CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Draglines are structurally complex and are subjected to loads that vary in frequency and intensity throughout their operational life. Considering the economics of scale, the extraction techniques are increasingly mechanised. Large sized equipment are being deployed. Dragline is an important excavating machine used in numerous surface mining operations worldwide. Towards this, the dragline offers the lowermost material removal cost per tonne (ton) and standard operating life of 40 years besides being the most versatile machine in the industry.

A dragline is a specialised piece of electrically powered heavy earth moving equipment used generally in stripping overburden. Machine size, bucket length, style and rigging strategies have slowly evolved through the years. In surface mines for exposing the minerals, generally, draglines are used (up to 50m depth). The standard weight of the dragline is generally more than 4000-ton, with bucket sizes ranging from 15$m^3$ to 120$m^3$. The capital cost of dragline is Rs 500 crore approx for bucket capacity of 62$m^3$.

A dragline system consists of a huge bucket that is suspended from a boom with double ropes. The bucket is manoeuvred by using ropes and chains. The hoist and drag ropes are generally powered by big diesel or electric motors. The drag rope is used to drag the bucket assembly horizontally. The buckets are dragged against to the blasted muck to fill for filling (Azam and Rai, 2018). By skillful manoeuvre of the hoist and the drag ropes, the bucket is controlled for numerous operations. The bucket is a crucial part of the dragline, which involves a capital cost of around Rs 13 crore approximately for the 62$m^3$ bucket.


Figure 1. 1: Dragline 8200 model in mine

For most mines which deploy dragline, the dragline is the most critical equipment from the point of view of its operation and productivity. The mining profitability is profoundly linked to the dragline productivity. The productivity of a dragline bucket is dynamically changed with the aid of various conditions evolving from operational, environmental, and human-based requirements. Also, they are governed to a great extent by the indiscretions and inhomogeneities in the working conditions. It has been determined that operational and resultant stress differences are critical issues that cause unstable stress to set off harm to the bucket and its working life (Golbasi and Demirel, 2015).

## 1.2 Components of dragline

The main components of dragline are given below.

1. Mast
2. Frame
3. Boom

4. Bucket
5. Hoist Rope
6. Drag Rope
7. Dump rope
8. Hoist drum
9. Driving Motor

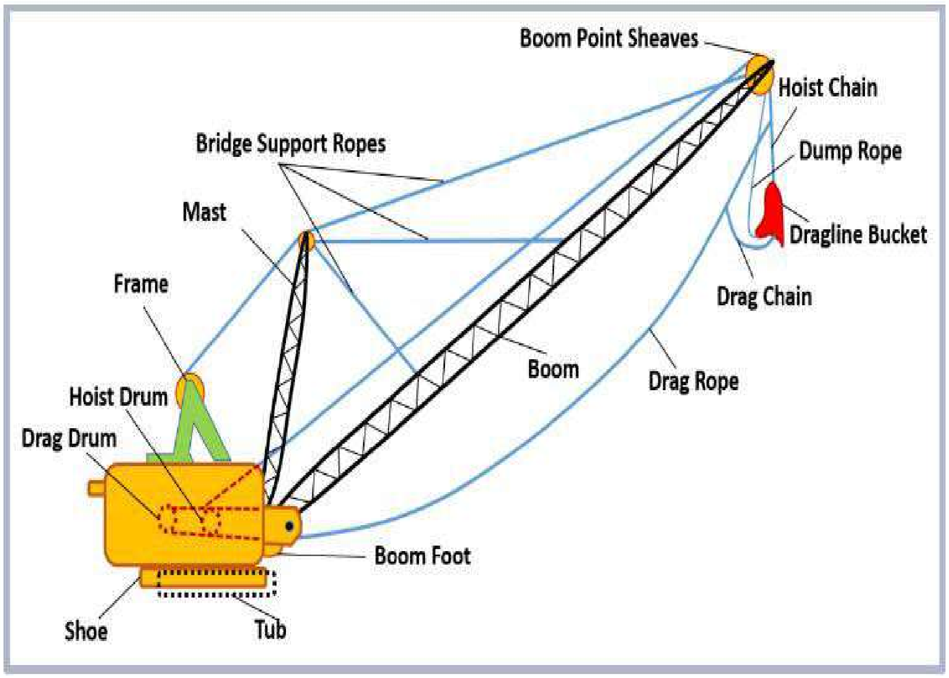



Figure 1. 2**:** Component of a dragline (Modified from Karpuz and Demirel,2016 )

A dragline system has two portions. The lower portion of a dragline consists of metallic chassis and moving mechanism while the upper portion of a dragline includes operator cabins and drives, haulage, and excavation elements such as boom, chain, bucket, and metal rope (Bright, 1985). Main components of a dragline are shown in Figure 1.2. The productivity of the dragline is affected by numerous factors. The overall productivity of dragline is mostly affected by the bucket filling, dumping, and swinging operations.

