An analysis of the optimalization of bucket series against soil removal rate at The Dredger 21 Singkep 1 in PT. Timah (persero) tbk, Bangka Sea Mining Unit of Bangka Belitung Province

Harminuke Eko Handayani
1Faculty of Engineering, Sriwijaya University, Indonesia
E-mail: harminuke@ft.unsri.ac.id

Abstract. Dredger 21 Singkep 1 is a ship that serves to conduct excavation of tin ore offshore. The dredger is equipped with digging tools such as bucket, ladder, ladder roll, onder roll and other supporting tools that are connected to become one unit that is called bucket series. The bucket series is the main tool of the excavation process which continuously operates that has an impact on the depreciation of the performance capability of the equipment so that it is necessary to conduct an analysis of optimization of the bucket series in order to operate optimally and the targets of the work plan of the removal rate of the soil can be achieved. Based on the observation and data analysis on the field it is known that the applied ladder suppression is 0.46 meter at the top soil and 0.26 meter at tin-borne layer which results in 229.54 m³ / hour of soil removal rate which is very far from the target of the planned work of the soil removal rate determined by the production team of 389 m³ / hour, so to fulfill the work plan of the LPT the ideal ladder suppression that must be applied is 0.57 meter for top soil and at the tin ore is 0.31 meter, out of this ideal ladder suppression, is obtained the removal rate of the soil of 408.25 m³ / hour. In addition to that, the ideal length of the steek to achieve that removal rate of the soil should be at the average maximum length of 1225 mm.

1. Introduction
Tin ore is formed from liquid magma containing mineral cassiterite (SnO2). The intrusion of granitic rocks rises to the earth's surface, then there will be a phase in which ore minerals are formed. These minerals accumulate and are associated in granite rocks and rocks that are penetrated, and eventually form vein [1]. The process of tin ore formation comes from two sources, granite rocks and side rocks. The types of tin deposit found in Indonesia's tin line are the primary tin deposit and the secondary tin deposit [2]. Tin ores mined in Indonesia generally are of alluvial tin deposits and are often referred to as secondary tin deposits or called tin placers. This type of tin ore has been detached from the primary sediment of primary tin, and by water is re-deposited in other lower places [3].

PT. Timah (Persero) Tbk of Bangka Sea Mining Unit currently operates two dredges in its mining [4]. The dredging for offshore tin mining is part of a long term plan to identify new dredging technologies for mining in deep waters of over 50 m of water depth [5]. A dredger is a ship that has a set of tools that serve to excavate minerals under water [6]. One of the dredgers used is the Dredger 21
Singkep 1 which operates in the waters of Bangka Island thats is equipped with the supporting tools of excavation activities, namely bucket series [7]. The bucket series is an assembly of pens, buses, and rolls that connect the buckets to each other that form chains and mounted on the ladder which will be lowered until it reaches the top soil and the tin-borne layer. Bucket moving upwards is assisted by onder roll at the bottom which has a function as a reversal of the chain to get to the sea surface and finally the sediment of the excavation material in the dump is accommodated by the dredger, while the impure impurity material which is worthless will be immediately discharged through the tailing band located on the rear of the ship [8 ]. Ladder roll as a medium for the bucket chain to surround the ladder like a chain on a bicycle [9].

The mining process carried out by the bucket series is very important to determine the amount of production as the more volume of soil is being extracted the faster the targets of the work plan of the soil removal rate is achieved. The continuously working bucket series will experience shrinkage of equipment performance capability that affects an elongation in the bucket chain so that it will be heavier at the time of dredging the land and the bucket chain will easily escape from onder roll and bucket turn per minute will be high. In addition to the shrinkage of the tool's ability in the bucket series, the ladder suppression also affects the rate of soil removal. The ladder functions as a bucket chain trajectory and for pressing the soil layer so that the bucket will be filled with a layer of soil. After observation of ladder suppression at Dredges 21 Singkep 1 is carried out in a certain month, it is found that it is still less than optimal to achieve the target of the work plan on the rate of soil removal.

The aforementioned problem is the background of the study entitled “An Analysis Of The Optimization Of Bucket Series Against Soil Removal Rate At The Dredger 21 Singkep 1 In Pt. Timah (Persero) Tbk, Bangka Sea Mining Unit Of Bangka Belitung Province”. The result of the study is expected to be able to assist the company to achieve the optimal bucket series and to achieve the target of the work plan on the rate of soil removal.

