



**GERMAN MONGOLIAN INSTITUTE FOR RESOURCES AND TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING**

The present work was submitted to the Faculty of Engineering

**Possibility of Alteration of the ore mechanical
property for improvement of the transfer
chute design problems**

Bachelor Thesis

Tengisdulguun Tumenjargal

Supervisor 1/ Examiner 1

Prof.Ph.D., Ariunbolor Purvee

Supervisor 2 / Examiner 1

Master Ariunbold Puntsag

Ulaanbaatar/Nalaikh, 2018



Statutory Declaration

Tengisdulguun Tumenjargal

14405793491024

Last Name, First Name

Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Possibility of Alteration of the ore mechanical property for improvement of the transfer chute design problems

independently and without undue external help. I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar/Nalaikh, August

15, 2018

Place, Date

Signature

ABSTRACT

The mining industry has been expanding rapidly in Mongolia for last 2 decades. As a result, many problems are arising which require solutions from Mongolian engineers. Effectiveness and productivity of copper mining industry depend on appropriate actions and processes of various types of devices, techniques and machineries, which are used at mining sites. One of these important devices is a transfer chute.

At Oyu Tolgoi mining site the discharge chute maintenance takes place every four weeks due to the wear and tear of liner and belt. It causes many difficulties at the Oyu Tolgoi mining site.

The purpose of this thesis is to improve the chute design in the copper mining industry, in particular to calculate and evaluate how the ore properties influence the wear and tear of the chute's liner and conveyor belt.

A brief introduction on basic elements of mining and processes of copper mining is given. Also in our study we attempted to review the required literature on some key aspects of chute design theory.

In our study we used a variety of geometrical, mathematical and mechanical engineering formulae and theories. In addition, we used computer programmes such as MATLAB, Inventor and EDEM.

We concluded that the transfer chute problem occurs not only at Oyu Tolgoi, but throughout the world. Globally, mining industries in many countries have chute design problems. Researchers have been studying these problems for years considering different aspects of it. According to the researchers one of these aspects of chute problem could be the influence of the ore property.

Regarding the Oyu Tolgoi transfer chute, when we calculated the influence of ore mechanical property to the chute perforation, the ore causes 572 Pa pressure to the chute liner and there is no possibility to perforate chute liner when using Hardox 500. Following the results of this calculation we raised a hypothesis that we need to study morphological properties of ore. According to our calculations and study, the ore has high pressure impact for a small area, specifically smaller than 184,3 mm². area. During the ore crashing process sharp, apical, spiky parts were carried to the chute and these parts cause the chute perforation and cause the problem to chute liner.

Resulting from above mentioned inference we concluded that in order to reduce transfer chute linear perforation, it would be a better practice to change the morphology of ore therefore to widen chute linear contacting area. In order to achieve these goals, it's needed to reduce ore particle size at the previous process (stage) of primary crushing process. Solving transfer chute problem needs further careful studies on changing and researching chute geometrical design and chute body material.

We suggest that there are still a number of open issues for research in improvement of chute design. The further researchers are needed to enrich combined experimental and theoretical study on changing chute geometrical design and chute body material in efficient ways.



ACKNOWLEDGEMENTS

First of all I would like to thank all my professors and lecturers and whole GMIT staff, who taught me different subjects during my 5 year study at the GMIT for their sharing great knowledge and encouragement.

I am also grateful to my supervisor, Professor Ariunbolor Purvee and cosupervisor, Master, Ariunbold Puntsag who believed in me and were continuously supporting me. I especially thank them for their supervision, helpful comments and valuable guidance on drafts of this thesis.

I also thank team of Oyu Tolgoi for sharing expertise and helping with supplementary materials such as ores sample and datas, suggestions and recommendations.

Special thanks goes to my peers, friends and roommates for their advice and their continuous support.

Finally, I want to express my warm appreciation and thanks to my family members for their thrust, encouragement, help and support.

Tengisdulguun Tumenjargal

Contents

Statutory Declaration	i
Abstract.....	ii
Acknowledgement.....	vi
Tables.....	vii
Figures.....	viii
Nomenclature.....	ix
Chapter 1 Introduction	1
1.1 Introduction	1
1.2 Literature review	2
1.2.1 The critical factors.....	6
1.2.2 Chute hoods	7
1.2.3 Chute body	9
1.2.4 The problems with chutes	10
Chapter 2. Copper mining	11
2.1 Copper	12
2.2 World copper mining process.....	13
2.2.1 Mining	13
2.2.2 Ore.....	14
2.2.3 Concentrating the ore	14
(1) Crucher machinery	15
(2) Belt conveyer	
(3) Definition of a chute	18
Chapter 3. Oyu tolgoi copper mining	19

3.1	Oyu Tolgoi.....	19
3.2	Oyu Tolgoi Mining Process	20
3.3	Oyu Tolgoi Mining Process Problem	22
Chapter4. Experimental study		25
4.1	Theory for calculation of ore properties	25
4.2	Hypothesis	36
4.3	Calculation	36
4.4	Result.....	38
Chapter 5 Conclusions and suggestions		40
5.1	Conclusion	40
5.2	Suggestion.....	41
References.....		42

Tables

Table 1. Inspection and access openings in chutes

Table 2. Common copper minerals

Figures

Figure 1. How NOT TO design a chute

Figure 2. Position of inspection hatches

Figure 3. Copper mining process

Figure 4. Classification of crushers

Figure 5. Classification of crushers

Figure 6. OT Primary Crusher conveyer

Figure 7. OT Discharge chute CVB-001

Figure 8. OT Discharge chute CVB-001 linear

Figure 9. Test for wall friction angle

Figure 10. Loaded belt profile at the discharge

Figure 11. Point of discharge

Figure 12. Trajectory at fast belt speed

Figure 13. Trajectory at low belt speed

Figure 14. Hood design

Figure 15. Formula for impact pressure

Figure 16. Velocity after impact

Figure 17. Flow through Spoon

Figure 18. Feed onto the belt

Figure 19. Non-dimensional wear parameter versus slope angle

Figure 20. PI pascal

Figure 21. Conveyor velocity vs Impact pressure

Figure 22. Bulk density vs Impact pressure

Nomenclature

A – area of chute (m^2)

C_{dc} - Belt design capacity (t/h)

S - Material stream speed (m/s)

D - Bulk density of the material (t/m³)

W_{wet} - is the wetted area in metres

W - belt width in mm

C_a - depth to center of area of ore burden (m)

A - is the cross section area of 100% loading in m²

α - angle of inclination of the belt at the discharge pulley.

