markov Model s (HMMs) speech recognition is elegantly used. It is a mathematical model including Probability functions.

From Markov chain model program to predict probability matrix for cutting process.

1.Goal: Compute $\sum_{j=1}^{n} Pij = 1$

2.Analysis:

$$bj_{b\_jt}(ot) = \sum_{m=1}^{M} cjm\eta(\mu jm, Ujm, O) \quad 1\leq j\leq N \quad (14)$$

where cjm is mixture weightining coefficient, mjm is vector mean, Ujm is co-variance matrix, M is mixture of number of components, with mean vector m and O= [O1, O2,--- O_T] Gaussian multivariate probability density function is

$$\eta_{eta}(\mu,U,O) = \frac{1}{\sqrt{(2pi)^{n}}} exp(-1\backslash 2(O-\mu)^{1} U^{-1}(O-\mu)) \quad (15)$$

Probability conditionality is as

$$P = (x_{n+1}=i_{n+1}| \; x_0=i_0,|x_1=i_1---,|x_n=i_n)=p=(x_{n+1}=i_{n+1}|x_n=i_n) \quad (16)$$

MarkonChain is $\{x_n, n \in T\}$

Therefore

$$P_{ij} = p(x_{m+k}=j| \; x_{m=i}), \; (i, j \in I) \quad (17)$$

In the form of Matrix as

$$P^{(k)} = \begin{bmatrix} p_{11}^{k} & -- & p_{1}^{k} \\ -- & -- & - \\ p_{n1}^{k} & -- & p_{r}^{i} \end{bmatrix}$$

& $\sum_{j=1}^{n} Pij = 1$

3.Algorithm:

- Sequence of calculating for each term
- To get final term combined with individual terms

4. MATLAB Code

```
O=[1,2,3]; % observation sequence
mu =[1,2,3]; % mean vector
U=[5,2,3; 4,5,6; 7,8,9];
n = 3 ; % dimensionality of O.
eta = (1.0/(sqrt(norm(U)*(2*pi)^n)))*exp(-0.5*((O-mu))*inv(U)*(O-mu)');
M=size(U)(2);
N=size(U)(1);
b_jt=[];
c=[5,2,3; 4,5,6; 7,8,9]; %weight matrix
for t=1:n
bj=[];
for j=1:N
b_temp=0;
for m=1:M
eta_jmt =
(1.0/(sqrt(norm(U(j,m))*(2*pi)^n)))*exp(-0.5*((O(t)-mu(j)))*inv(U(j,m))*(O(t)-mu(j))
');
b_temp=b_temp+c(j,m)*eta_jmt;
end
bj=[bj,b_temp];
end
b_jt=[b_jt,bj'];
end
b_jt
```

In tool wear prediction a mathematical approach with standard deviation and method of parallel curves is incorporated.

Program to predict probability matrix for tool wear

1.Goal: Compute $p_i = M_{ij}(k)/M_i$ i,j = 1,2---n

2.Analysis:

$Q_i = |Q_{1i,} Q_{2i}|$, i= 1,2---n
$Q_{1i} = x^{(0)}(k) + C_iC$
$Q_{2i} = x^{(0)}(k) + D_iD$
(18)

Based on tool wear C_i& D_i are constant vectors.

Transition Probability matrix is

$p_i = M_{ij}(k)/M_i$ i,j = 1,2---n
(19)

3.Algorithm:

- Sequence of calculating for each term
- To get final term combined with individual terms

4.MATLAB Code

```
%input
X0=[1,2,2];
k=1;
C=[1,3,2];
D=[5,3,2];
 n=3 % dimension of D or C
% calculation
Q1=zeros(1,n);
 Q2=zeros(1,n);
Q=[ ];
for i=1:n
 Q1(i)=X0(k)+C(i);
Q2(i)=X0(k)+D(i);
Q=[Q;[Q1(i),Q2(i)]];
end
Q
%---------
%Input
Mk=[1,2,4; 3,5,6; 8,6,4];
M=[10,20,30];
% calculation
Pk=zeros(n,n);
for i=1:n
for j=1:n
Pk(i,j)=Mk(i,j)/M(i);
end
end
Pk
%----------
%input
x_hat_0=[1,3,4];
A=[2,3,4];
B=[4,5,6];
% calculation
Y=[ ];
for k=1:n
y_temp=0;
for i=1:n
y_temp=y_temp+x_hat_0(k)+(A(i)+B(i))/2.0;
end
Y=[Y,y_temp];
end
Y
```

Program to predict strain effects of path and damage-parameter

1.Goal: Compute $w = \sum(\frac{\Delta}{\epsilon})$ $\frac{delta\_epsilo}{epsilon\_f}$

2.Analysis:

Flow stress expression with effects of strain path is

$\sigma = (B\epsilon^n)$ $[1+C \ln(\frac{}{1})][(\frac{\theta m}{\theta m-})+a \exp(-0.00005(\theta - 7)^2)]$ (20)

ϵ, θ, θ_m, θ_r, are stain rate, strain, melting point temperature and room temperature.

