Determining the Value of Archard's Co-efficient on the Bottom Plate of Excavator Bucket: An Experimental Approach

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***Abstract*—Heavy Earth Moving Machines (HEMM) is used mainly for opencast mining and construction works. These machines are used largely for mining to excavate the overburden and the raw materials e.g. coal, iron ore, copper etc. Most of the components of these machines are subjected to major abrasion impact and wear. In this paper, the value of Archard co-efficient has been determined for the abrasion phenomena in the bottom surface of the excavator bucket. One most necessary and important goal in engineering is to develop performance relationships between all the variables and parameters in a system, in mathematical form. Similarly, in tribological systems, it is necessary to establish a mathematical relationship between the different variables. Engineers and designers should have equations to predict wear rates. Unfortunately the available equations are not adequate to predict the product life with confidence. So, researchers normally use equations where the parameters are formed from data taken from experimental analysis or theoretical means. Wear of a material is influenced by many factors, including properties of the material, such as hardness, elasticity, yield strength, strain hardening and fracture strain etc. Wear rate on a surface can be normally determined by using Archard's equation, which states that the wear loss is linearly proportional to the sliding distance and the normal load, but inversely proportional to the hardness of the material. The objective of the present work is to observe the abrasion characteristic on the surface of excavator bucket and calculate the value of Archard co-efficient from the data collected from the experimental analysis.**

Keywords—HEMM, Archard Coefficient, Abrasion.

I. Introduction

Several research works has been carried out in past few decades to establish a generalized wear equation, which will be able to predict the wear rate on different tribological system [1]. But unfortunately no equation was found to have been developed strictly from the fundamental and intrinsic quantities of science. Moreover, most of the available equations are empirical and consist of some parameters which are valid for some specific environment. Till date there is no equation that has been developed which will truly valid for every kind of wear mechanism. Due to these constraints Archard's wear equation has been used in this paper. Another reason of using this equation is its simplified form with easily measurable parameters.

Friction and wear on the bottom plate of the excavator bucket is unavoidable. But the rate of wear can be controlled either by some simple modification on the surface or by adding some protective bars [2]. This kind of strategy to minimize wear is widely considered as an effective method of reducing failure of the equipment [3]. Reduction of wear on the mining equipment is one of the challenging activities in mining industry, as it reduces early breakdown possibilities and also prevents increased maintenance cost [4-6]. Maintenance costs are a major part of the total operating costs of all manufacturing or production plants [7] and it covers almost 60% of the total production cost [8]. In different research work, investigators [9–11] clearly demonstrated the strong interaction between loads and sliding velocity to cause wear of a material, some has also expressed the severity of the wear from the calculation of wear coefficient [12–15]. The aim of the recent work is to determine Archard's coefficient for the bottom plate of excavator bucket, experimentally.

II. Methodology

To evaluate Archard's coefficient, it was necessary to collect basic data. For that purpose a set up (Test rig) was fabricated. The test rig consists of a scaled model of excavator bucket, mounted on a shaft, moving inside a container, containing overburden material, which is a typical mixture of coal, clay sand, granite stone chips, as shown in Fig. 1. The shaft has been mounted on the top of the model bucket. One end of the shaft has been fitted on the chuck of the horizontal center lathe and another end has been rested on a bearing mounted steady rest to rotate the model bucket about the horizontal axis of the center lathe. The container filled with overburden material, has been placed on the center lathe in such a way so that the model bucket can rotate inside the container. At the time of rotating inside the container, the model bucket will lift the overburden material and the materials will pass through the bottom plate of the model bucket. The back side of the scale model remains open so that the overburden materials

Figure 1: Experimental setup

once lifted by the bucket will be dropped into the container again due to gravity. Another purpose of that opening is to allow the free flow of the material throughout the surface of the scale model. From the entire experiment, volume of material loss on the bottom plate was calculated. For the calculation of the volume of material loss, thickness of the bottom plate was measured at different areas, indicated in Fig. 2, with the help of a digital Micrometer. The measurement was taken in 0th, 9th, 15th and 22nd hour of running. In this way the reduction of the thickness at these particular points on different interval can be calculated. For better accuracy the entire plate was virtually divided into four sections, i.e. section A, B, C and D (Fig. 2) length of the entire plate was 0.175 meter and the length of the each section was 0.04375 meter. The volume of material loss was then calculated by taking the average of reduction of thickness on the respective points of the respective sections. For example, to calculate the volume of material loss in section A, the average reduction of thickness in point nos. 11, 12, 13, 14, 15 were considered. The length and width of that section was known and is given in Table 1. During the entire experiment no changes were observed in length and width. Total load per cycle was calculated by considering the density of overburden material and percentage of volume of the prototype filled up by the overburden material.