γ - is the angle of repose (typically 34°–37°)

R - the point at which the ore stream leaves the belt

r - pulley radius over lagging (m)

h - belt total thickness (m)

K - factor K

θ - the angle between the horizontal and the drop point

L - length

t - time intervals

H - height

P_i - impact pressure

V_1 - impact velocity

V_2 - velocity along chute after impact

ϕ' - wall friction angle

W_c - wear factor

Q_m - throughput kg/s

K_c - ratio of velocity of sliding against chute surface to initial velocity

B - chute width (m)

N_{wr} -non-dimensional abrasive wear

W_{csw} -wear on chute side walls

W_c - abrasive wear factor

V_{ey} - vertical component of the exit velocity

W_a - abrasive wear parameter

μ_b - friction coefficient between the bulk solid and the conveyor belt

V_b - belt speed

θ_e - chute slope angle with respect to vertical at exit.

Chapter 1 Introduction

1.1 Introduction

Since the beginning of the civilization, flint was discovered on the Earth's surface and humans used flint to make tools and weapons. This marks the foundation of mining industry. Ancient Egyptians used to mine malachite, which they used for making pottery and ornaments because of its distinctive bright green colour. Subsequently, the ancient Egyptians also extracted turquoise, copper and gold. During the Industrial Revolution, Americans and Australians played the main role in developing the surface mining. Metallurgy was born thanks to the new technologies developed by their scientists. Metallurgy is a science of extracting metals from their ores and modifying metals for different uses, such as making cars, tools, machineries and weapons as well as using metals for building and architecture. As the demand for variety of metals rose, mining under the ground became necessary. Nowadays, we not only extract the base metals and coal, but also rare earth metals, which are used for smartphones, televisions and computers. It is uncommon to reach rare metals.

Mining industry requires number of devices, techniques, machinery and equipment. One of them is a chute.

Transfer points are recognised as critical areas within a bulk solids handling facility (Benjamin 1999, 2001.) They can be found in variety of range of industries, including mining. To facilitate transfer, a *chute system* is used to direct bulk ore from a discharge point to a receiving point. Transfer chute system consisted of several elements such as a curved Hook, a curved Spoon, a rock box, an impact plate or U- form chute. The initial objective of chute is to control the flow of ore through the transfer process.

The failure of chute can be costly and could cause numerous troubles. Mistakenly designed and badly maintained transfer chute able to cause 'bottleneck' troubles in terms of plant capacity. For example, there are considerable costs associated with a troublematic transfer chute (ranging from \$15k to \$50k), the installation of the chute system (cost depends upon the number of personnel involved), and of course, lost production (approximately \$600/minute=\$36/hour). All costs are in Australian dollars. In addition to

financial criteries, environmental and safety issues are concern and dependent upon the performance of a transfer chute system.

It is obvious that an excellent transfer chute design from the outset able to negate the costs associated when the chute and/or conveyor belt needs to be replaced or repaired on a regular basis due to poor design principles. If the velocity profile of the ore flowing through the transfer at a number of critical locations can be correctly predicted at the design stage, the potential for a successful chute design is greatly increased. A colliery will thus benefit from minimised downtime losses, higher product yields and improved product quality.

Aim of the thesis

The purpose of this thesis is to improve the chute design in the copper mining industry, in particular to calculate and evaluate how the ore properties influence the wear and tear of the chute's liner and conveyor belt. As a result of this to extend chute work capacity as well as reduce wearing of liner and belt.

Material and methods

As a material we used a transfer chute from Oyu Tolgoi mining industry. We visited Oyu Tolgoi mining industry on 12, March, 2018 in order to meet real condition of chute at the site. Parametres and datas of chute was given by Oyu Tolgoi team. Also we were supplied as a source of material sample of ore.

In our study we used variety of geometrical, mathematical and mechanical engineering formules and theories. Also we used computer programmes such as MATlab, Inventor, EDEM.

1.2 Literature review

This section will review chute design literature. Number of research studies were done on elements of chute and troubles associated with badly designed chutes and the models and design methods available to calculate or predict ore flow aspects at each components.

Ore discharge is one of the key factors in transfer chute design. Because it determines the exact point at which the ore leaves the belt. A number of varios methods exist in the literature for modeling ore discharge as well as the studies of Arnold & Hill (1989,1990a, 1990b, 1991a, 1991b, 1993) Booth (1939) BFGoodrich, BTR, C.E.M.A (1997), Colijn&

Conners (1972), Dunlop (1982), Korzen (1984b, 1989), Roberts (1997b, 2001) and Roberts et al. (1987)

As shown by Arnold (1993) and Arnold & Hill (1990a, 1991a, 1991b), derivations for ore discharge can be divided into two areas: slow discharge, where the ore wraps around the head pulley to some extent before discharging; and fast discharge, where the ore will discharge at the point of tangency between the belt and head pulley. An important aspect of accurate trajectory prediction is the determination of the wrap angle (α_d) and discharge velocity. Korzen (1989) and Roberts (1997b, 2001) provide the most comprehensive method of determining whether a conveyor belt is running in the high or slow speed condition. In their work, a belt can be described as high-speed if it meets the condition.

Korzen (1989) in his literature noted about useful technique models, that used the concept of adhesion and inertia of the material on the belt and allowance was made for the variation in static and kinematic friction.

Booth (1934) noted the effects of friction between the particle and the belt, however he did not write adhesive effects in the analysis. These two techniques require iterative procedures to obtain results.

Similar to Booth, Dunlop (1982) used the concept of friction acting between the material and the belt. The work of Golka (1933a), Goodyear (1976), the C.E.M.A (1977) and two M.H.E.A (1986,1989) guides, and the manuals of centripetal acceleration in their work.