2. Research Methodology
The location of the study is at PT. Timah (Persero) Tbk of Bangka Sea Mining Unit. The study is only conducted for Dredger 21 Singkep 1 which focuses on bucket series.

This stage of the study is followed by data collection directly in the field. The required data are the primary and the secondary data, namely the ladder suppression value by observing the ladder depth indicator, the side wire speed, the cycle time of the ship movement and the bucket speed per minute (BPM), observing the turning of overall bucket series. So, based on the data obtained, theoretical and real soil removal rate can be calculated by using the following equation formula [10].

Determining the theoretical Value of Soil Removal Rate (SRR):

\[ SRR = \text{Ladder Suppression} \times \text{Trap Progress} \times \text{Wire Speed} \]  
\[ \text{Information:} \]
\[ SRR = \text{Rate of Soil Removal (m}^3/\text{h)} \]

Determining the Real Soil Removal Rate:

\[ SRR = \text{Theoretical SRR} \times (\text{Side Wire Speed: BPM}) \]  
\[ \text{Information:} \]
\[ SRR = \text{Rate of Soil Removal (m}^3/\text{h)} \]
\[ \text{BPM} = \text{Bucket per minute} \]
Continuously working and moving equipment will experience shrinkage of wear or tear which may affect LRR, so it is necessary to collect the data of the total length of the measured bucket chain and compared with the standard chain length so that the percentage of wear of the chain will be obtained by using the following equation formula [10]:

\[
\% \text{ elongation} = \frac{\text{The total length of the measured bucket chain} \times 100}{\text{The total length of standard chain}} \quad \text{(3)}
\]

\[
\% \text{ elongation per hour} = \frac{\% \text{ Annual elongation} \times 10}{\text{running hours}} \quad \text{(4)}
\]

Data processing is carried out against the primary data and the secondary data obtained from the observation. The calculation is performed to obtain ladder suppression and maximal elongation of bucket chain needed by the dredgers. The results of the processing are the ideal ladder suppression, ideal length of steek and the maximum elongation of the chain’s length.

An analysis is performed against the aforementioned values so that the points related to the bucket series are obtained. Based on these points, the optimal bucket series to be applied to the Dredger 21 Singkep 1 can be determined in order to meet the rate of soil removal of the work plan (WP).

3. Results and Discussion

3.1 Analysis of Soil Removal Rate by Method of Regulating Ladder Suppression

The suppression of the ladder greatly influences the rate of soil removal. The greater the ladder suppression value, the greater the rate of the soil removal becomes. The direct field observations on the ladder suppression resulted in the following data of 35 top soil data and 35 data of tin-borne layer. The data were then processed to reveal the ladder suppression applied of 0.46 meter for top soil and 0.26 meter for tin-borne layer which resulted in a rate of soil removal of 229.54 m³/hour, while on the work plan (WP) the rate of soil removal that must be achieved is 389 m³/hour, so it is necessary to get the ideal ladder suppression so that the rate of soil removal can be achieved.

3.2 Tool Performance Relationships in Bucket Series that Affect the Rate of Soil Removal

The ideal rate of soil removal can be achieved if the factors that cause the rate of soil removal that has been planned by the company is not achieved, namely the condition of the tool in which the equipment that continuously operates will decrease in its ability. The relationship of excavation tool and the rate of soil removal is very crucial, particularly in the bucket series.

3.2.1 The Relationship of the Depth Value of the Ladder Suppression in Bucket Series Against of the Soil Removal Rate. The results of the observations of ladder suppression for the top soil and the tin-borne layer, it was revealed that the average ladder suppression in August was 0.46 meters in the top soil and 0.26 meters for the tin-borne layer which resulted in a rate of soil removal of 229.54 m³/hour, while on the work plan (WP) the rate of soil removal that had been set by PT. Timah (Persero) Tbk was 389 m³/hour, so that the applied ladder suppression could not meet the soil removal rate of the work plan, therefore ladder suppression value must be increased again in order to achieve the rate of soil removal that has been planned by the company.

