BİLİMSEL MADENCİLİK DERGİSİ
SCIENTIFIC MINING JOURNAL
TMMOB Maden Mühendisleri Odası Yayını / *The Publication of the Chamber of Mining Engineers of Turkey*

Orijinal Araştırma / *Original Research*

CYCLE TIME SEGMENTS AND CYCLE TIME DISTRIBUTION CURVES OF MINING SIZE WHEEL LOADERS – A CASE STUDY

MADEN YÜKLEYİCİLERİNDE İŞ DÖNGÜSÜ EVRELERİ VE İŞ DÖNGÜSÜ DAĞILIM EĞRİLERİ - OLAY ÇALIŞMASI

Metin Özdoğan[a,*], Hakkı Özdoğan[a]

[a] İdeal Makine Danışmanlık Ltd. Şti., Ankara, TURKEY

Geliş Tarihi / *Received* : 18 Ocak / *January* 2017
Kabul Tarihi / *Accepted* : 21 Şubat / *February* 2017

Keywords:
Electrical wheel loader,
cycle time segments,
cycle time distribution curves,
normal distribution curve,
skewed distribution curve.

ABSTRACT

Mining wheel loaders loading haul trucks, in contrary to earthmoving equipment which have 360 degrees slewing capability of upperframe, have an entirely different cycle time phases: Travel to dig (TTDG), Dig (DG), Travel to dump (TTDMP), and Dump (DMP). Therefore, the cycle time (CT) of a mining loader is comparatively higher than that of an equivalent sized excavator with a rotating upper frame. However, whenever mobility and versatility of the loading tool is essential such as selective mining applications the wheel loaders are favoured. Investigating cycle time segments may give qualitative and quantitative hints for improving the cycle times of the loader applications upon changing the operators and the truck spotting layouts. Therefore, studying cycle time statistics and cycle time frequency distribution curves are important. In the article, two cases are explored one being from Brasil, the other one is from Turkey. Sample CT segments and CT distribution curves are investigated and discussed

Anahtar Sözcükler:
Elektrikli yükleyici,
iş döngüsü evreleri,
iş döngüsü dağılım eğrisi,
normal dağılım eğrisi,
çarpık dağılım eğrisi

ÖZ

Kazdıklarını kamyona yüklemekte olan tekerlekli maden yükleyicilerinin döngü süresi evreleri kule dönüşlü makinalardan bütünüyle farklıdır. Bu evreler kazıya gidiş, kazı, boşaltmaya gidiş ve boşaltma evrelerinden oluşur. Bu nedenle maden yükleyicisinin iş döngüsü eşdeğer kule dönüşlü yerkazardan daha uzundur. Ancak seçmeli kazı gerektiren madenlerde olduğu gibi çok gezingenlik ve esneklik gereken uygulamalarda yükleyiciler yeğlenir. İş döngüsü evrelerinimn incelenmesi iş döngüsünü geliştirme yönünde nesnel ve nicel ipuçları verebilir. Özellikle operatör değişikliklerinde ve kamyon yanaştırma düzeni değiştirildiğinde, bu evreler incelenmelidir. Bu yüzden iş döngüsü istatistiklerini ve iş döngüsü dağılım eğrilerini incelemek olağanüstü önemlidir. Bu makalede biri Brezilya'dan biri de Türkiye'den olmak üzere iki olay çalışılmıştır. Örnek iş döngüsü evreleri ve iş döngüsü dağılım eğrileri araştırılmış ve tartışılmıştır.

* Corresponding author: metinozdogan@gmail.com

INTRODUCTION

Traditionally wheel loaders are used in auxiliary works in mining such as spoil heap loading of ore and coal and as backup equipment. The growing size of the off-highway trucks necessiated the development of larger mining size wheel loaders in recent years. The large wheel loaders are used in overburden and/or ore digging and loading operations wherever the conditions are favourable and benches are blasted. The wheel loaders are capable of load haul and dump of the material to the bunkers if the hauling and dumping distances are favourable and to haul trucks.

The wheel loader application necessiates more bench space for manoevouring (wider benches); needs a level and stable floor in order to protect tyres which is a big investment item. Floor must be flat and dry due to the fact that traction force of the tyres is a key factor in wheel loader operation. Wheel loader application needs stronger floors ie higher ground pressure of 0,41 MPa to 0,552 MPa (4,22 kg/cm^2 to 5,62 kg/cm^2 (Grant, 2016).