William E. Sabina, Richard P Stahura, R Todd Swinderman in their paper „Chute Problem Checklist“ listed 31 problems of chute and formulated their solution. We mentioned here the most important problems and their solutions.

1. Problem – Spillage. a) If skirtboard too far from belt. Solution - Set skirtboards 12mm above belt and add inner liner to form labyrinth seal. b) Load Zone Turbulence. Solution - Provide curved acceleration gate. c) Load Centering. Solution - Provide flow training gates. d) Transfer Housing Acting as a Hopper. Solution - Design out all possible back-ups or provide jog start and regulating gate for existing belt. e) Poor Skirtboard Seal. Solution - place impact idlers on minimum centers, use latest type of seal rubber, support belt under seals with continuous pads, used steel impact idlers except when rubber is mandatory. f) Impact Idler Maintenance. Solution - Use specially designed idlers or removable stands

under standard idlers to facilitate and promote maintenance. g) Inadequate Skirtboard Length. Solution - provide accelerating and training gates.

2. Problem - Load centering. Solution - Provide flow training gates or centralizing idlers.

3. Problem - Material degradation. Solution - Provide flow acceleration gate, reduce belt speeds and material fall distance.

4. Problem - Belt tracking. Solution - Keep the conveyor clean and rotating components well maintained

5. Problem - Chute wear. Solution - Provide highest grade abrasion resistance lining available, provide adequate doors and enclosure size to facilitate inspection and maintenance.

6. Problem - inadequate inspection capability. Solution - Provide an inspection door in the head chute, load zone, and at every 3 m.

7. Problem - Belt damage from large lumps. Solution - Provide grizzly bars in impact zone, provide cushion pads under belt in impact zone, install rip detectors.

8. Problem - Belt wear and abuse. Solution - Use routine maintenance and good quality skirtboard and belt cleaners. Determine proper barrier pressure to avoid belt wear.

9. Problem - Material build-up/plugging. Solution - Prevent sticky material from touching chute walls, provide multiple belt cleaners with automatic or mechanical excitation for cleaning, line all contact areas with UHMW plastic, apply flow aid devices.

10. Problem - Structural support for exiting conveyor. Solution - common support for load chute and exiting conveyor.

11. Problem - Lack of design attention. Solution - Utilize trained personnel to design and draft transfer solutions.

12. Problem - Conveyor is loaded in transition area of belt. Solution - Use generous transition area and specialized transition idlers. Do not load before center line of first standard troughing idlers in impact area.

13. Problem - Skirts not supported rigidly enough. Solution - Support skirts with uprights and cross members.

14. Problem - Spillage trips belt alignments. Solution - Locate belt alignment switches near tail pulley, out of area subject to spillage of large lumps. Locate safety stop switches out of path of lumps. May use extension deflector.

15. Problem - Insufficient room for belt replacement. Solution - Put easily removable idlers in load zone, creating room for belt replacement.

16. Problem - Auxiliary equipment installed as an afterthought. Solution - Specify access area and provide equipment in design.

17. Problem - Material characteristics are unknown. Solution - Follow CEMA classifications, employ testing laboratory.

18. Problem - Determining bulk density. Solution - Determine bulk density under variety of conditions.

19. Problem - Access to both sides of conveyor equipment. Solution - Allow 450mm or 1/3 of the belt width between conveyor and any permanent obstruction. Specify equipment necessary to reach far side of conveyor.

20. Problem - Build-up on inside return strand of conveyor. Solution - Install deck plate, should be used in conjunction with tail protection plow.

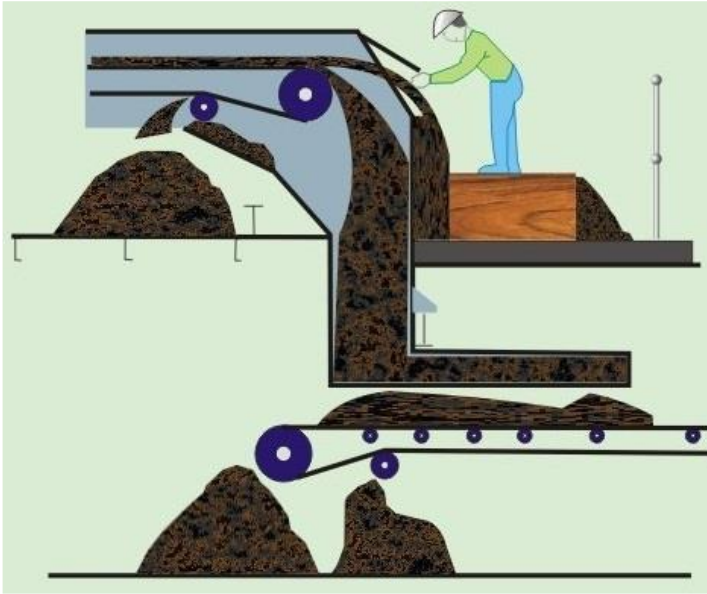


Figure 23. How NOT TO design a chute

1.2.1 The critical factors

There are some critical factors which are supreme in design of the chute. These are:

- Reduction of impact on the chute faces
- Reduction of impact on downstream belt
- Centralized loading onto the downstream belt.

Also the following characteristics are influential for efficient chute:

- Is not prone to blockages
- Allows for the transfer of ore with minimal wear to the chute surfaces
- Allows for the transfer of ore with minimal wear to the downstream belt
- Results in minimum ore degradation
- Results in minimum dust production
- Centralizes the load onto the downstream belt, hence minimizing belt wander
- Results in minimum ore segregation.

In order to achieve the all above mentioned goals, the designer or engineer ought to know a logical design sequence as follows:

- Know and understand the properties of the ore to be conveyed
- Know and understand the nature and characteristics of the application
- Plot the trajectory of the ore
- Design the Hood (discharge collector) and define conditions for minimum wear in the chute, or, in the event that a Rock Box is selected, design the Rock Box so as to collect and transfer ore in an appropriate channel.
- Design the Spoon (discharge distributor) and define conditions for minimum wear in the chute and on the downstream belt.