## 1.3 Dragline bucket

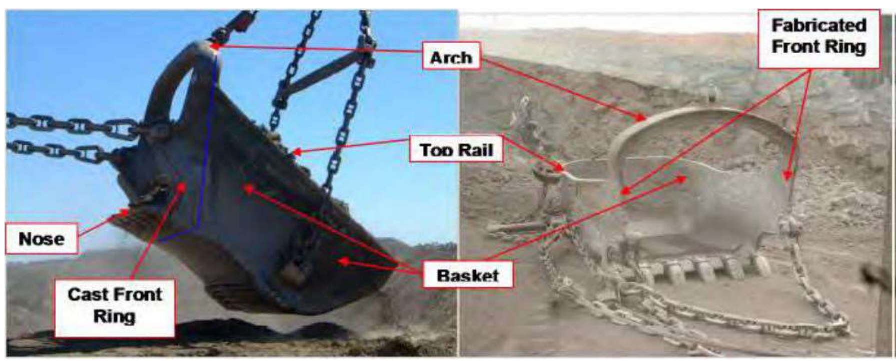
In dragline operation bucket is an essential component. There are different types of bucket available for the draglines provided by different manufacturers. The bucket ought to be matched for maximum productivity in the rugged field conditions.

Figure 1. 3: A large dragline bucket

Bucket is the element of a dragline, which is in direct contact with the rock material. The bucket teeth penetrate the broken rock material, while it is dragged towards the machine by drag rope. By this dragging, the blasted material gets filled into the bucket. During this process, teeth are in direct contact with the rock material and are subject to maximum stress, wear and tear. It was found from the official maintenance records that the overall life of a bucket is 1000-1200 hours, and tooth life is 200-300 hours. By using the correct dragline bucket teeth profile, wear can be minimized. This will facilitate the teeth penetration and bucket operation in blasted muck. Generally, the corner teeth of the bucket are subjected to greater wear. When the bucket is loaded repeatedly at an angle, then irregular wear occurs on the loading side. If the teeth profile is faulty, the penetration becomes deficient, power consumption increases and overall productivity of dragline is reduced. Wear life, and tooth performance are the main factors for replacement of the bucket tooth. If the overburden materials are abrasive, then there exist greater demands of both the design and strength of bucket and teeth ( Handbook, Caterpillar Performance 2017 ).

## 1.4 Details of the bucket assembly

The dragline bucket is made up of different parts. It consists of the basket, arch, cast lip, nose, cast front ring, top rail, fabricated front ring, hoist trunnion and the cutting edge (or teeth) of the bucket.




(a)


(b)

Figure 1. 4: Bucket assembly and their parts (a) Mains parts (b) Cast lip and teeth (Dragline Dictionary Edition, 2014)

The front ring of the bucket is either fabricated or cast, and the nose and arch of the bucket are added. The basket of the bucket is made of steel for giving good strength. For further increasing the strength of the bucket top rail is provided. The arch of the bucket is made from fabricated structure or cast. It provides the structural strength to the front ring and arc anchors. The arch can be rectangular or tubular hollow section, and the front ring of the bucket connects the lip, drag hitch, the arch, and cheek. The bucket lip is generally cast, and other parts can be fabricated or cast. The lower hoist chains are attached in the hoist trunnion. Trunnions are generally designed with two holes to allow the hoist chains to be attached in the front or rear position. For different carry angles and dump adjustment, these positions are allowed for further adjustment. All of these features must be clarified when purchasing a new bucket (Dragline Dictionary Edition, 2014).

The bucket is fabricated to operate around different service intervals in which essential areas need to be replaced during the life of the bucket. It is manufactured from highly tempered and quenched steels, giving it high strength as well as high abrasiveness in required areas (Dragline Dictionary Edition, 2014).

## 1.5 Wear of dragline bucket

For the dragline bucket itself, the primary mode of wear is material abrasion. As a result, the areas of the bucket that spend the most time moving through material tend to receive the highest levels of wear. These include the lip, floor, inner cheek plates, bottom wear package, lower corners, and sides. The wear on the lip and inner cheek plates are generated by the soil flow in and out of the bucket during digging and dumping actions. The wear on the bottom wear package is generated by the dragging of the bucket through the dirt while in digging mode.

## 1.6 Static and dynamic loading conditions

In this research work, the analysis has been conducted in two cases. One is static, and the other one is dynamic loading conditions. In static loading condition, bucket dead load and payload (mass of loaded material) are considered under a stationary state of the bucket. The load is assumed to be applied on the filled bucket in hanging position. This condition is attained just after loading and immediately before the commencement of swinging operation for a very short time in dragline operating cycle. Therefore, under this situation of static loading condition, the role of the vertical load along the base of the bucket has been considered to be important. Dynamic loading condition occurs when the bucket moves in a forward direction for filling the broken rock material. When the bucket moves forward by cutting the overburden material, the load of the overburden material is applied on the bucket teeth when we take the bucket teeth, you call it the cutting force, but when it is taken into the response of the overburden material, it is called the resistive force.