3.2.2 The Relationship Between the Steek Distance and the Soil Removal Rate. The supporting component of the bucket chain is the steek distance, so that the digging tool component can dig up
maximally, it is necessary to see the relationship between the steek distance and the rate of soil removal. To observe the effects of the change of the steek length on the soil removal rate, a graph of the relationship between the average length of the steek and the rate of the soil removal in the period from 2014 to 2016 that can be seen in Figure 1 up to Figure 3, the measurement of the steek length is done once a month.

The graph of the relationship between the average steek length and the Soil Removal Rate (SRR) in 2014 can be seen in Figure 1. In October it is clearly shown the contrast in which the soil removal rate is high at the point of 364 m³ / hour and the average point of the steek length is low at 1229 mm which indicates that the rate of soil removal will be high if the average length of the steek is low.

The data of the 3 year-period reveal that the ship was not fully operational for 12 months in 1 year due to the annual maintenance. The maintenance which is done once a year may take a long duration of 2 to 3 months.

The graph of the relationship between the average length of steek and SRR of 2015 can be seen in Figure 2 in which in the month of June the rate of soil removal is below the average point of the steek length indicating that if the length of steek is high, the soil removal rate decreases.

![Figure 1](image1.png)  \textbf{Figure 1.} Graph of Relationship Between the Average Steek Length and the LRR of the Year 2014

![Figure 2](image2.png)  \textbf{Figure 2.} Graph of Relationship Between the Average Steek Length and LRR of the Year 2015
Figure 3. Graph of Relationship Between the Average Steek Length and LRR of the Year 2016

The Graph of the relationship between the average steek length and LRR in 2016 can be seen in Figure 3 in which in July it is clearly shown that the soil removal rate is higher than that of the previous months due to the low average steek length.

It can be seen in the graphs of the relationship between the length of the steek and the rate of the soil removal that increase of the length of the steek is the opposite of the rate of soil removal obtained. In which the greater the value of the steek length, the lower the value of the rate of soil removal and vice versa, the rate of soil removal will be large if the value of the steek length is low.

3.2.3. The Relationship Between Chain Elongation in Bucket Series and Running Hours On the Soil Removal Rate.

The wear rate of the bucket chain can be seen from the data of the chain length increase rate and compared with the standard chain length so that the elongation of the bucket chain it can be seen.

In Table 1 it is shown that as the number of running hours of production of excavation is high, then the percentage of elongation will be greater because the bucket chain rotates continuously. Based of the data of a 3 year-period that have been obtained and processed, a graph of relationship between elongation percentage or elongation and the running hours.

| Year | Total Elongation per year (%) | Total Running Hours (Hours) |
|------|-----------------------------|----------------------------|
| 2014 | 32.78                       | 3998                       |
| 2015 | 24.24                       | 2933                       |
| 2016 | 10.48                       | 678                        |
In Fig. 4 the graph of the relationship between elongation percentage and the running hours, it is shown that the elongation is directly proportional to the running hours, in which the more the running hours, the longer the length of the bucket chain. If the bucket frequently touches the soil layer it will affect the load borne by the driving force, which will become larger resulting in damage and the bucket turns per minute will be slower, so that the impact on the rate of soil removal obtained. Therefore, it needs to be reviewed again regarding the ideal chain length for the process of the excavation to become better and the rate of the soil removal increases.

3.3. Optimal Bucket Series To Increase Soil Removal Rate

The relationships between the performance of the work of the tools in the bucket series and the rate of soil removal should be properly studied, so that the ideal performance of the tools can be obtained so that the bucket series can run optimally to increase the rate of soil removal.

3.3.1. Ideal Ladder Suppression. The results of observations and data processing in the field, it is revealed that the applied ladder suppression is not suitable to meet the rate of soil removal of the work plan, hence the calculation of the ideal ladder suppression is performed so that the planned removal rate of soil can be achieved. So, to achieve the rate of soil removal of the work plan of 389 m³/hour, the ideal ladder suppression obtained is 0.57 meters for top soil and 0.31 meters for the tin-borne layer. Out of the ladder suppression the rate of soil removal obtained is 408.25 m³/hour.