As a process is repeated and could be affected by different factors such as limitations on head room, variations in lump size or in fact, the sort of material.

Even the designer or engineer is forced to compromise on several design criteria (e.g. chute and belt wear and material degradation) the requirement to prevent blockages and reduce the possibility of spillage must never be compromised.

1.2.2 Chute hoods

The chute hood should be dimensioned to cater for the following:

The side plates should clear the pulley face by a minimum of 50 mm. This distance is measured from the inside of any liner plates which may be attached to the chute hood.

The hood height at the ore entrance should be at least $0.5 W$, where W refers to the belt width. The height should allow sufficient space for the ore burden to pass unhindered, including the possible incidence of larger rocks located on top of the normal burden. In this case, the minimum hood height should be in excess of $3 \times bL$, where bL is the maximum lump size.

The hood flanks and cover should extend backwards at least 850 mm from any nip point.

The hood may be provided with inspection or access openings, as required, located out of the ore stream. The inspection openings should be easily and safely accessible.

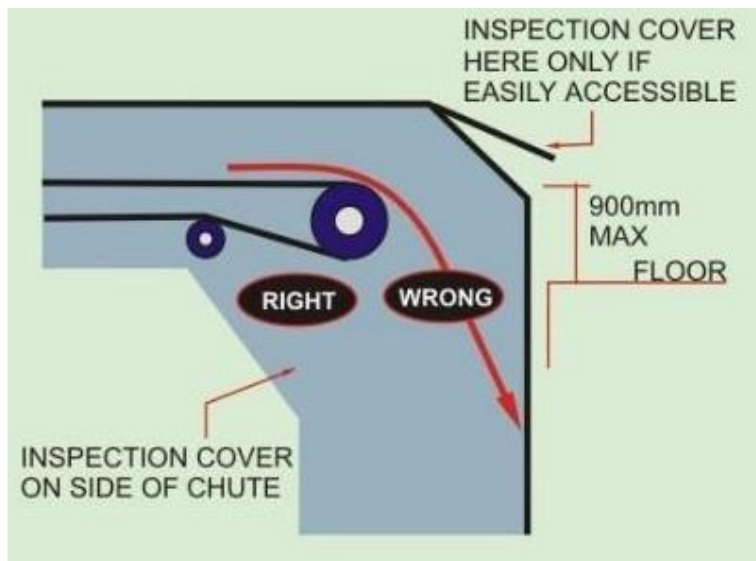


Figure 24. Position of inspection hatches

The inspection openings should be covered. For chutes that are de-dusted, the inspection and access openings should be designed to allow the minimum ingress of false air. The opening size must be sufficient for its purpose.

Table 3. Inspection and access openings in chutes

Purpose	Height	Width
Observation	300	250
Servicing belt cleaners, sprays	300	350
Liner replacement	450	600
Maintenance personnel access	650	650

Where de-dusting is required, the hood should be provided with a back screen or apron seal, to limit the ingress of false air. The apron seal may be made of 3 mm (minimum) reinforced rubber cloth, attached to the chute hood entrance. The apron seal should be

vertically slit to allow the ore to pass. The slits are normally spaced at typically between 100 mm and 150 mm.

The hood is placed over the head or discharge pulley, which is located with respect to the equipment being fed. The location of the pulley is determined by consideration of the ore trajectory over the pulley and the nature of the equipment being fed. The ore trajectory is determined by the application of standard calculations. For conveyors discharging into hoppers and bins, the conveyor discharge pulley can be located to either feed the bin centrally when the bin is empty, or to allow central feed when it is full, as specified by the engineer. For cases where, for structural reasons, the bin must always be centrally loaded, the conveyor hood must be equipped with an adjustable impact plate or curved trajectory plate, in order to deflect the ore stream into the desired path.

1.2.3 Chute body

The chute body should be designed to suit the transfer requirements, without changing the direction of the ore severely. The area of the chute containing the body of the ore flow must be at least 2.5 to 3.0 times the area of the ore, based on the design capacity of the conveyor and the ore speed at the point of consideration. The minimum area of the chute is then given by

$$A = \frac{2.5 \times Cdc}{3600 \times S \times D} \text{ (m}^2\text{)}$$

The thesis is structured as follows. Chapter 1 contains a brief introduction, literature review. In Chapter 2, an introduction of copper mining, copper mining processes and an ore, its key elements such as crusher machinery, belt conveyor, roasting are presented.

In Chapter 3, an introduction of Oyu Tolgoi mining and its troubles are presented.

Chapter 4, is dedicated to the theory which is crucial for designing a chute.

Chapter 5 illustrates processes of our experimental study.

Finally, Chapter 6 summarises the main points of this thesis and suggests directions for further research on construction of chute for copper mining industry.

1.2.4 The problems with chutes

Below mentioned chute problems list was presented at the Chute Design Conference organised by the Bionic Institute in 1992. The problems as well as the solutions there to endure essentially the same even with the passage of time.

- | | |
|-------------------------------|---|
| -Spillage | -Chute Wear |
| -Load Zone Turbulence | -Inadequate Provision for Belt Cleaning Equipment |
| -Load Centering | -Inadequate Inspection Access |
| -Poor Skirt Board Seal | -Belt Damage from Large Lumps |
| -Impact Idler Maintenance | -Belt Wear and Abuse |
| -Inadequate Skirt Card Length | -Ore Build Up -Plugging |
| -Dust Control | -Noise |
| -Ore Degradation | -Structural Support of Chute and Skirts |
| -Belt Tracking | -Lack of Attention to Detail Design |
| -Poor Provision for Clean Up | |
| -Loading onto Transition Area | -Safety Issues |
| -Corrosion | -Housekeeping |
| -Unknown Ore Characteristics | |
| -Economic Considerations | |

Many of the above are maintenance related issues there are many that can be grouped under one banner: LACK OF ATTENTION TO DETAIL

Chapter 2. Copper mining

2.1 Copper

Copper is ductile base metal which is famous for its high thermal and electrical conductivity. Because of its iridescent, golden red color copper is simply identifiable and detectable. The copper and its alloys have been utilized by humans for thousand of years worldwide. As a consequence of its performance as an electrical conductor, copper is commonly found in related applications, in involving the wiring for our homes and offices, and in the circuitry, connectors, and components that make virtually all electronic tools and devices function. Bright reddish-brown metal which is called pure copper that, when exposed to corrosive environments, can take on a green-hued patina. This green layer of copper sulfate associated with chemical process caused by alkalis, ammonia, sulfate compounds and acidic rainwater.