## 1.7 Numerical simulation techniques

For strength calculation of the structures working under known boundary and loading conditions, finite element method (FEM) analysis is the most significant method. The FEM analysis of any structural element supports in forecasting the structural masses and design in which it will act under stress conditions (Abo-Elnor, Hamilton, and Boyle, 2003). For simulation and analysis purpose, finite element methods are used to optimise, design and develop any mechanical part. The simulation results include deformation, damage, equivalent stress, factor of safety and fatigue life under different loading conditions.

Von -Mises theory has widely been recognized as the most reliable basis for design, mainly when working with ductile materials (Hearn, 1997). This theory is frequently called the Huber-Henky-Von-Mises theory, as it was proposed by M.T. Huber of Poland in 1904 and independently by R.Von Mises of Germany in 1913.This theory states that failure occurs when the maximum shear strain energy component in the complex stress system is equal to that at the yield point in the tensile test (Hearn, 1997).

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \leq 2\left(\frac{S_{yt}}{N}\right)^2 \qquad (1)$$

Where $\sigma_1$, $\sigma_2$ and $\sigma_3$ are principal stress

$S_{yt}$ = Yield strength

N= Factor of safety

In this study, dragline bucket analysis includes examination and understanding of the stress distribution, factor of safety of the bucket body, the optimum rake angle of bucket teeth and the resistive force under different working conditions. Numerical modelling and simulation method has been used for examining all the said crucial parameters.

## 1.8 Statement of the problem

Draglines are heavy-duty earthmoving equipment. Their weight varies between 2000 to 7000 ton. To excavates and overcasts the blast material with the help of long and massive booms having a length of 100 m or so. During this working process, loading and unloading changes the stress in the working element of dragline bucket. This stress causes the fractures, wearing and fatigue failure etc. in the dragline bucket. During the dragging of bucket it is essential that the digging force must exceed the resistive force. Focus on the whole study and analysis is required towards the interaction between rock and bucket teeth to find out the Von-Mises stress, damage, deformation, fatigue life, factor of safety, fatigue sensitivity, optimum rake angle and resistive forces on the bucket teeth.

## 1.9 Objective and scope of the study

In the proposed context, the main goals of the present study are to find the Von-Mises stress, damage, deformation, fatigue life, factor of safety, fatigue sensitivity, resistive forces and optimum rake angle of teeth under the different operating conditions of the dragline.

Main objectives, of the present work, are summarized below as :

- Development and simulation of a 3D solid model of the bucket using Finite Element Analysis.
- To evaluate the resistive forces under varied loading conditions.
- To critically analyze the FEM simulated dragline bucket model and evaluate the Von-Mises stress, damage, fatigue life, deformation behaviour, factor of safety and fatigue sensitivity values on different components of dragline bucket.
- To compare the results of static and dynamic loading conditions on stress, damage, fatigue life and factor of safety.
- To optimise the rake angle of bucket teeth for minimizing the resistive forces on the bucket teeth.

## 1.10 Research questions

Following Research Questions (RQs) have been formulated to cover the objectives and scope of the present work:

**RQ 1.** How to develop the best 3-D simulation model of the bucket using Finite Element Analysis and state-of-art Computer Aided Design techniques?

**RQ 2.**How does the resistive forces under varied loading conditions of the bucket in the static and dynamic conditions, affect the stresses and their pattern in the bucket structure and its assemblies?

**RQ 3.** How to analyze the FEM simulated dragline bucket model, under static and dynamic loading conditions to properly evaluate the Von-Mises stress, damage, fatigue life, deformation behaviour, factor of safety and fatigue sensitivity values on different components of dragline bucket?

**RQ 4.** What are the major influencing parameters for comparing the results of static and dynamic loading conditions on stress, damage, fatigue life and factor of safety of bucket and its assemblies?

**RQ 5.**What is the optimum rake angle of bucket teeth while handling the blasted muck piles, for minimizing the resistive forces on it?

## 1.11 Summary of thesis

The thesis work has been divided into six chapters. A brief explanation of each chapter is given below.

Chapter 1 is an introduction part which includes the relevance of the study. It exactly computes the main objectives of the research. Chapter 2 includes a comprehensive literature review and previous studies about the dragline and its component. Chapter 3 discuss the steps of research methodology, development of a 3D solid model of dragline bucket in AutoCAD and simulated the model in ANSYS. Chapter 4 shows the calculation of loading and unloading weight of the bucket and evaluate the resistive force on the dragline bucket teeth. To develop a relationship between resistive force and angles of bucket teeth in the form of equation. In Chapter 5 simulation results, graphical representation, validation and discussions are included. Chapter 6 includes conclusions and future work in the subject fields are computed. In the end, references and appendices comply.