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Dragline Cycle Time Analysis - Case Study

B. Erdem
Department of Mining Engineering, Cumhuriyet University, Sivas, Turkey
A.G. Paşamehmetoğlu
Atılım University, Ankara, Turkey

ABSTRACT: Draglines operate in cyclic nature. Excluding the infrequent walking a dragline spends its time by digging the dirt and paying it out on a spoil pile. Considering a dragline perform tens of thousands of cycles per year, it is obvious that even a small reduction in a single cycle time would result in a significant increase in productivity. Thus it is to the benefit of a mine that dragline cycles are to be critically analyzed and corrective measures taken. Although there exist different opinions on what segments constitute a dragline cycle, in this study it is accepted that a dragline cycle is composed of the following pieces: © loading the bucket by dragging it towards the dragline, © swinging the full bucket along a predetermined arc, ® paying out the dirt onto a spoil pile, © swinging the empty bucket back to excavation face and © positioning the bucket to re-load. The study is based on field investigation conducted on six draglines with different capacities and operating modes. Stopwatch study is performed. Influence of cut dimensions, nature of material excavated, mode of digging, type of bucket employed, swing angle, operator preferences and experience, condition of dragline on cycle time is analyzed. The results are tabulated and presented in tables and graphs.

1 INTRODUCTION

Demand on energy is continuously increasing. Coal, which is the most homogeneously spread raw material throughout the earth's crust, is among the most demanded fossil fuels. A considerable portion of coal is produced by surface mining methods. Regarding the economics of scale extraction methods are highly mechanized and equipment with huge capacity are utilized.

Draglines have been abundantly used in coal mining for decades, either as stripper or stripper and coal extractor. As these equipment possess certain inherent advantages, which their rivals do not, they must be operated in a round-the-clock fashion for high productivity and low costs.

Despite its colossal posture a dragline can be said to have a simple routine of work, which is composed of the following basic procedures: digging and walking. Among them walking is a steady process on which the mine design team has little control. Almost all walking draglines take a step of approximately 2 m within a time period of 0.75-1 min. The design of strip panels, equipping a specific unit with one operator's room on the desired side or with two on both sides and the management's strategy in coal loading operation largely affect the frequency and the length of long deadheading periods, during which the unit is unproductive.

Digging, on the other hand, is a controllable item. It is a repetitive process which mainly consists of scooping, swinging the full bucket along a circular arc of predetermined length, dumping, swinging back and repositioning the bucket for the next bite. It must be immediately noted that transition between these successive components can not be sharply distinguished and therefore there is no common agreement as to what components constitute a dragline cycle. In its simplest form a cycle is a function of scooping, swinging+dumping and retuming+positioning. A cycle however, is described as composing of dragging to fill the bucket, swinging, dumping and returning back to the cut face (Anonymous, 1977; Szymanski et al. 1989; Parlak, 1993; Rai et al. 2000). A last approach adds one more component, which is termed as positioning of the bucket or preparation to drag (Bandopadhyay and Ramani, 1979; Anonymous, 1984; Anonymous, 2001).

2 DATA GATHERING METHODOLOGY

2.1 *Objectives of the study*

This paper presents the results ot a field study carried out to analyze dragline cycle time. The main objectives of the study are as follows:

a. Determining the components of a dragline cycle
b. Analyzing scooping and time spent during this process
c. Exposing the correlation between full swing angle and swing time
d. Analyzing dumping and time spent during this process
e. Exposing the .correlation between back swing angle and swing time
f. Analyzing the differences between full swing and back swing processes
g. Analyzing repositioning and time spent during this process
h. Introducing conditions that determine "hoist-dependent" or "drag-dependent" cycles.

All of the objectives listed above were analyzed for various excavation modes, such as key cutting, main cutting and chopping.

2.2 *Methodology followed*

Out of nine units operating at various surface mines in Turkey six were visited. Basic characteristics of the systems at the time of visits are given in Table 1.

Neither of the draglines was equipped with a duty-cycle recording and data acquisition systems. For this reason a precision stopwatch with 10 lap functions was used for recording dragline cycle components.

Dragline swing angles were measured at a sensitivity level of 5 degrees. The circle along which the dragline can make a full turn was divided into intervals of 5 degree central angles. Recording the starting and finishing intervals, swing angles were determined. The methodology is depicted in Fi«ure 1.