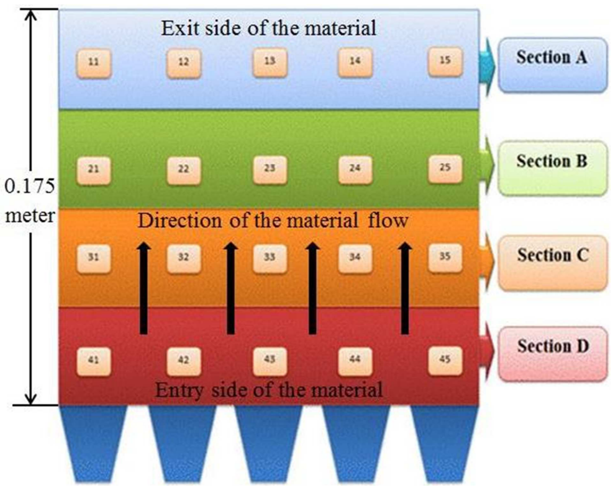

Figure 2: Schematic diagram of the bottom plate, indicating the measuring points. Direction of material flow.

Material used to fabricate the scale model was Manganal, which is high manganese, austenitic (non-magnetic) work-hardening steel, also known as Hadfield steel. Its chemical composition is Manganese (12.00% to14.00%) and Carbon (1.00% to 1.25%) [16]. Hardness of the manganese steel is known and sliding distance for this experiment is implies the length of the bottom plate used in experiment, as the overburden material passes through the entire plate. From the above parameter the Archard’s coefficient can be calculated by using the equation

$$Q = KWL / H \tag{1}$$

Where

Q	Volume of material removes (Meter^3)
W	Load on the base plate (Newton)
L	Sliding distance (Meter)
H	Hardness of the material (B H N)

From the experiment the relation between the Archard’s coefficient with time and Archard’s coefficient between sliding distance can also be evaluate.

III. RESULTS AND DISCUSSION

Table no. 1 contains the data obtained from experiment and the calculated values of Archard co-efficient at different time interval. During the experiment the rotational speed of the prototype was 16 rpm. The relation of the Archard’s coefficient with time and sliding distance has been shown in the graph. Fig 3 shows the variation of Archard’s coefficient with respect to time. In which it has been observed that a wear rate coefficient decreases with respect to time. The reason behind this is the work hardening property of Hadfield steel [17-18]. From the time being the no. of working cycle increases, and the steel received continuous impact and stresses which helps in increasing of surface hardness [19].

Table 1: Values of Archard’s coefficient at different time intervals and different time

Position	Measuring points	Initial thickness (mm)	Thickness After 9 hours (mm)	Thickness After 15 hours (mm)	Thickness After 22 hours (mm)	Length of the Section (Meter)	Load (N)	Width of The Section (Meter)	Calculated Value of Archard’s coefficient After 9 Hours ($Meter^3$)	Calculated Value of Archard’s coefficient After 15 Hours ($Meter^3$)	Calculated Value of Archard’s coefficient After 22 Hours ($Meter^3$)
Section A	11	9.98	9.98	9.98	9.98	0.04375	74.7	0.23	1.96E-05	1.02E-05	1.08E-05
	12	10.13	10.1	10.08	10.05						
	13	9.87	9.86	9.82	9.81						
	14	9.87	9.84	9.82	9.8						
	15	9.85	9.85	9.85	9.85						
	16	9.78	9.78	9.78	9.78						
Section B	21	10.3	10.18	10.02	9.94	0.04375		0.23	3.49E-05	1.80E-05	2.24E-05
	22	10.3	10.18	10.04	9.94						
	23	10.3	10.1	10.1	9.88						
	24	10.2	10.02	9.9	9.76						
	25	9.85	9.62	9.5	9.41						
	26	10.12	9.9	9.84	9.72						
Section C	31	10.8	10.42	10.16	10.07	0.04375		0.23	2.61E-05	2.03E-05	1.86E-05
	32	10.6	10.38	10.22	10						
	33	10.08	9.88	9.74	9.58						
	34	10.1	9.86	9.7	9.54						
	35	10.51	10.2	10.06	9.91						
	36	10.36	10.06	9.94	9.71						
Section D	41	10.03	9.74	9.54	9.32	0.04375		0.23	5.76E-05	4.06E-05	4.88E-05
	42	9.2	8.9	8.7	8.5						
	43	10.16	9.86	9.66	9.42						
	44	10.81	10.52	10.32	10.1						
	45	10.8	10.46	10.3	10.1						
	46	9.47	9.16	9	8.82						