Electric Wheel Mining Loaders: Today both mechanical wheel loaders (MWL) and electric wheel loaders (EWL) are available for mining size applications. Electric wheel loaders are mainly favoured instead of equivalent mechanical drive loaders because of the fuel economy which is 45 to 60 % less than the mechanical one depending on the application (Norris, 2013). Lubricant consumption amount is smaller since it has not got any gearboxes and conventional transmissions. Furthermore, less number of components means less parts consumption. Because of its simple structure, repair and maintenance expenditures are less. Eventhough the first capital investment is a little bit higher with respect to equivalent mechanical drive ones, this difference is compensated in a short while with the lower cost of operation (Ozdogan and Ozdogan, 2015a).

The electric wheel drive system consists of a brushless switched reluctance motor combined with high-power semiconductor switches and digital controls. The SR motor includes a rotor with no magnets or windings and a stator whose poles contain a winding, similar to a field of a DC motor. The SR system employs the principle of magnetic attraction to move the motor's rotor from pole to pole creating rotation (Fleet, 2012). SR motor achieves rotation by the sequential energizing of stator poles. When the stator pole winding is energized, the nearest rotor pole is attracted into alignment with that stator pole. The rotor will follow this sequence, attempting to align rotor poles with energized stator poles. However, as the rotor and stator poles align, the stator poles switch off and the next group of stator poles switch on, continuing the rotation of the rotor (Fleet, 2012). The switched reluctance motor generates continuous movement by consecutively switching the currents on and off, thus ensuring the poles on the rotor are continually chasing the stator current. The movement achieved is a function of the current flowing through the winding and the characteristics of the iron in the rotor (Fleet, 2012).

A typical electric wheel loader loading cycle is ideal for capitalizing on capturing regenerated power with multiple braking. Utilising switched reluctance system allows power generation to be fully regenerative, resulting in a very efficient wheel loader operation. During braking or retarding electrical motors become generators and feed power back into the generator which is connected to the diesel engine. Ultimately, this causes the generator to operate as a motor and turns the diesel engine (Ozdogan and Ozdogan, 2015b).

One of the reasons why electrical Wheel loader is preferred by the mine sites is the fuel saving achieved by the equipment. It regenerates power in breaking or retarding during the phases of cycle time; as motors behave as generators and pump the power back to the generator; generator acts as motor and drive the prime mover diesel engine. That is how the major fuel saving is achieved.

Technical Specifications of the Electric Wheel Loaders Examined are given in Table 1, See Photograph 1.

Table 1. Some technical specifications of L-1350 Electric Wheel Loader (Anon a, 2016)

Specification	Standard Lift Model	High Lift Model
Country	Brasil	Turkey
Engine, kW	1193	1193
Breakout Force, kN	961	987
Operating Weight, t	184	186
Static Tipping Load, t	102	95
Bucket Capacity, m3	23	21
Payload, t	-	31
Payload Limit, t	-	34
Overload Limit, t	-	37.4
Critical Overload Limit, t	-	40.8

Photograph 1. L-1350 is loading to Hitachi EH400AC-3 truck at the gold mine

Technical Specifications of the off-highway trucks loaded by the 21 m^3 electric wheel loaders are as follows:

Table 2. Some technical specifications of the trucks being loaded by L-1350s

Specification	Cat 785C	EH400 AC-3	Cat 793
Country	Turkey	Turkey	Brasil
Engine (kW)	1082	1864	1693
Nominal Payload (t)	136	212	227
Loading Height (m)	4.97	6.13	13.14
Operating Weight (t)	250	384	386
Operating Width (m)	6.64	7.29	13.41

Loader and Truck Spotting layouts: Wheel loader operators should also be trained on truck spotting techniques to have shorter cycle times. Truck spotting is the responsibility of the loader operator, (Anon.a). The hands on training courses cover the truck spotting layouts and techniques which are illustrated below. It is one of the important factors impacting the cycle time improvement.

As depicted in Figure 1, V-type truck spotting and loading is to be favoured. Operator to make a tight V-pattern between the material, wheel loader pivot point and the truck (Anon. a, 2016).