The parameter for damage is

$$w = \sum(\frac{\Delta}{\epsilon}) \quad \frac{delta\_epsilo}{epsilon\_f} \quad (21)$$

3.Algorithm:

- Sequence of calculating for each term
- To get final term combined with individual terms

4.MATLAB Code

```
%inputs  no_of_increments=
% initial value of
delta_epsilon_f=epsilon_f=
%damage parameter
 w=0
for increments=1:no_of_increments
 w = w+delta_epsilon_f/epsilon_f
% update formula for delta_epsilon_f and epsilon_f goes here
end
```

Heat flux is generated between tool surface and rock layers

Program to predict heat flux in the cutting tool
1. Goal: Compute $q^c = k(\theta_B-\theta_A)$

2.Analysis:
The amount of frictional het-flux is calculated bt
$q^r = (1-f)\ \eta\ \tau\ \upsilon_s$
(22)

τ, υ_s, η, f are stress at friction, velocity at sliding, thermal energy from fraction of mechanical energy, fraction of heat creeping into rock.

Conductive heat-flux occurred due to temperature variation of rock and chip interface. It is powered by equation

$$q^c = k(\theta_B-\theta_A) \quad (23)$$

3. Algorithm:
- Sequence of calculating for each term
- To get final term combined with individual terms

4.MATLAB Code

```
%input
f=
eta=
tau=
v_s=
k=
theta_A=
theta_B=
 % amount of frictional heat flux
q_r = (1-f)*eta*tau*v_s
% conductive heat flux
q_c = k*(theta_B - theta_A)
```

Nodal wear rate is time dependent. Before cutting phase nodal wear rate is zero at contact of tool and work piece nodal wear rate exists.

Program to predict average nodal wear rate

1. Goal: Compute wij= $\frac{\int_{t0}^{t0+z} w_{ij}(t}{z}$

2. Analysis:

Nodal wear-rate is

$$w_{ij}= \frac{\int_{t0}^{t0+z} w_{ij}(t}{z} \quad (24)$$

Nodal average wear-rate is

$$wij_{w\_dot\_avg}= \frac{\sum_1^n (w_{ij,k}{}^{w\_dot\_ij}+w_{ij,k+1})\cdot(t_{k+1}{}^{t}-t}{z_z} \quad (25)$$

n is complete milling loop subsegmented into n-1 minute portions by n equally spaced space points.

3.Algorithm:
- Sequence of calculating for each term
- To get final term combined with individual terms

4.MATLAB Code

```
%inputs
Z=
 t=[1,2,3,4];
w_dot_ij=[2,3,4,5];
n=size(t)(2);
%Nodal average wear rate
w_dot_avg_ij = 0;
for k=1:(n-1)
w_dot_avg_ij=w_dot_avg_ij
+(w_dot_ij(k)+w_dot_ij(k+1))*(t(k+1)-t(k))*0.5;
end
w_dot_avg_ij = w_dot_avg_ij/Z;
```

In prediction of tool wear on flank face and rake cutting time on tool wear appears at tool tip which propagates with varying depth on tool rake face.
Program to predict nodal displacement caused by tool wear between two simulation cycles

1. Goal: Compute $\Delta VB_B= \frac{w}{tc}$

2. Analysis:
Nodal movement generated by tool wear between generated two cycles is given by

$$\Delta d_{i,k} = w_{i,k}\Delta t_k,\ \ i= 1,\text{---}N \quad (26)$$

To an infinitesimal time increment dt is given by

$$\Delta VB_B= \frac{w}{tc} \quad (27)$$

3. Algorithm:
- Sequence of calculating for each term
- To get final term combined with individual terms

4. MATLAB Code

```
 %input
t=[1,2,3];
w_dot = [1,2,3; 4,5,7;2,3,1];

n=size(t)(2);
N=size(w_dot)(1);
for k=1:(n-1)
delta_t=t(k+1)-t(k);
for i=1:N
delta_d(i,k)=w_dot(i,k)*delta_t;
end
end
```

4 Conclusion

This paper shows the code development for theoretical analysis of tool wear due to rock cutting. Codes are developed in MATLAB for various Hidden Markov models to predict tool wear due to cutting temperature, interface stresses and strains. The codes were developed for the following aspects:

- The keen insight for tool wear probability is done for Markov Chain probability analysis. A discrete-weight variables aligned into a number of segments by available transitions is done through coding.
- Coding is done for the movement of tool rock interface.

References

[1] A.K.Matta, "C-Based Design methodology and topological change for an Indian Agricultural tractor component," journal of the Institution of Engineers(India): Series A., Springer, vol.04, issue.13, pp.375-378, 2017.

[2] A.K.Matta, "The integration of CAD/CAM and RapidPrototyping in Product Development A review,"

elseiver, procedia material science pp.3438-3445,vol.2,2015

[3] A.K.Matta, "Metallic Product Prototyping, testing and web visibility for manufacturers," Reference module in materials science and Materials engineering, Oxford, Elsevier, 1-10, 2018doi:10.1016/B978-0-12-803581-8.11438-9.