In order lo analyze the influence of location of a particular digging point on the time spent for filling the bucket another method was adapted. The cut was divided into regions on the basis of nearness lo the point on which the dragline is located. Thus, the horizontal and vertical planes were divided into three regions: near, medium and *far;* shallow, medium and deep, respectively (Figure 2). It must be noted here that this method is qualitative and relative in nature, which does not take into consideration real dimensions. When it is considered that dragline cuts are designed in the same manner, it can be safe lo assume (hat the dimensions can be eliminated. For instance, under normal operating circumstances the farthest point a dragline can reach is the vertical projection of the boom sheave on the cut. Likewise the deepest point for a dragline is the one on which the limit of the hoist rope is reached.

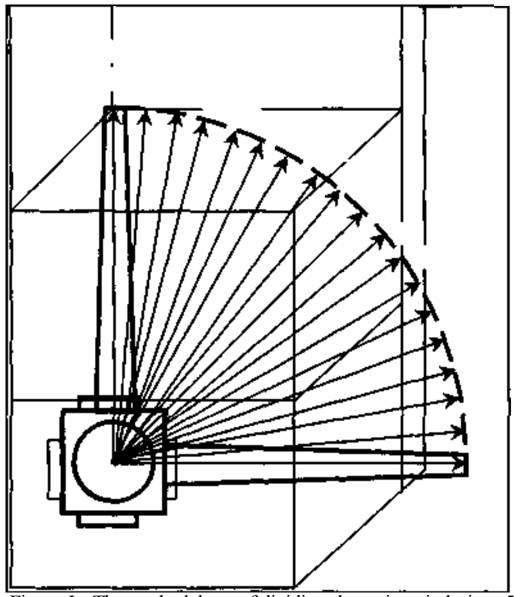


Figure I. The methodology of dividing the swing circle into 5 degree intervals.

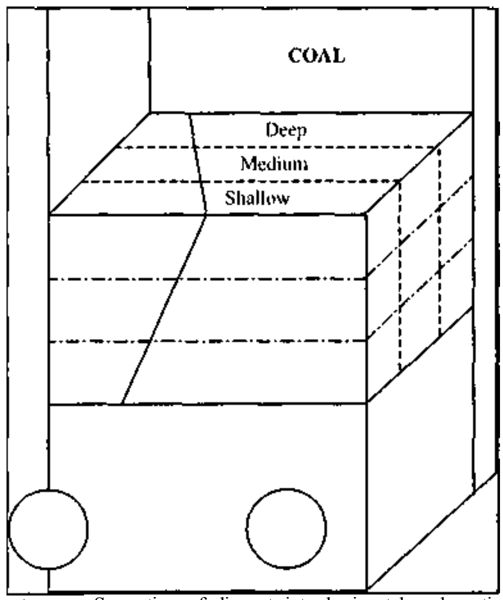


Figure '. Separation of die cut into horizontal and vertical renions.

Table 1 Charactetıstıcs ot'draglines» and panels on which they aie deployed.

Di agîmes	Bucket capacity (in³)	Pit width (ill)	Bench height (III)	Mode of operation at ihe tune of visit	Overburden Chaiactenstics
Diag#1	22 9	75	25	Bencil prepaıatıon	Blasted marl & conglomeiale
Diag#2	24 S	50	30	Budge prepaıatıon	Rehandled mai l
Dug #3	24 5	65	25	Budge preparation	Unblasted limestone
Diag#4	25 2	60	12	Duect excavation	Blasted marl
Diag#5	49 7	88	32	Woikmg on budge	Rehandled mai l
Diaj!#6	53 5	50	.30	Direct casting	Unblasted clayey marl

2.3 *Discrimination of cycle time components*

As mentioned earlier one of the main difficulties in recording a dragline's cycle time is discriminating successive components from each other. They really seem interconnected. For instance swinging full and dumping appeal as two successive parts of a single operation as do swinging back and repositioning. It is likely this reason that a dragline cycle is accepted to compose of different components among researchers. For the authors of this paper, the solution to decide on what components a dragline cycle could have appeared as watching the operator closely. At the boundary of any two phases all the operators used the drag and hoist levers and swing pedals more clearly and more sharply. Knowing that a dragline's response to an operator's moves take some seconds the method developed during data gathering phase was the continual observation of the bucket.