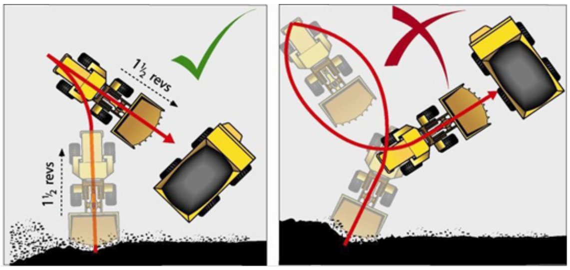

Figure 1. Wheel loader and truck spotting layouts (Anon. b, 2016)

Sometimes there are situations where it is difficult for the loader to work left to right. In these cases it is best to perform parallel digs, which run right to left, See Figure 2. The dig face is narrow. In a parallel dig, there is usually no pocket, so position the trucks at 15 to 20 degrees from perpendicular. That sets up the V-pattern for the loader (Anon. b, 2016).

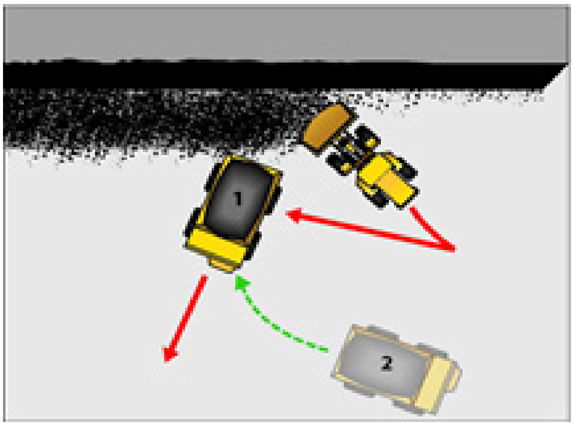

Figure 2. Wheel loader's paralel dig layout (Anon. b, 2016)

Cycle Time Segments of Earthmoving Equipment: Hydraulic shovels, electric rope shovels and walking draglines have rotating upper frames; swing roller assembly swings on swing roller path and the upper frame is slewed by swing pinion thru a swing ring gear. Therefore, the cycle time segments of these equipment having slewing roller assembly between lower and upper frames are basically digging, swinging to load or dump, dumping and swinging back to digging. However, this is not the case with wheel loaders; in order to complete the cycle the equipment has to travel back and forth. In contrary to revolving frame shovels, wheel loaders have different cycle time segments: Travel to dig (TTDG), Dig (DG), Travel to dump (TTDMP), and Dump (DMP). Özdoğan and Özdoğan (2015b) studied the cycle time phases of electric wheel loaders.

Cycle time distribution curves and cycle time segments statistics give clues about the performance of the equipment and the operator and the success of the present truck and loader layout at the bench. Thus give hints to improve the cycle times; naturally, improving cycle times imply shortening the cycle times.

1. ELECTRICAL WHEEL LOADER CASES MONITORED

The electric wheel loaders in question have on-board PreVailSystem® monitors. The wheel loaders have mainly two types of applications: The major application is to dig and dump to a hauler. Minor application is dig, haul and dump to a bunker, to as spoil heap or to a in pit dump area. In the monitored cases, the loaders were loading to off-highway mining trucks. If the loader is dumping to a truck tray, the dump segment includes raising of full bucket beyond the level of truck body. Therefore, it is expected that dumping time is higher than that of a dig-haul and dump to an in-pit spoil area application.

1.1. An Iron Ore Mining Application of Mining Loader

The first electric wheel loader investigated is a high-lift electric wheel loader (L-1350) having a 21m^3 bucket operating at an iron ore digging in Brasil and loading into 200 tonnes range off-highway trucks in 8 passes. The average payload of the bucket is 29 tonnes and the average cycle time is 44,74 seconds for the case explored. Average truck filling time is 7,25 minutes (Klink, 2015).

Cycle time of a wheel loader comprises of Travel To Dig (TTDG), Dig (DG), Travel To Dump (TTDMP), and Dump (DMP) phases. Duration of segment times depends on the truck loader layout at the face, skill and experience of the operator and design features of the equipment, pit geometry and blasting. See Table 3, 4 and Figure 3 and 4. Please note that in the cases explored the wheel loaders were loading haul trucks; therefore travel to dump phase should be understood as travel to truck to unload the bucket.