If we look back human history copper is considered to be one of the initial metals which is used by humans. The basic reason for its early discovery and usage is that copper can be found naturally in relatively pure forms. Although different types of copper tools, weapons and decorations have been discovered approximately in 9,000 BC. And some archaeological evidence suggests that it was the early Mesopotamians who around 5000 to 6000 years ago were the first fully harness ability to extract and work with copper.

Copper is typically extracted from oxide and sulfide ores that contain between 0.5 and 2.0 percent copper.

The refining techniques owned by copper producers depend on the ore type, as well as other economic and environmental factors. Some data suggest that about 80 percent of global copper production is extracted from sulfide sources.

Copper occurs in three different mineral groups as sulfides, carbonates and silicates. Sulfide minerals are Chalcopyrite, Bornite, Chalcocite and Covellite. Carbonates minerals are Azurite and Malachite. Silicate mineral is Chwsocolla.

The three main categories of copper deposits are porphyry deposits type, strata-bound deposits type, and massive sulfide deposits.

Many copper deposits contain more than one valuable metal. The other metals are classified as coproducts or byproducts, depending on their relative value.

Important byproducts in porphyry deposits are molybdenum, silver and gold. Roughly 60 percent of world molybdenum production is a result of copper mining.

In terms of individual countries, nearly half of the market economy countries copper resources located in Chile and the United States, with approximately 32 and 17 percent of the total, respectively. Australia ranks third in copper resources with 7 percent, and Peru.

From common household electrical wiring to boat propellers and from photovoltaic cells to saxophones, copper and its alloy are employed in a myriad of end-uses.

To better understand copper's various applications, the Copper Development Association (CDA) has categorized them into four end-use sectors: electrical, construction, transport and other. The percentage of global copper production consumed by each sector is estimated by the CDA to be:

- Electrical 65%
- Construction 25%
- Transport 7%
- Other 3%

Aside from silver, copper is the most effective conductor of electricity. This combined with its corrosion resistance, ductility, malleability, and ability to work within a wide range of power networks, makes the metal ideal for electrical wiring.

2.2 World copper mining process

Approximately 200 years ago the UK was announced as a main world source of copper and there were mines in Cornwall and Wales. Now these mines have closed and as we mentioned above today the biggest copper mines are in Chile and North America. These world popular copper mining industries produce thousands of tonnes of copper ore per year.

The main ores of copper are: Chalcopyrite, Bornite, Malachite.

The ores are extracted by either traditional mining (open pit or underground) or by leaching. The copper is then recovered using physical and chemical techniques.

Copper minerals and ore are found throughout the Earth's crust. They occur in both sedimentary and igneous rocks. The outer 10km of the crust accommodates 33g of copper for every tonne of rock. This is not enough to call it commercially viable to extract the rock. Copper mines are only set up where there is more than 5kg of copper per tonne of rock (0.5% by mass). Ideally, the figure should be closer to 2%.

The following flow chart 1 (Fig.3) shows how copper is extracted from its ore and converted into pure metal.

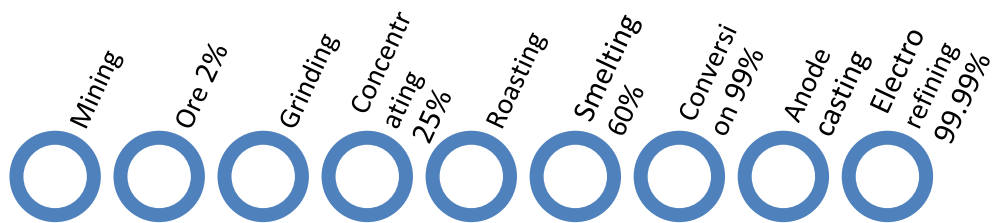


Figure 25. Copper mining process

2.2.1 Mining

Copper can be extracted from its ore by traditional mining and leaching.

Traditional mining as an underground and an open pit. The underground mining is sinking a vertical shaft into the Earth to an appropriate depth and driving horizontal tunnels into the ore. 90% ore is mined by open pit method. Ores near the surface can be quarried after removal of the surface layers.

The ore is treated with dilute sulphuric acid. This Trickle slowly through the ore dissolving copper to form copper sulphate. The copper is recovered by electrolytic refining.

Conveniences and advantages of this process are:

- Much less energy usage than in traditional mining
- No waste gases are given off

- It can be used on ores with as little as 0.1% copper-for this reason, leaching extraction is growing in importance.

2.2.2 Ore

There are variety of types of copper ore found worldwide. More than 80% of all of the world copper extracted from sulphide ores.

An ordinary ore incorporates only 0.5% to 2.0% copper. It is a measure of the value of copper that it is worth extracting it from such tiny concentrations. The ore is a mixture of minerals and rock (called gangue). The following table 2 shows the most common copper minerals.

Table 4. Common copper minerals

Mineral	Formula	Appearance	% copper in mineral
Cuprite	Cu_2O	Red, earthy	88.8
Chalcocite	Cu_2S	Dark grey, metallic	79.8
Bornite	Cu_5FeS_4	Golden brown, metallic	63
Malachite	$\text{CuCO}_3\text{Cu}(\text{OH})_4$	Bright green, earthy	58
Azurite	$2\text{CuCO}_3\text{Cu}(\text{OH})_4$	Blue, glassy	55
Chalcopyrite	CuFeS_2	Golden yellow, metallic	35

2.2.3 Concentrating the ore

The ore is crushed, ground and then enriched by Forth Flotation. Below diagramm shows crushing process to Froth floatation.