Accoiding to the methodology given above the digging phase commenced when the bucket was started to drag in towards the dragline. The phase of lull swing started when the bucket cleared off the ground. Dumping began when the mouth of the bucket inclined down and material flown. Backward swing started when the bucket is saved from momentary tixed suspension and accelerated towards cut face. Finally transition to repositioning is discriminated by the conscious effort of the operator in finding a suitable location tor the bucket to position tor the start ot the next dig cycle. It must be noted that in this particular phase, the boom can still be swinging back slowly.

3 CASE STUDY

The ultimate aim of such a study would actually be discovering ways to reduce cycle time and thus increase the productivity of stripping systems by some significant percentages. In this study field observations were conducted at six dragline panels to analyze the components of cycle time on various bases.

3.1 *Digging*

Two criteria were employed in classifying draglines: depth and proximity of the point on which digging started. Though the cuts were divided into blocks of two dimensional pairs such as shallow-near or far-deep, etc. only the results of one-dimensional analyses are presented here.

When key cutting practices are concerned, data gathered from three operations reveal that digging time is positively correlated to the depth and proximity of the digging point. While draglines #2 and #5 worked on easy-to-excavate material, dragline #4 dug blasted bench that was harder. This situation can be observed in Figures 3 and 4.

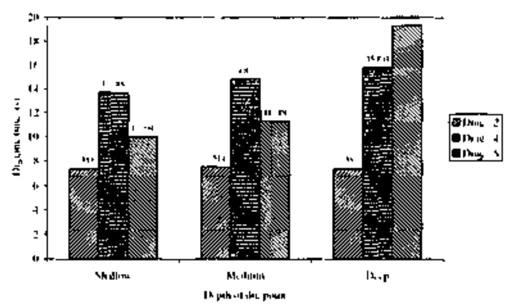


Figure 3. Digging time as a function ot depth ot dig point on key cutting

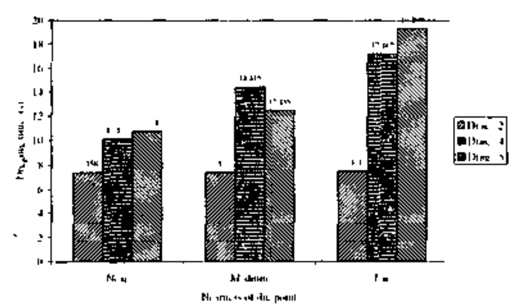
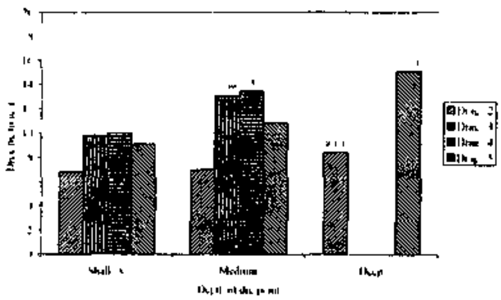
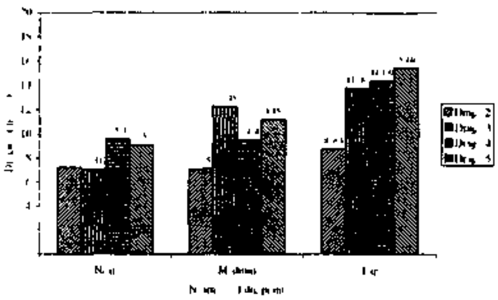


Figure 4. Digging lime as a lunciion ot pioximily of dig point on key cutting

A similar behavior was obseived in main cutting practices Digging tune is positively correlated to the depth (Figure 5) and proximity (Figure 6) ot" the digging point. Time spent at this operation increases with going away from the dragline It should be noted that, like #3, dragline #4 operated on hard material, as well Another obvious point to mention is that digging main cut matenal took 2-3 seconds less than key cut material This difference is attiibutablc to the working spaces