Figure 3 depicts the percentages of the segments of the cycle time as a result of a week's observation, see Table 1, too. Cycle time consists of 21,9 % Travel to dig segment, 9,7 % Dig segment, 49,7 % Travel to dump segment and 18.7 % Dump segment. Travel to dump segment takes the highest time among the segments as expected because in this segment the equipment travels towards the haul truck with full bucket. The second highest time is consumed in Travel to dig segment, which should not take such a high percentage; I think it due to the layout of truck and loader with respect to the bank. The third highest time consuming segment is Dump with 18.7 % which is expected to be a time consuming segment because the full bucket is lifted up to a higher level than the truck body for dumping. It is a difficult segment due to the fact that the loader is overcoming the gravity of the earth. The digging time is the shortest with 9,7 % indicating that muckpile is good fragmented.

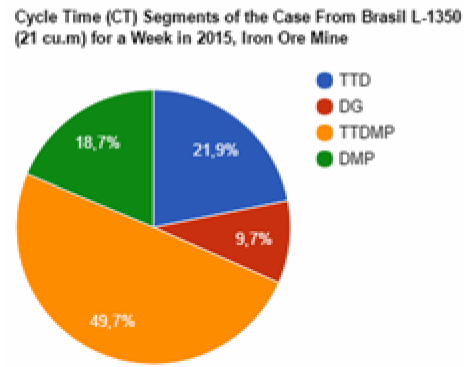

Figure 3. CT segment percentages of the mining loader in the iron mine

Table 3. A week's CT statistics of Feb 24–March 2015 L-1350 (an iron mine in Brasil)

Shifts (8h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
Shift 1	9.76	4.34	22.14	8.33	44.53
Shift 2	9.19	5.00	22.71	9.50	46.42
Shift 3	7.62	4.83	22.88	7.87	43.28
Mean	8.86	4.72	22.58	8.57	44.74

Monitoring cycle time segments is important; analysis of time of each segment gives hints on the layout of the loader and haul truck, skill and experience of operator, fragmentation of the muckpile etc. By analyzing the cycle time phases one may have clues on how to shorten the cycle time.

1.2. A Gold Mining Application of Mining Loader

The second electric Wheel loader studied have a 21m^3 bucket and a highlift one (L-1350) operating at gold mine in Turkey. The loader operates in digging rock and ore and load 150 tonnes rock trucks in five passes whereas loading 220 tonnes trucks in 7 passes. Average bucket payload is about 30 tonnes; average cycle time was in the range of 45 seconds (Anon a, 2016). The rock material is of volcanic origin with a loose density of 1,30 tonnes/ m3 and it is very abrasive. It is a hardrock operation and the banks are blasted. The deposit is a porphyry gold deposit formed beneath coeval Miocene volcanic complex in western Anatolia. It is a low-grade, bulk-tonnage open pit mining operation; gold recovery is by heap leaching. Haul road distance to dump area varies from 1,5 km to 3 km; grade varies from 3% to 7% depending on the depth of operation in the pit.

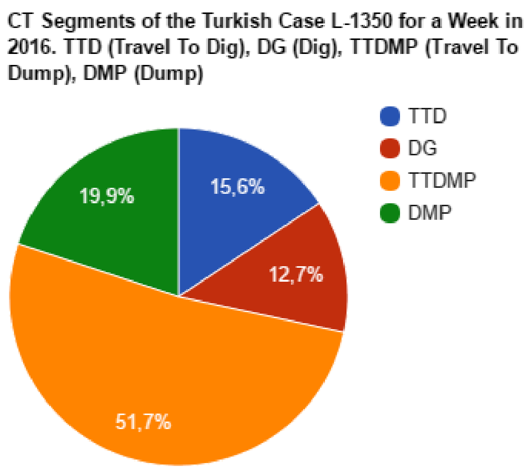

Figure 4. CT segment percentages of the mining loader in the gold mine

Segment time percentage sequence of the application in Turkey is TTDG-15.6 %, DG-12,7%, TTDMP-51,7 % and DMP-19.9 %, See Table 4 and Figure 4. As expected the most difficult (time consuming) segments are the ones performed with the bucket having payload in it in other words travel to dump and dump to haultruck tray segments, assuming operators are skilled and experienced and layout of loader, haultrucks, and position of the loader with respect to the bank are allright.