(1) Crucher machinery

Mining crusher machinery is aimed to break down extremely hard ore, such as stone, into small rocks, gravel, or stone powder. Mining crusher machines are used to reduce raw ore, such as mined ore, which are extremely hard to break down. Mining crusher machines essentially apply mechanical force and pressure to these raw ores enabling their break down at an efficient pace and rate of processing. Mining crusher machinery comprises heavy mining equipment that applies enormous enforce to hard ores.

Mining crusher operations are often classified by the size to which they break down ore that is fed into the machinery. Mining crusher machinery has phases and steps of crushing to ensure that force is distributed throughout an efficient adequate process formulated to prevent break down of machine parts. Initial mining crusher phases break down raw ore into coarse fragments, reducing them to smaller pieces for further processing. Secondary mining crusher machinery reduces these smaller fragments into desired consistencies.

Excavator transporters deliver raw ore to the mining crusher feeder for initial processing. The feeder mashine is commonly a conveyor belt or other type of surface which moves the ore toward the mining crusher then on toward screens for further processing. During the time ore is unquestionably reduced at this stage, there are other more stages to processing many mined ores. Mining crushers are the preparatory stage and they are subject to needing a great deal of repairs. We are able to find mining crusher machines as a mobile on the mining site or at the factory.

Mining crusher machines are remarkably valueable to the mining process. Only these machines make it possible to reduce ore to fine consistencies for processing and using of adored excavated resources. Crusher technology allows these things potential.

Crushing process includes two steps:

- primary crushing process
- secondary crushing process

The primary crushing has two types of jaw crusher and gyratory crusher. Their output is high and feed size is huge. The secondary crushing has three types generally. There are cone

crusher, roll crusher and impact crusher. Gyratory crusher has 2 types.

Classification of crushers

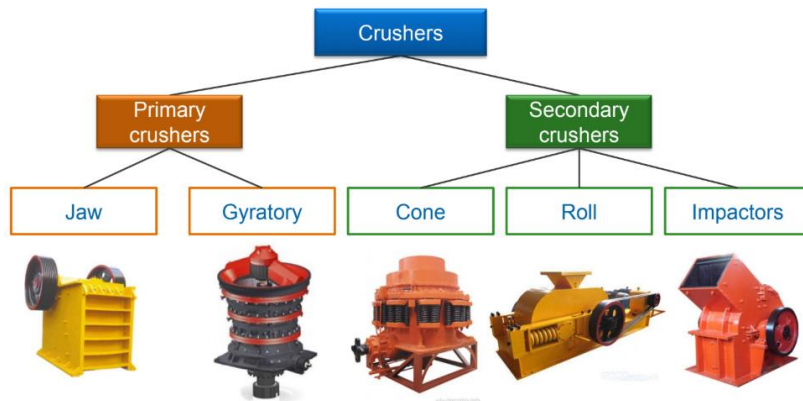


Figure 26. Classification of crushers

(2) Belt conveyer

The conveyor belt is wound around the drive drum and the tail exchange roller constructs an endless belt. The higher and lower sections of the conveyor belt are supported on the idler. The tensioning device allows the conveyor belt the required tension for regular operation. While operation is in action, the drive roller drives the conveyor belt through the friction between it and the conveyor belt. The ore is loaded from the loading point onto the conveyor belt to form a continuous moving stream, which is unloaded at the unloading point. The general ore is loaded onto the upper belt (bearing section) and is unloaded at the nose roller (here, the drive drum). It can also be unloaded in the middle using a special unloading device.

Belt conveyer system able to carry ores in bulk and bagged, such as stone, sand, coal, concrete, cement, gravel, fertilizer, mineral ore, limestone, coke, sawdust, wood chip, bulk ore, grain, corn flakes, carbon black, etc. There are different types of conveyors:

- Chute conveyer
- wheel conveyer
- roller conveyer
- gravity roller conveyer
- live powered roller conveyer
- chain conveyer

- flat belt conveyor
- magnetic belt conveyor
- bucket conveyor
- screw conveyor
- belt conveyor

Belt conveyor is composed of several parts such as belt, idler, pulleys, drive unit and supporting structure.

Conveyor belts commonly made of pvc, rubber, wire reinforced,

PVC conveyor belts, or solid woven conveyor belts, are dominantly used in the mining sector to transport aggregates, ores, and fines from the mine (whether open-pit or underground) to the mine plant and/or the stacker system. PVC is used both in underground and above-ground applications. Therefore PVC is popular for its anti-corrosive properties. PVC is also flexible, putting less strain on the conveyor support. It is resistant to any damage, resistant to impact damage and cannot be damaged by oil and bacteria. PVC conveyors are also very simple to install. Also there are great variety of PVC belt weaves with different levels of strength and resistant properties.

Therefore rubber conveyor belts are commonly used in both the mining as well as industrial applications. Being a cheaper alternative to the PVC and nylon weave conveyor belts, rubber conveyor belts also still provide the corrosion resistant properties, and flexible support for delivering ores. On the other hand, rubber conveyor belts are not as resistant to tearing and impact damage as the solid woven belts.

Wire belt systems or wire mesh conveyor belts are more rigid than the PVC and rubber conveyor belt systems. However, wire mesh conveyor belts can be utilized in variety of applications of which rubber and PVC cannot. This involves any process that comprises the application of heat. Because of this property, wire belt systems are commonly assisted and utilized in an array of industrial processes for producing. Heat resistant conveyor belts are usually manufactured from metal composites with different levels of limited anti-corrosive qualities. Wire-reinforced PVC belts are also designed for the mining industry and they may be less flexible and more difficult to install and manage. However, they can perform while transporting astonishingly heavy loads.

Conveyor system are very popular worldwide and used in a range of industries because of its diverse benefits they provide.

The powdered ore is mixture with special paraffin oil which makes the copper mineral particles water repellent. It is then fed into a bath of water containing a foaming agent which produces a kind of bubble bath. When jets of air forced up through the bath, the water repellent copper mineral particles are picked up by the bubbles foam. They float to the surface making a froth. The unwanted waste rock (gangue) falls to the bottom and is removed. The froth is skimmed off the surface and the enriched ore (mainly the copper mineral) is taken away for roasting. The mixture of water, foaming agent and paraffin is recycled. After this stage the enriched ore now contains 25% copper by mass.