Figuie S Digging time as a function ot depth ot dig point on ni.un cutting



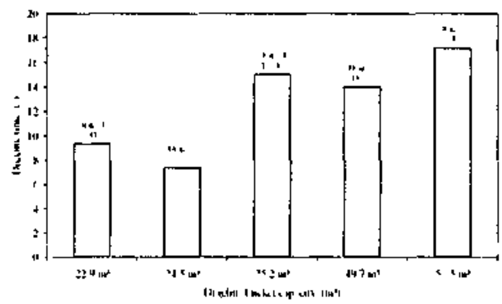
Figuie 6 Digging time as a function ot proximity of dig point on main cutting

There exists a positive correlation between the digging time and the bucket capacity ot units, other parameters being equal Figures 7 and 8 illustrate the cases on key and main cutting, lespecuvely

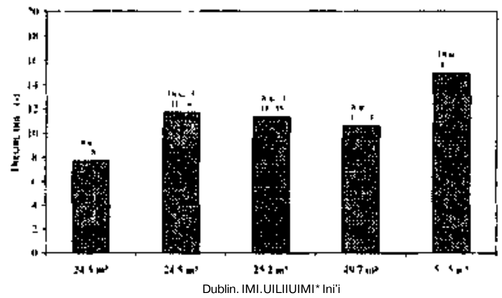
3 2 *Swinging (full & back)*

The time spent during full and back swinging phases weie observed, recorded, averaged and grouped at 5 degree swing angle intervals for various modes of excavation

On all modes ot excavation there exists a strong positive correlation between swing angle and swing time The relations are presented in Figures 9, 10 and 11 toi key cutting, main cutting and chop cutting, lespectively



Figuie 7 Digging time .is a function of diaglme bucket capacity on key cutting



Figuie 8 Digging time .us a function of dragline bucket capacity on main cutting

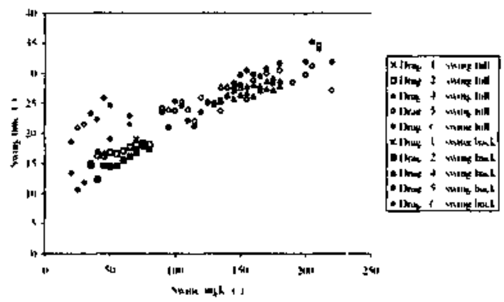
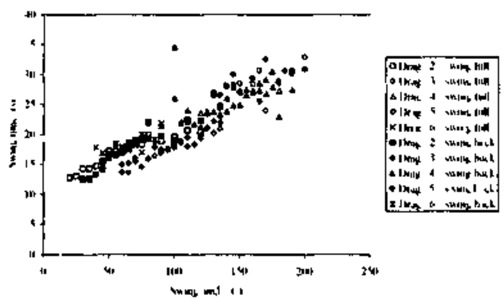


Figure 9 Swing time as a function of swing angle on key cutting



Figuie 10 Swing time as a function of swing angle on main cutting

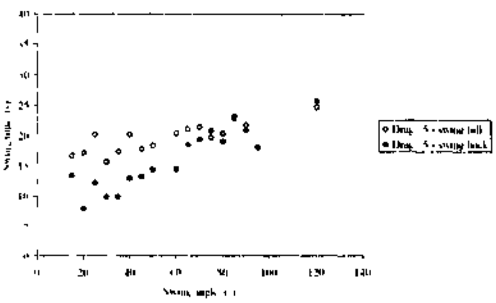


Figure 11. Swing time as a function of swing angle on chop cutting

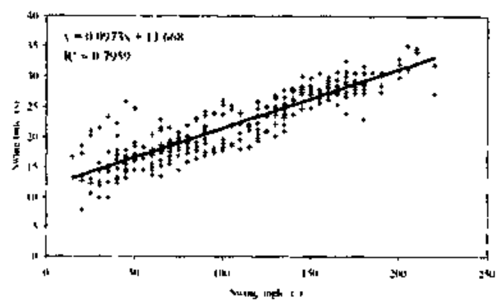


Figure 13. Swing time as a function of swing angle for all modes of excavation

It can be observed from Figures 9, 10 and 11 that swing back times are slightly less than (~1-2 s) those of swing full. This can be attributed to the fact that lesser load is carried by the boom when swinging back. To better visualize the case, all the data gathered in full swing and back swing phases were re-handled and statistically evaluated. The results, which are supportive, are shown in Figure 12.