Table 4. A week's CT statistics of year 2016 (L-1350) of a gold mine in Turkey

Days (24h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
Day 1	7.33	5.80	24.80	8.19	46.19
Day 2	7.19	6.21	20.95	9.30	43.65
Day 3	7.25	5.55	23.12	8.78	44.72
Day 4	7.32	5.80	24.80	8.19	46.19
Day 5	6.18	5.26	21.94	9.16	42.61
Day 6	6.32	5.24	21.78	9.29	42.78
Mean	6.93± 0.49	5.64± 0.34	22.90± 1.49	8.82± 0.48	44.36± 1.47

2. CYCLE TIME DISTRIBUTION CURVES

Cycle time distribution curves and cycle time segments statistics give clues about the performance of the equipment and the operator and the success of the present truck and loader layout at the bench. Thus give hints to improve the cycle times; naturally, improving cycle times imply shortening the cycle times.

2.1. Samples of Normal (Bell-Shaped) Distribution Curves

Travel to Dig (TTDG), Travel to Dump (TTDMP) segments of the cycle time (CT) is associated with speed and manuevering specifications of the equipment, bench geometry and the layout of truck w.r.to loader. Dump (DMP) segment time is associated with the design features of the bucket and size of the truck (dumping height). However, Dig segment is mainly associated with the fragmentation performance of blasting rounds.

The sample illustrated in Figure 5 is a two shift a day operation, See Table 5. The daily cycle time distribution curve indicates that the operators of the both shifts managed to have an average of about the same cycle times. Vertical axis depicts Frequency of cycle times in counts, whereas horizontal axis depicts frequency range of total cycles, See Figure 5.

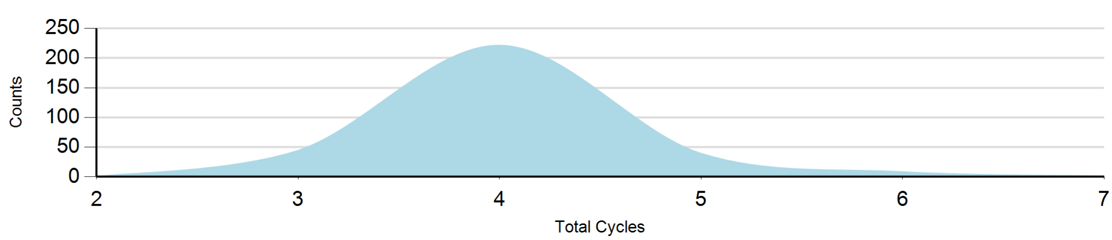

Figure 5. Daily Cycle time frequency distribution curve of Oct 15-16, 2016 (PreVail System®)

Table 5. Cycle time segments statistics of Oct. 15-16, 2016

Shifts (12h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
(07AM-07PM)	7.03	5.14	21.84	8.75	42.83
(07PM-07AM)	5.32	5.37	22.04	9.56	42.38
Mean	6.18	5.26	21.94	9.16	42.61

Table 5 and Figure 5 depict a good example of sucessful operators' cycle distribution. The following sample, Figure 6 and Table 6, is also a good distribution curve indicating a steady and smooth operation in both shifts.

2.2. Samples of Skewed Cycle Time Distribution Curves

As mentioned earlier, qualitative analysis of cycle distribution curves may indicate how good the performance of operator in different shifts. Some of the cycle time distribution curves are skewed ones, Figure 7, Figure 8, and Figure 9. Skewed CT distribution curves imply that the operator of each shift has had two different average of cycle times. Eventhough, it is not a good performance for the operators, it is not uncommon especially in two shift a day applications.

In the sample curve above, Figure 7, there exist two peaks; which implies one of the operators of the shifts achieved shorter average of cycle times than the other one, See Table 7. Figure 7., is a sample for a distribution curve skewed to left.

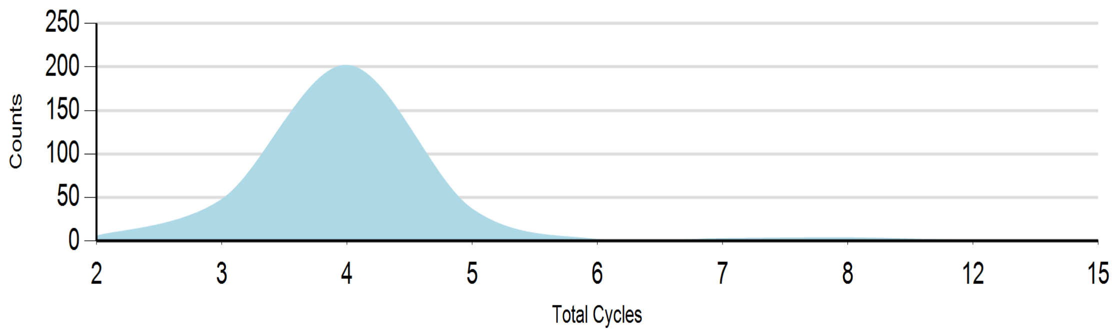

Figure 6. Daily Cycle time frequency distribution curve of Oct. 16-17, 2016 (PreVail System®)