(3) Definition of a chute

A chute is defined in the Oxford dictionary as “*A sloping channel or slide for conveying things to a lower level*”. This is a perfect definition of both a curved chute, where the chute body acts as the slide or of the sloping portion of the ore in a Rock-Box type chute where the ore is the slide.

Chute consists of hood body and skirts.

Chapter 3. Oyu tolgoi copper mining

3.1 Oyu Tolgoi

The Oyu Tolgoi mine is a combined open pit and underground mining project in Khanbogd sum within the south Gobi Desert, approximately 235 kilometres (146 mi) east of the Ömnögovi Province capital Dalanzadgad. The site was discovered in 2001 and is being developed as a joint venture between Turquoise Hill Resources (a majority owned subsidiary of Rio Tinto) with 66% ownership and the Government of Mongolia with 34%. The mine began construction as of 2010 and shipped its first batch of copper on 9 July 2013.

The Oyu Tolgoi mining project is the largest financial undertaking in Mongolia's history and is expected upon completion to produce 450,000 tonnes (500,000 short tons) of copper annually.

Oyu Tolgoi deposits contain an estimated 2,700,000 tonnes of copper and 1.7 million ounces (48,195,000 grams) of gold. It also contains 1.9 thousand tonnes of silver and 205 thousand tonnes of molybdenum. Production began in 2013 and is scheduled to reach full capacity in 2021. Over the anticipated lifespan of the mine (>50 years), Oyu Tolgoi is scheduled to produce 430,000 tonnes (470,000 short tons) of copper per year, an amount equal to 3% of global production. Oyu Tolgoi is also expected to produce 425,000 ounces of gold annually, with "by-product silver and molybdenum".

Oyu Tolgoi is going to use both underground and open pit mining techniques. Initially the mine will process 70,000 tonnes of rock per day, ramping up to 85,000 tonnes from both the open pit and the underground mine (underground mining is to be done by block caving). The yield from the first phase of mining will be ground through one semi-autogenous grinding mill (SAG mill). Expansion to new underground areas will result in an additional increase of up to 140,000 tonnes per day with a possible increase to 170,000 tonnes per day.

As mentioned in Oyu Tolgoi website since 2012, they have been mining ore from the Oyu Tolgoi open pit. This is where all the product that currently produce and export comes from.

After being extracted from the open pit, the ore is treated by a series of complex processes in the Oyu Tolgoi concentrator to create a fine powder called copper concentrate. This concentrate is then exported by road to international markets.

Longer term, Oyu Tolgoi is planning to develop the underground phase of the mine, to access the best minerals from deep below the surface where 80 per cent of the value of Oyu Tolgoi is found.

3.2 Oyu Tolgoi Mining Process

At the Oyu Tolgoi extracting minerals involves a four-step process: blasting, excavation, removal and initial primary crushing.

The open pit is mined using a combination of excavator dump trucks and shovel dump trucks. Ore is removed from a series of benches which are linked to the top of the pit by a 40 meter wide trench road. Each truck transports around 290 tonnes of excavated soil and ore to the top of the pit where it is stockpiled or sent to the primary crusher. Hydraulic and cable operated electric excavators (Bucyrus RH 340B and 495HR shovels) are used alongside Komatsu 930E-4SE dump trucks. A total of 28 dump trucks have been used on site since August 2012.

(1) Blasting

Explosives are placed in holes drilled into the ground and safely detonated. This loosens the earth, preparing it for excavation.

(2) Excavation

After blasting, giant Bucyrus excavators scoop up ore from the loose ground. Geological surveys allow engineers to know how much metal can be found in each part of the open pit.

(3) Removal

Between two and three shovels of ore are then dumped into giant, 290 tonne Komatsu haul-trucks. Oyu Tolgoi has a fleet of 28 of these giant machines. These operate in shifts, driving the ore out from the bottom of the open pit.

(4) Primary crusher

Just outside the top of the open pit, the haul trucks dump the ore into the primary crusher. This breaks the ore up into volleyball sized pieces of rock which are then ready to be sent on a 2.7 km conveyer belt to the Oyu Tolgoi concentrator.

There are more than 1,000 Komatsu 930E-4SE trucks operating at mines around the world. With a horsepower of between 2,700 and 3,500, their key strength lies in their ability to travel uphill without losing power. As the mine goes deeper, the trucks will become even more productive. It is a high quality, durable and reliable vehicle with a strong electrical system. Each wheel has its own engine and coolant system. Two Bucyrus 495HR steel cable shovels are in operation at the mine. The Bucyrus 495HR shovel is a highly efficient vehicle with a bucket capacity of 56 cubic metres.

Gyratory crushers

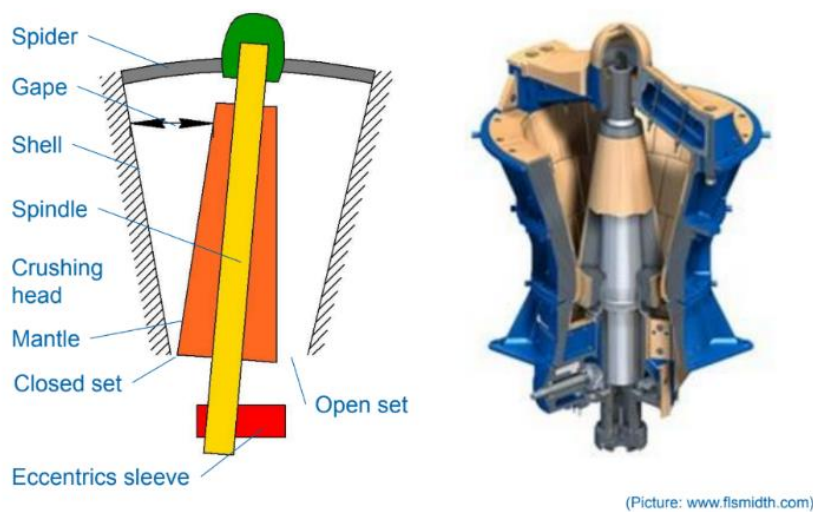


Figure 27. Gyratory crushers

OT installed “flsmidth” 130mm gape gyratory crusher. After primary crusher P80 of copper ore is 130mm.