In the result obtained from the calculation it has also been observed that the value of the Archard’s coefficient has a tendency to decrease with the increasing value of the sliding distance. Fig. 4 shows the variation of Archard’s coefficient with respect to sliding distance.

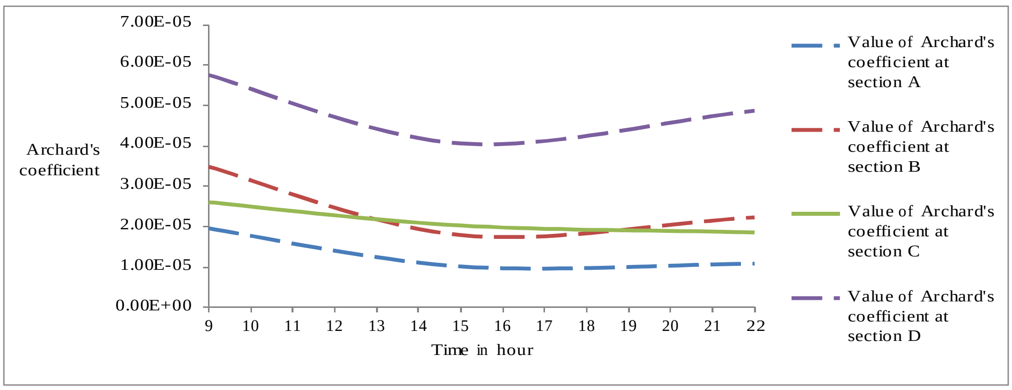

Figure 3: Time vs. Archard coefficient at different section

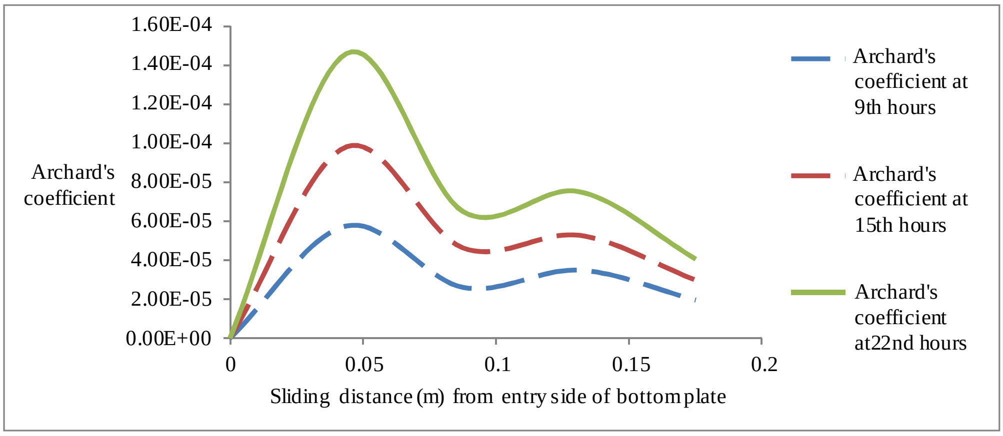

Figure 4: Sliding distance Vs. Archard's coefficient at different section

IV. CONCLUSION

In this paper an effort has been made to determine wear rate coefficient using Archard's equation from the values obtain from experimental analysis, and it has been observed that the wear rate coefficient has been increased with respect to time. The main reason of this behavior is the work hardening property of manganese steel. The more impact and hammering it receives, the harder the surface becomes.

During the lifting of material from the container, the system exerts extra pressure on the material by the front portion, and during dumping, at the rare end of the base plate, the material flows smoothly into the container. As a result, at the front portion of the base plate the coefficient shows a higher value, but at the rear end it shows comparatively less value. From the entire experimental study it can be concluded that the difference in material removal rate on two different areas in the same plate is because of the difference in pressure applied by the system.

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