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Effect of spike parameter quadratic fit on wear in excavator bucket

The main purpose of this work is to identify the relation between particle shape parameter and complex wear mechanism that usually occurs in heavy earth moving machines (HEMM) used in open pit mines. In this work the wear phenomenon has been analyzed for the bottom plate of buckets used in excavators like shovel and dragline. Abrasive particles having different shape parameter present in earth material has been collected for measuring the shape parameter. An attempt has been made to evaluate the particle geometry by calculating its spike parameter quadratic fit, which indicates the value of the spikes present in the particle periphery. Particles having different spike parameter have been analyzed and noticed that the wear is varied with respect to the particle spike parameter.

Keywords: *Wear; abrasion; spike parameter; HEMM*

I. Introduction

Till date lots of attempt has been made by the researchers to quantify wear for dry sliding phenomena by the means of different parameters like particle size [1, 2] abrasive hardness [3, 4] load and speed [5, 6]. But only very few has been tried to reach the goal by means of analyzing the particle shape parameter. Yuhbdir et al [7] calculate angularity in terms of the average number of the tangent; Lees [8] calculated value for a single corner. It has also been reported that the particles having different shape factors also have different abrasivity, and have direct influence on wear [9-12]. From the literature it has been observed that the measurement of particle angularity is the most necessary step to evaluate particle angularity [13-14].

In this work granite stone chip has been used as abrasive particle. An experimental set up has been used for the particle collection on random basis. At the different interval of the experiment particle has been collected for the purpose of the measuring its spike parameter. Corresponding wear rate on the surface used are also measured at the same time interval.

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II. Methodology

In our previous work [15] we have explained the detail of our experimental set up, in which a prototype of excavator bucket rotated inside a container filled with the stone chips as overburden material. The experimental set up was remaining unchanged for our present work and the abrasive particle collect randomly at every 9 hours of the experiment. It is observed that the abrasive particles used in the experiment loose its abrasivity with time as the spikes of the particles become partially rounded. At every interval four abrasive particles have been collected to calculate spike parameter.

A. Spike Parameter Calculation

In order to calculate spike parameter of any particle it is required to extract particle boundary from its image. This extracted boundary is considered as the profile of the abrasive grit in which wear depends and the spike parameter of that profile is considered as the direct measure of the abrasivity of that profile. Initially particle boundary has been extracted from the image of the abrasive grits by the image processing technique, performed in commercial software MATLAB. The spike parameter calculation of that particle boundary is then determined by involving the following steps which is also available in open literature [9-12].

1. The approximate particle boundary centroid $(\bar{x}, \bar{y})$ is located and a circle with average radius ($\bar{r}$) is drawn. The perimeter center, $\bar{x}, \bar{y}$ is then calculated to determine average radius ($\bar{r}$). (Fig.1)
2. The areas outside the average radius circle, consist the spikes (defined by $r >$) are considered to be responsible for material removal, while the areas inside the circle are considered not to be a part of wear mechanism.
3. The spikes outside the boundary are defined by a start point (*sp*) where it first crosses the circle, midpoint (*mp*) where r is maximum for that spike and end point (*ep*) where it crosses the circle again.
4. The first side (*sp-mp*) of the first spike is rotated about sp by ϕ_1, to the x-y axis. This results in *sp-mp* being collinear with x'-axis. (Fig.2).
5. The polynomial (in this case quadratic) is fitted to the boundary segment sp-mp in the x'–y' coordinate system.

We have to differentiate the function then solve at *mp* to find its slope and from that we are getting α_1. The local slopes are represented by angles α_1 and α_2

6. Again repeat steps (4) and (5) for second side (*ep-mp*) to find $\alpha_{2.}$ (Fig.3)
7. $\phi_{1,}$ $\phi_{2,}$ α_1, α_2 is then used to determine apex angle (θ) at *mp* for spike 1.
8. Repeat the steps from (4) to (7) for all other spikes present in the particle boundary in order to calculate the value of apex angle.
9. The spike value i.e. *SVQ* is calculated by the following formula. $SVQ = \cos(\theta/2)$.
10. So average all *SVQ* for boundary is done to find spike parameter (quadratic fit), $SPQ = SVQ_{average}$.