Sample no. 2, depicts that then both operators of the two shifts are good performers, even better than the first sample; deviation from the mean cycle time value is narrower. The smaller the deviation from the mean value is, the better the performance and productivity of the equipment and the team are.

Table 6. Cycle time statistics of Oct. 16-17, 2016

Shifts (12h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
(07AM-07PM)	7.11	5.13	21.45	9.05	42.92
(07PM-07AM)	5.53	5.34	22.10	9.53	42.64
Mean	6.32	5.24	21.78	9.29	42.78

Table 7. Cycle time segments' statistics of Sept. 01-02, 2016

Shifts (12h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
(07AM-07PM)	8.12	5.48	21.10	8.72	43.46
(07PM-07AM)	6.38	5.61	25.14	8.84	45.98
Mean	7.25	5.55	22.12	8.78	44.72

Figure 8, is a sample of cycle time distribution curve of skewed to right. The curve has two peaks again implying two different distinctive cycle time averages for the two shifts worked. The

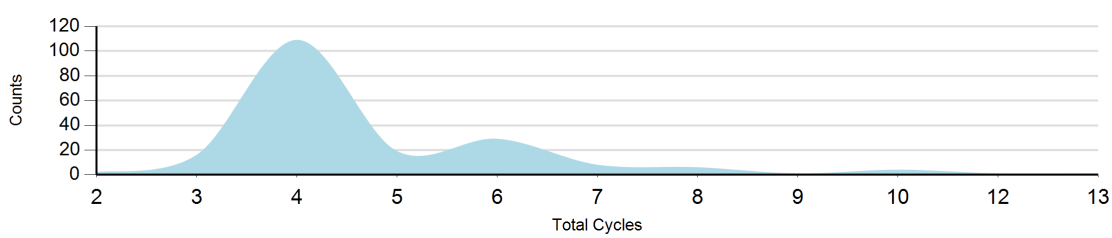

Figure 7. Daily cycle time frequency distribution curve of Sept 01-02, 2016 (PreVail System®)

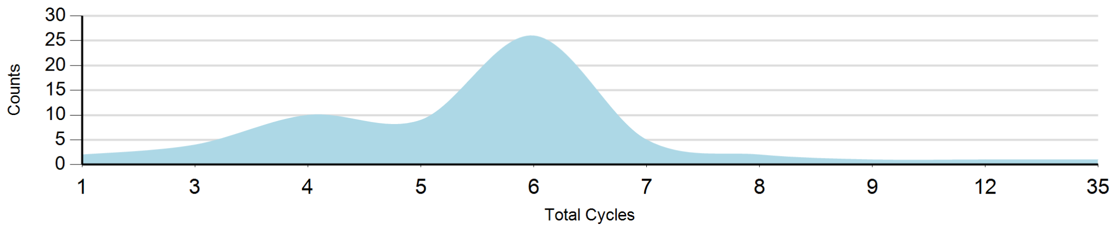

Figure 8. Daily cycle times' distribution of L-1350 EWL on March 2-3, 2016 (PreVail System®)

operator working in shift 07AM-07PM achieved a mean cycle time of 42,39 seconds; whereas the other operator working in shift 07PM-07AM had an average of 48,43 seconds, See Table 6.

This type of distribution curve is seen in the operations held in two shifts; distribution curve skewed to right. It has two mediums; two operators have different medians, Figure 8.

Table 8. Cycle time segments statistics of March 2-3, 2016

Shifts (12h)	TTDG (s)	DG (s)	TTDMP (s)	DMP (s)	CT (s)
(07AM-07PM)	12.48	4.14	17.78	7.97	42.39
(07PM-07AM)	8.48	5.21	25.82	8.89	48.43
Mean	10.48	4.68	21.80	8.43	45.41

TTDMP time reflects how good the truck spotting is with respect to the EWL. In shift 07AM-07PM truck spotting seems to be better because travel to dump time is comparatively shorter.