3.3.2. Ideal Steek’s Length. Based on the graphs of the relationship between steek’s length and the rate of soil removal from Figures 1 to 3, Table 2 is made in which each of the highest rates of soil removal annually is fed into the table along with the average length of the steek so that the average ideal steek’s length is obtained. Based on the data of the average steek’s length which has the highest rate of soil removal in each year, the ideal average length of the steek to produce a higher rate of soil removal is obtained. In Table 2, the average number of good steek gain is 1225 mm.

| Year | Average Length of Steek (mm) | Soil removal rate (m³/hour) |
|------|-----------------------------|---------------------------|
| 2014 | 1233                        | 432                       |
| 2015 | 1232                        | 518                       |
| 2016 | 1212                        | 403                       |
| **Average** | **1225**                  |                           |
Table 3. The Data of the Elongation Percentage Per Year And the Total Length of Chain Per Hour

| Year | Elongation Percentage (%) | Addition of the Total Length of Chain Per Hour (mm) |
|------|---------------------------|-----------------------------------------------|
| 2014 | 0.0082                    | 14.38                                         |
| 2015 | 0.0083                    | 14.55                                         |
| 2016 | 0.015                     | 26.30                                         |
| Average | 0.0105                  | 18.41                                         |

3.3.3. Ideal Bucket Chain. The data obtained from the results of the study in Table 3, namely the percentage of elongation is proportional to the number of hours of production which means that the greater the number of hours of production of excavation, the greater the percentage of elongation.

The percentage of the elongation of the entire length of the bucket chain is 0.0085% which means that entire extension of the length of the bucket chain after operating in one hour results in an elongation length of 18.41 mm. The maintenance of the bucket chain itself is carried out in order to avoid elongation or excessive elongation. The inspection and repairs are not necessarily carried out monthly, but they should be done in accordance with the running hours of the ship.

4. Conclusions

Based on the results of the study and the previous discussions, the following conclusions are drawn:

1. The rate of soil removal of the work plan that has been established by the production team of PT. Tima has a target of 389 m³ / hour, while the real soil removal rate in the field reaches only 229.54 m³ / hour.
2. The rate of soil removal is not achieved due to the tool factor in the bucket series, namely ladder suppression and the side wire velocity, in which the applied ladder suppression is only 0.46 meters for the top soil and 0.26 meter for tin-borne layer which produces LRR of 229.54 m³ / hour.
3. The optimal bucket series to achieve the rate of soil removal in accordance with the work plan is 389 m³ / hour, so the average ideal ladder suppression is 0.57 meters for the top soil and 0.31 meters for the tin-borne layer. With the ladder suppression, the soil removal rate obtained will be 408.25 m³ / hour, the speed of side wire needs an increase into 6.45 meters / minute on the top soil and 5.68 meters / minute on the tin-borne layer and the for bucket chain itself the applied steek’s length must be 1225 mm.

References

[1] Osberger R 1958 Buku Catatan Tentang Geologi Pulau Bangka (Notes on the Geology of Bangka Island) (Washington: Government printing office)
[2] Sujitno S 2007 Sejarah Penambangan Timah di Indonesia (The History of Tin Mining in Indonesia) (Pangkal Pinang: PT Timah (Persero) Tbk)
[3] Hardjono S, Sutedjo W, Soemarto N, Mulyadi S and Marangin 1992 Pengantar Pertambangan Indonesia, Asosiasi Pertambangan Indonesia (Introduction to Indonesian Mining, Indonesian Mining Association) (Jakarta)
[4] Bray R N 1979 Dredging Handbook For Engineers (London: Edward Arnold)
[5] Randall R E 2002 A bucket wheel dredge system for offshore tin mining beyond the 50m water depth Ocean Engineering 29(14): 1751-1767
[6] Admir R F 2008 Method for estimating clamshell dredge production and project cost Official Journal of WEDA vo7 7 No. 1
[7] Siahaan M A 1986 Mesin Gali Mangkok Dan Permasalahannya (Bowl Digging Machine and Its Problems) (Pangkal Pinang: PT Timah (Persero) Tbk)
[8] PT Timah (Persero) Tbk 2009 *Operasi Kapal Keruk* (Dredger’s Operation) (Pangkal Pinang: PT Timah (Persero) Tbk)

[9] Jusufusfin B 1992 *Perkapal Kerukan* (Dredging Technique) (Pangkalpinang: PT Timah (Persero) Tbk)

[10] Mustika A 1995 *Dasar Pemindahan Tanah Kapal Keruk* (The Basics of Soil Removal by Dredgers) (Pangkal Pinang: PT Timah (Persero) Tbk)