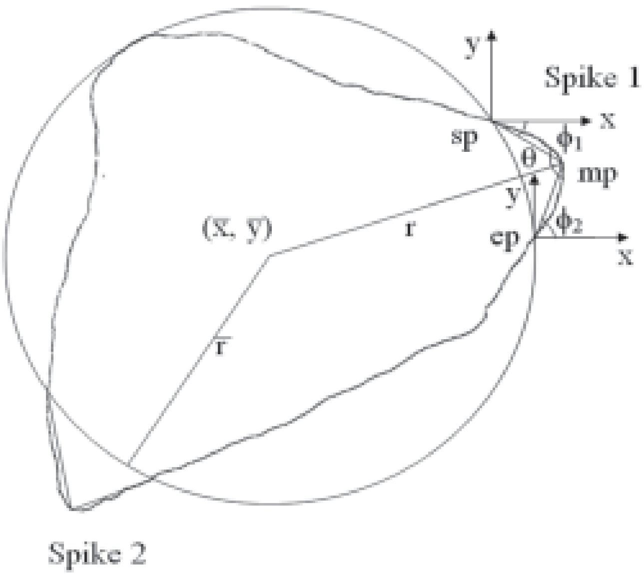

Fig.1 Spike parameter calculation

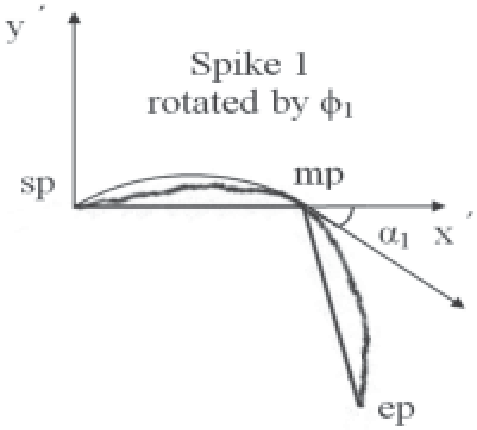

Fig.2 sp-mp rotation

III. Result and discussion

The available literature about the evaluation of spike parameter indicates the two dimensional boundary analysis

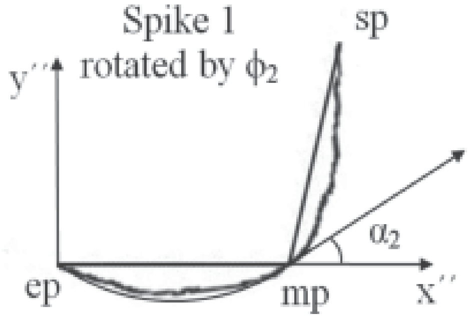

Fig.3 ep-mp rotation

of a three dimensional object, here the abrasive particle. The spikes present on that boundary are considered to be responsible for material removal. The most important thing, which has been ignored while evaluating the spike parameter are the presence of other spikes, which actually present in the particle, but not visible from the angle at which the image of the particle has been taken. To override this shortcoming a new method has been opted. The particle is rotated 360º about X, Y and Z axis. In every 45º interval of each rotation an image of the particle has been captured to extract its boundary profile. It has been observed that this method reveals the existence of other different boundaries having different spike parameter for the same particle. Particle boundaries obtained in X, Y and Z rotation are shown in Figs.4, 5 and 6 respectively.

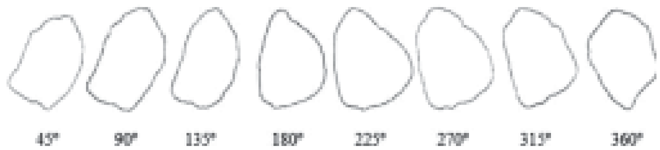

Fig.4 Rotation along X axis

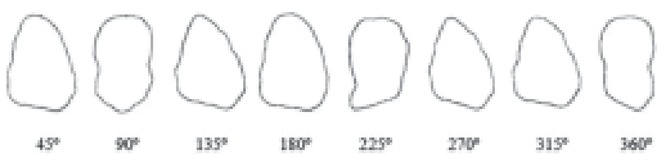

Fig.5 Rotation along Y axis

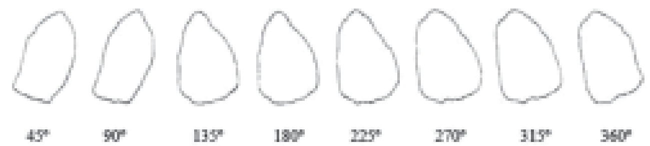

Fig.6 Rotation along Z axis

Values of *SVQ* obtained are demonstrated in Table I.