3. CYCLE TIME AND PRODUCTIVITY PARAMETERS OF LOADING EQUIPMENT (DISCUSSION)

Singh & Narendrula, (2006) cited the factors affecting the productivity of loading equipment in a comprehensive manner. The productivity of the loading equipment is influenced by primary and secondary parameters.

The primary parameters are Cycle time (CT),Bucket Fill Factor (BFF), Tonnes per Hour (TpH), Power (Fuel) Consumption), Utilization (U) %, Equipment Wear. The secondary parameters are Loading Equipment Design Features, Loading Geometry and Practice, Muckpile Characteristics, Operating Conditions.

Normal distribution curve, Figure 9a, indicates that the performance of the operators in both shifts are about the same achieving more or less the same mean cycle time values

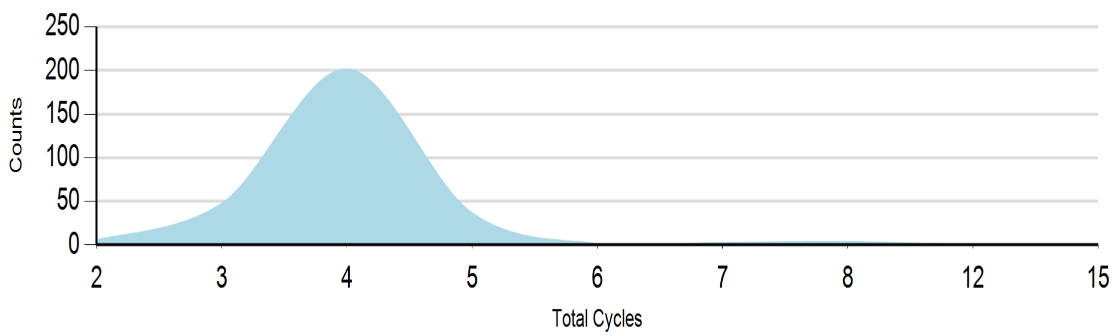

Figure 9 a. Normal cycle time frequency distribution curve (PreVail System®)

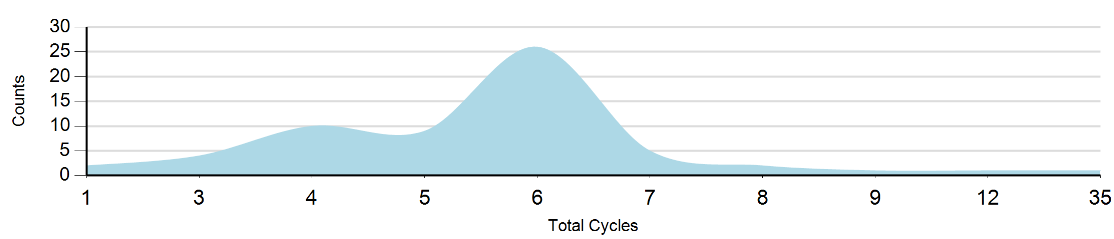

Figure 9b. Cycle time distribution curve skewed to right (PreVail System®)

Distribution skewed to right, which is seen (common) in two shift a day operations. One can see qualitatively that one of the shifts had longer cycle times than the other, Figure 9b.

Loading Equipment Design Feature factors comprises of Bucket size and shape, Breakout force, Digging Trajectory, Machine size, Capacity and power. Loading Geometry and Practice factors comprises of Loader and Muckpile Orientation (positioning), Machine Dimensions and Loading Area, Maneuvering space, Strategy for Muckpile attack, Strategies for oversize material handling. Muckpile Characteristic factors are Rock fragmentation, Muckpile Geometry, Looseness, Flow Characteristics, Angle of Repose. Operating Conditions factors are Training and experience of operator, Floor Conditions, Moisture content, Loading frequency.

Distribution skewed to left, which is seen (common) in two shift a day operations. One can see qualitatively that one of the shifts had longer cycle times than the other, Figure 9c.

of the loader and hauler operators qualitatively. Smooth bell-shaped distribution curves indicate a steady operation with steady cycle times. The curves with two peaks indicate that cycle time averages achieved by the two operators are not alike.

Travel to dig, travel to dump to truck segments of the cycle time is associated with speed and manuevering specifications of the equipment, bench geometry and the layout of truck with respect to loader. Dump to truck tray segment time is associated with the design features of the bucket and size of the truck (dumping height). Dumping period may be effected by unconformity of the height of the truck body and lifting height of the mining loader. However, Dig segment is mainly associated with the fragmentation performance of blasting rounds.