[4] Xie L, "Estimation of two-dimension tool wear based on finite element method,"karisruhe university, 2004.

[5] A.K.Matta,N.Tamiloli, P.S.Prem Kumar, S.Mohanty, S.S.Pattnaik"Experimental analysis of Erosive behavior on Al-Sicp based MMC using micro particle (Al_2O_3) as Erodent", IOP Conference Series: Material science and engineering, 455(1), , pages 012094, 2017.

[6] A.K.Matta, K.ShyamPrasad,I.Jayanth "Metal Prototyping the future of Automobile Industry: A review", elseiver, procedia material science, materials today proceedings 5(9),17597-17601,2018.

[7] A.K.Matta, K.ShyamPrasad,JayanthChavali, Adapa Dinesh Babu, Adhityakumar Chukka, "Computer-aided Engineering for four wheeler accelerator pedal", IJPAM, vol.18, issue 24, 2018. PP.1-10, ISSN:1314-3395

[8] A.K.Matta,N.Tamiloli, P.S.Prem Kumar, S.Mohanty, S.S.Pattnaik"Problems and Challenges in MMC contributing to RP ", IJMTST, vol.04, issue 1, 2017 ISSN: 2455-3778.

[9] A.K.Matta,"Preparation and toughness studies of Acetal (POM) & PTFE blend", vol.no.2,issue 12,IJMTST, dec 2016, ISSN:2455- 3778, pp 63- 67.(

[10] A.K.Matta,"Modeling of micro turbine for Rapid prototyping", vol.no.2,issue 7,IJMTST, july 2016, ISSN:2455- 3778, pp 19- 22.

[11] A.K.Matta, Dr.D.RangaRaju, Dr.K.N.S.Suman "Modeling and optimization of Rapid prototyping for an Agricultural Tractor component", Discovery Engineering, 2016. vol.04, issue.13, pp.375-378, ISSN:2320- 6675.

[12] A.K.Matta, Dr.D.RangaRaju, Dr.K.N.S.Suman, "3D Design support and software compensation for Rapid Virtual prototyping of Tractor Rockshaft arm", Taylor and Francis, CRC PRESS, Balkema publication, 2015.ISBN 978-1-138-02849-4, PP.91-94.

[13] A.K.Matta "Optimization of Brake rotor by using Taguchi method and 3D Finite Elements ",IJAER, ISSN 0973-4562 Volume 10, Number 13, pp 33175-33177 (2015).

[14] A.K.Matta, A.S.Kranthi "Fabrication of a six- Legged robot with crank and slotted lever mechanism using RF communication ", IJAER, ISSN 0973-4562 Volume 10, Number 13, pp 33170-33174 (2015).

[15] A.K.Matta, "Optimization of operation parameters on a Novel internally ventilated cross drilled disc brake by using Taguchi Method " IJESTA ISSN 2395-0900 Volume 1, Number 5 (2015), pp. 8-14

[16] A.K.Matta,Dr.R.UmamaheswaraRao,Dr.K.N.S.Suman,Dr. V.Rambabu, "Preparation and characterization of Biodegradable PLA/PCL polymeric Blends", elseiver, procedia material science 6 (2014) pp.1266-1270.

[17] A.K.Matta ,V.Purushottam, Dr.R.UmamaheswaraRao, "Brake Rotor Design and Finite Element Analysis" IJMER ISSN 2249-0019 Volume 4, Number 1 (2014), pp. 29-33

[18] K.PrasadaRao, G.Anuradha,M.Anil Kumar, R.UmamaheswaraRao"The Six Sigma Approach To Reduce Specific Roll Consumption In Medium Merchant & Structural Mill"(IJREST) ISSN 2250-3676Volume 2, Issue 1 July-Sept.,2013, pp 120-129.

[19] A.K.Matta ,V.Purushottam, R.UmamaheswaraRao, Dr.C.L.V.R.S.V.Prasad "Construction of a Test Bench for bike rim and Brake Rotor" IOSR Journal of engineering (IOSRJEN) ISSN: 2250-3021 Volume 2, Issue 8 (August 2012), PP 40-44

[20] A.K. Matta, R.B. Pothula and R.U. Rao "Design and Analysis of Steam Turbine Blades using FEM" International Journal of Mechanical Engineering Research. ISSN 2249-0019 Volume 2, Number 2 (2012), pp. 67-73,2012.

[21] A.K Matta, D.VenkataRao, P.RameshBabu and R. UmamaheswaraRao " Analysis of Gas Turbine blades with materials N155 and INCONEL 718" International Journal of Advances in Science and Technology, Vol.4,No.1, pp 46-50, 2012.

[22] A.K.Matta, D.VenkataRao and A.SwarnaKumari "Convective Heat Transfer Analysis of Gas Turbine Blades Using Finite Element Method",IJMER , Vol1,no.3, pp 391-397 , 2011.

[23] A.K.Matta ,"Development and Impact Testing of a pultruded composite material highway guardrail" Research Journal of engineering and Technology(RJET) ISSN: 0976-2973 Volume 4, Issue 3 July-Sept.,2013, pp 132-135.