The particles collected, are grouped into three population (a) Approximately round particle (Fig.7, (b) Medium sharp particle (Fig.8) and (c)

Sharp particle (Fig.9). Four particles of each group are selected for experiment and for each group wear volume

TABLE: I SVQ VALUES OF A PARTICLE AT INDIVIDUAL ANGLE OF DIFFERENT AXIAL ROTATION

Rotation	SVQ at								SVQ_{avg}
axis	45^o	90^o	135^o	180^o	225^o	270^o	315^o	360^o	
X	0.3467	0.3213	0.3420	0.1993	0.3007	0.2840	0.3090	0.3012	0.3005
Y	0.173	0.4226	0.2588	0.1822	0.5446	0.2079	0.2164	0.3987	0.3006
Z	0.4539	0.3699	0.2503	0.2672	0.3502	0.4305	0.3987	0.3461	0.3583
$SPQ=[(SVQ_{avgX} + SVQ_{avgY} + SVQ_{avgZ})/3]$									0.3198

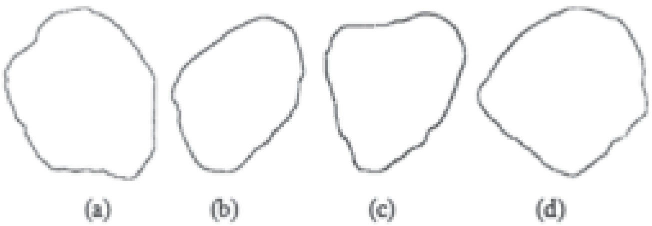

Fig.7 Approximately rounded particle

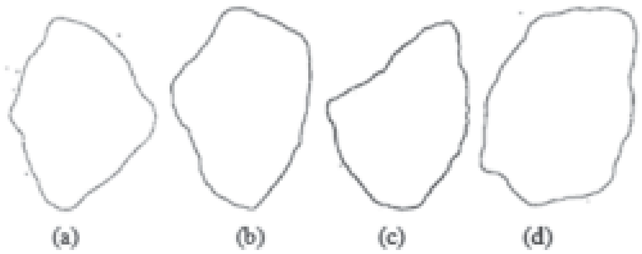

Fig.8 Medium sharp particle

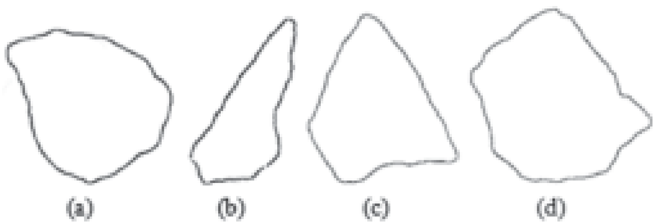

Fig.9 Sharp particle

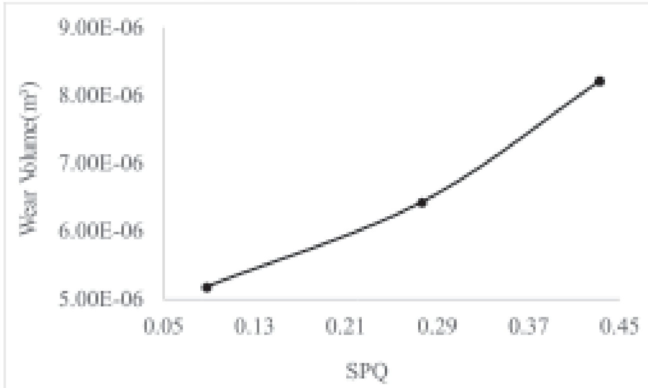

Fig.10 SPQ vs. wear volume

TABLE: II SPQ VALUES OF ALL THE PARTICLES COLLECTED

	Population	SVQ				SPQ = $SVQ_{average}$	Wear Volume(m^3)
		a	b	c	d		
1	Approximately round particle	0.0108	0.0718	0.1047	0.1652	0.0881	$5.172*10^{-6}$
2	Medium sharp particle	0.2537	0.3127	0.2974	0.2419	0.2764	$6.420*10^{-6}$
3	Sharp particle	0.4177	0.4652	0.4305	0.4191	0.4331	$8.211*10^{-6}$

measured are given in tabulated format (Table II).

A graph (Fig.10) of SPQ vs. wear volume is also plotted to observe the relation between SPQ and wear

IV. Conclusions

In this work, the abrasive particles have been collected at different time interval to calculate the spike parameter quadratic fit. The conclusions are made from the analysis are:

- Every particle has been rotated 360° in three directions. In every 45° interval particle boundary has been extracted to calculate spike parameter.
- In the above method spike parameter of every abrasive particle has been calculated very accurately.
- Wear on the surface has been measured at the same time interval in which the particles were collected to measure spike parameter.
- It has been observed that with the increasing value of the spike parameter quadratic fit wear is also increasing.
- Spike parameter can be used to characterize particle abrasivity and angularity.

References

[1] Sasada T., Oiie M., Emori N., (1984): The effect of abrasive grain size on the transition between abrasive and adhesive wear, *Wear*, vol 97, pp.291-302.

[2] Mishra M., Finnie I., (1981): On the size effect in abrasive and erosive wear, *Wear*, vol 65, pp 359-373.