In loaders, the crowd force is generated by the traction of the tyres and hoist force is represented by the curling motion of the bucket. For this reason, a sound and dry and a flat bench floor is a requisite for loader application in mines. The loaders and trucks did not encounter with any water problem. Breakout force of wheel loader is created by lift and tilt cyclinders wheras crowding force is dependent on traction force.

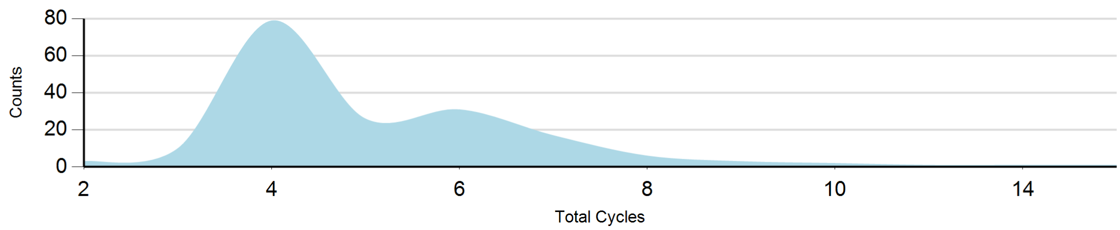

Figure 9c. Cycle time frequency distribution skewed to left (PreVail System®)

CONCLUSIONS

For the cases studied total cycle time segments percentages are as follows in sequence of the Brasilian and the Turkish cases: TTDG : 21,9 % and 15,6 %; DG : 9,7 % and 12,7 %; TTDMP : 49,7 % and 51,7 %; and DMP : 18,7 % and 19,9 %. Eventhough, the operational conditions are entirely different except the brand and capacity of the two loaders and the capacity of the haul trucks, it is interesting to note that the hardest segments of the cycles are travel to dump and dump phases which are the segments performed with full buckets. The Brasilian case have travel to dig phase time higher than the travel to dumptime, it might be due to the loader truck layout.

Cycle time distribution curves of loaders are handy in quick evaluation of the performance

Exploring the cycle time segments of mining loaders are important because they may have hints for the field engineer to improve the cycle time; thus, in turn improving the productivity of the loader.

The major factors in improving the productivity of a mining loader is to have optimum bucket fill factors and shorter dig times which are mainly governed by the mean muckpile particle size and its' distribution. Therefore, there is need for a good cooperation between the pit engineer and the blasting engineer for a sound and productive operation.

The effect of bucket dumping height on cycle time of the wheel loaders, and the effect of loader and haul truck size match on cycle time and its segments are the topics recommended for future studies.

REFERENCES

Anon. a, 2015. PreVail System Daily Reports, U.K.

Anon. b, 2016. North Pacific Training and performance, Inc. Canada’s “Loader Training Manual Sample”, LoaderManual-Sample-English.pdf, Canada

Fleet, M., 2012. Personal communication on “Hybrid Drive Electric Mining Loaders”, Longview, Texas, USA

Grant, M., 2016. “Hydraulic Shovel vs Wheel Loader” Quarry Academy. https://www.911metallurgist.com/blog/wp-content/uploads/2016/01/Hydraulic-Shovel-vs-Wheel-Loader.pdf

Klink, D., 2015. Personal Communication “P&H Surface mining equipment”, Milwaukee, WI, USA

Norris, J., 2013. Personal Communication, P&H LeTourneau Factory., Texas, U.S.A.

Ozdogan, M. ve Ozdogan, H, 2015 a. “Diesel-electric mining loaders-A case study”, DOI : 10.13140/RG.2.1.4714.4728 https://www.researchgate.net/publication/276206831_Diesel-Electric_Mining_Loaders_- A_Case_Study

Ozdogan, M.ve Ozdogan, H, 2015 b. “Analytics of cycle time and target load of electric mining loaders-A case study”, DOI : 10.13140/RG.2.1.4924.4644 https://www.researchgate.net/profile/Metin_Ozdogan/publications

Singh, S.P. and Narendrula, R., 2006. “Productivity indicators for loading equipment” maintenance and Engineering, May 2006, pp. 1-7, Canada. https://www.researchgate.net/publication/268802680_Productivity_indicators_for_loading_equipment