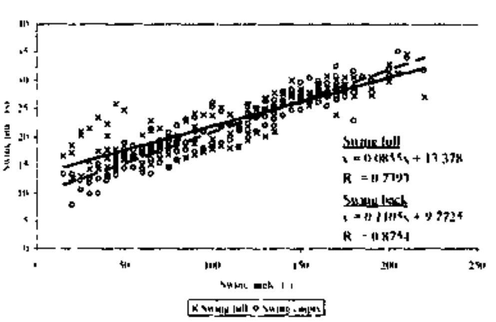


Figure 12 Swing time as a function of swing angle on full and back swing cycles

A final analysis, which covered all the data from swing cycles, is presented in Figure 13. The data show an irrefutable relation between swing angle and swing time. A regression equation is fitted with an acceptable degree of fit. Table 2 presents the relation between swing angle and swing time in statistical terms for various modes of operation.

Table 2. Results of regression analyses on swing time.

Operating mode	Regression equation y = swing time, (s) x = swing angle, (°)	Degree of fit (R^2, %)
Chop cutting - swing full	y = 0.0708x + 15.727	73.01
Chop cutting - swing back	y = 0.1546x + 7.005	83.18
Key cutting - swing full	y = 0.0742x + 16.003	74.46
Key cutting - swing back	y = 0.1125x + 10.223	91.98
Main cutting - swing full	y = 0.1057x + 10.039	85.30
Main cutting - swing back	y = 0.1031x + 10.170	82.58

3.3 *Dumping*

Bucket dumping is a straightforward procedure, on which very few operational parameters is believed to be significant. Larger buckets may require longer time to dump or the operator may speed up or retard the process. The data observed in this study is presented in Figure 14. Dumping time seems to be within 3-5 seconds for all modes of excavation, which is slightly less than those published previously (Szymanski et al. 1989; Rai et al. 2000).

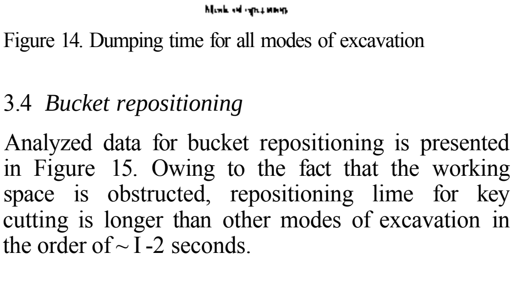


Figure 14. Dumping time for all modes of excavation

3.4 *Bucket repositioning*

Analyzed data for bucket repositioning is presented in Figure 15. Owing to the fact that the working space is obstructed, repositioning time for key cutting is longer than other modes of excavation in the order of ~1-2 seconds.

4 CONCLUSIONS

Results of a field study on dragline cycle time analysis were presented. Six dragline operations were visited. The detailed analysis of data gathered indicated the following:

a. Digging time is greatly influenced with the fragmentation of the material excavated. Bucket fiil factors and digging times could well be improved by better blasting practises.

b. Digging time can also be improved by maintaining the bucket in good condition. A proper angle of attack between the teeth of the bucket and the ground and sharp teeth are thought to be essential.

c. Swing times (both full and empty) are positively correlated to swing angles. Since time passed-for swinging cannot be reduced then dragline panel design must be so optimized that dragline swing angles are kept at a minimum.

d. Almost all of the cycles were swing-dependent. In the case of narrow and deep key cuts, cycles tended to be hoist-dependent. Where the swing angles were smaller than 30 degrees, cycles became drag-dependent, which took longer than larger-swing-angle cycles due to longer pay-out processes. They must be avoided.

e. Dumping time and repositioning time are fluctuating within a narrow time interval. They could be taken constants for all modes of operation.

f. Operator's experience is thought to play role on the following phases: digging, dumping and repositioning.

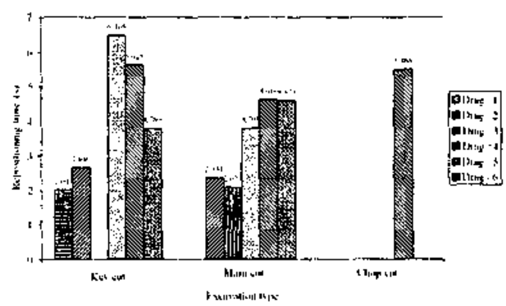


Figure 15. Repositioning time for all modes of excavation

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