[3] Hokkirigawa K., Kato K., (1988) The effect of hardness on the transition of the abrasive wear mechanism of steels, *Wear*, vol 123, pp 241-251.

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- If designing of theoretical model would be done in same platform where analysis is to be made then more accurate results would be obtained.
- More extensive work can be done to replace the existing traditional materials and which are under use without any deep study.
- A dynamic study can be conducted in software like ADAMS if hydraulic interface is to be created between the ripper and hydraulic cylinders; also there are other platforms too for designing as well as simulation like use of Neural Network, Abaqus, and Matlab.
- Similar study can be conducted for a single shank giant ripper. A transient vibrational analysis can be done using ANSYS for impact ripper too.

References

[1] Intensity Analysis and Structural Optimization on the Rack of the Ripper, paper by Keli Zhao, Yawei Zhao, Zhen Shi, Wen Li Ye, Chuabin Zheng in International Conference on Advances in Construction Machinery and Vehicle Engineering (ICACMVE-2013) ISBN: 978-1-60595-128-7.

[2] Caterpillar Handbook of Ripping 12th Edition, Ripping Equipment Selection, 13.

[3] BEML's BD155, CATERPILLAR's D8T and KOMATSU's D155 catalogue.

[4] Visualization of Strain influence on cutting edge of different Austempered Ductile Iron (ADI) products: FEA in Dozer Blade with ANSYS R 15.0, paper by Dalgobind Mahto and N E Mastorakis from Jaipur Institute of Engineering & Technology, Jaipur, India and Technical University of Sofia, Bulgaria respectively in Conference on Advances in Information Science and Computer Engineering.

[5] Data Sheet 151en Hardox 400 2014-06-03.

[6] Conquest Steel and Alloys, SAILMA Steel Plates, Grades and Sheets, SAILMA 450HI.

[7] Chapter- Structural Steel: Types, Properties and Products.

[8] Bulldozer BD155 Shop Manual, Work Equipment, Maintenance Standard, 54-1.

[9] United States Patent, Oct.4, 1983 "Pivotally Mounted Ripping Teeth Assembly on Dozer Blade".

[10] "Replacement Wear Parts for Caterpillar Machinery", Replacement Ripper Parts for Dozers & Loaders, 13-19

[11] Identification of the Forces on a Bulldozer Ripper with a Neural Network Methodology by Miguel Curinha Samarra and Luis Manuel Roseiro, Department of Mechanical Engineering Coimbra Institute of Engineering – Polytechnic Institute of Coimbra Rua Pedro Nunes – Quinta da Nora 3030 – 199 Coimbra – Portugal.

[12] Transient Vibration Analysis of Impact Ripper by Gening XU and Meng HE, Jian-feng WU, College of Machinery Engineering, Taiyuan University of Science & Technology, Taiyuan,030024, P.R. China.

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(Continued from page 195)

[4] Torrance A. A., (1981): A new approach to the mechanisms of abrasion, *Wear*, vol 67, pp 233-257.

[5] Wang A. G., Hutchings I. M., (1981): The number of particle contacts in two-body abrasive wear of metals by coated abrasive papers, *Wear*, vol 122, pp 132-133.

[6] Mishra M., Finnie I., (1981): Some observations on two-body abrasive wear. *Wear*, vol 68, pp 41-56.

[7] Yudhbir, Abediazadeh R., (1991): Quantification of particle shape and angularity using the image analyzer. *Geotechnical Test. J*. vol 14, pp 296-308.

[8] Lees G. (1964): A new method for determining angularity of particles. *Sedimentology*, vol 3, pp 2-21.

[9] Hamblin M. G., Stachowiak G. W., (1995): A multi-scale measure of particle abrasivity and its relation to two body abrasive wear, *Wear*, vol 190, pp 190-196.

[10] Hamblin M. G., Stachowiak G. W., (1995): A multi-scale measure of particle abrasivity, *Wear*, vol.185, pp.225-233.

[11] Hamblin M. G., Stachowiak G. W.,(1996): Description of abrasive particle shape and its relation to two-body abrasive wear, *Tribology Transaction*, vol 39, pp 803-810.

[12] Stachowiak G. W.,(2000): Particle angularity and its relationship to abrasive and erosive wear, *Wear*, vol 241, pp 214-219.

[13] Torrance A. A.,(1981): An explanation of the hardness differential needed for abrasion. *Wear*, vol 68, pp 263-266.

[14] Winte R. E., Hutchings I. M., (1974): Solid particle erosion studies using single angular particles. *Wear*, vol 29, pp 181-194

[15] Sarkar M., Ghosh S. K., Mukherjee P. S., (2015): Analysis of Wear Generation in Mine Excavator Bucket. *Industrial Lubrication and Tribology,* vol 67/1, pp 52-58.