Next step is handling, carrying out the ore which comes from primary crusher to the bunker.

3.3 Oyu Tolgoi Mining Process Problem

At the Oyu Tolgoi mining industry 2.7km belt conveyor transport the crushed ore into feeder which feeds the ball mill. There are 2 belt conveyors and one is straight and without inclination. Second one is inclined into bunker. Belt conveyor one and two connected by discharge chute.

Nowadays Oyu Tolgoi is facing a problem with their chute. Because of badly design chute is requiring maintenance service every 4 weeks. We are aiming to delay maintenance serving time at least 8 weeks as well as improving its design, ore quality and calculating ore properties.



Figure 28. OT Primary Crusher conveyor

Discharge chute maintenance takes time every four weeks because of the wearing of liner and belt.

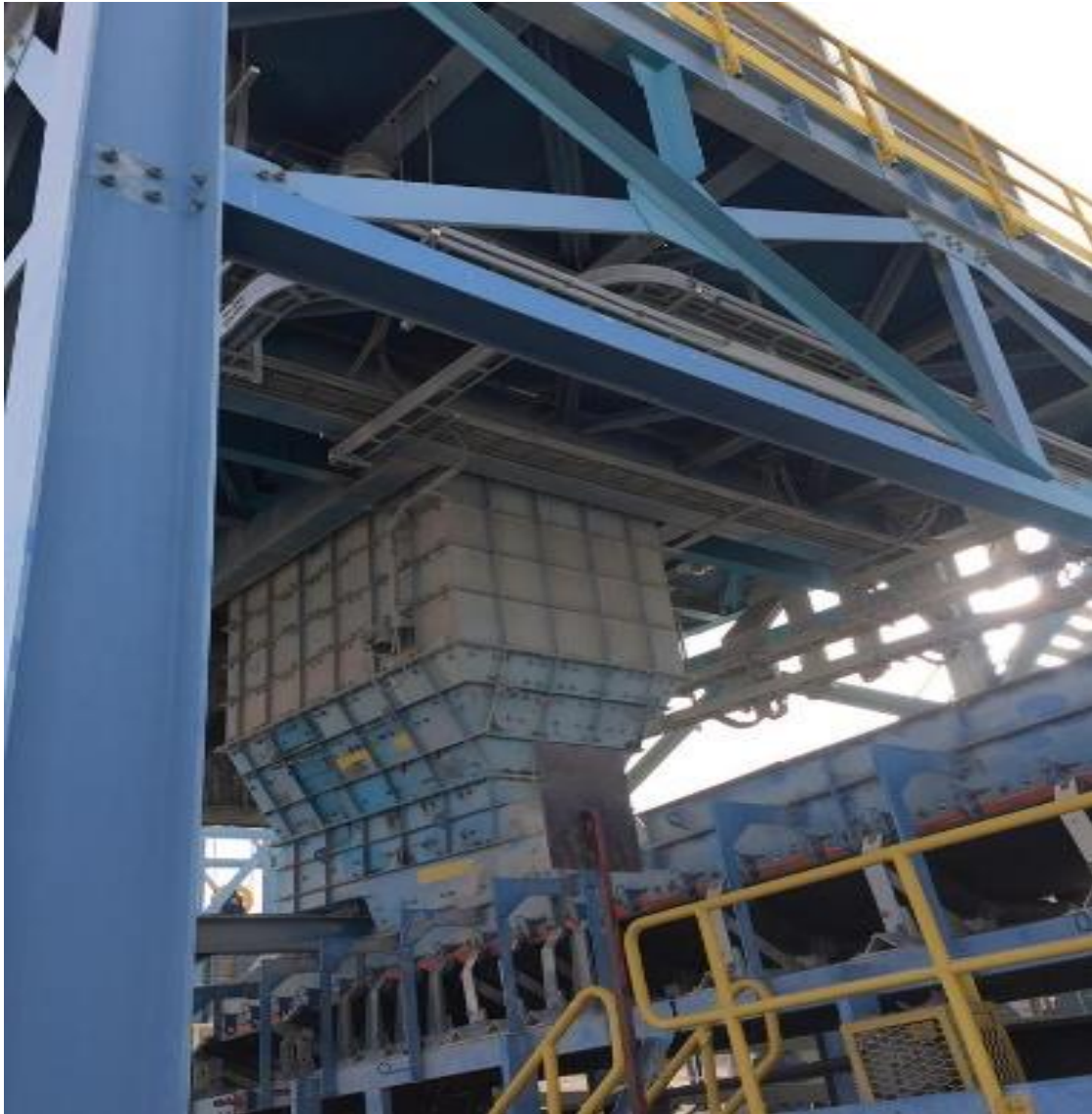


Figure 29. OT Discharge chute CVB-001



Figure 30. OT Discharge chute CVB-001 linear

Chapter 4 Experimental study

4.1 Theory for calculation of ore properties

Knowing the inherent properties of the ore being conveyed is critical to the successful design of transfer chutes.

The obvious properties which would probably have been used in the selection of the required belt parameters to suit the duty are:

- The type of ore (e.g. coal) and whether it is abrasive or corrosive
- The particle size and particle size distribution (mm) – highly dependent on process
- The bulk density ρ (kg/m³)
- The belt surcharge angle (λ°)
- The angle of repose (θ°).

As mentioned above ore characteristics are published in manuals and catalogues it is always best to run typical bulk flow tests on the specific ore to be conveyed.

An important property is ascertaining the point at which the ore begins to slide down the chute face for different types of liner ore. This is typically established by testing, utilising a system similar to the Jenike Johanssen Shear testing system – however in this case, a force is applied to a block of the ore and then the pressure is released and the block tilted until it begins to slide. The test is performed at different loads and with different wall ores, effectively simulating the impact of ore on the chute face and the angle at which the impacted ore will slide.

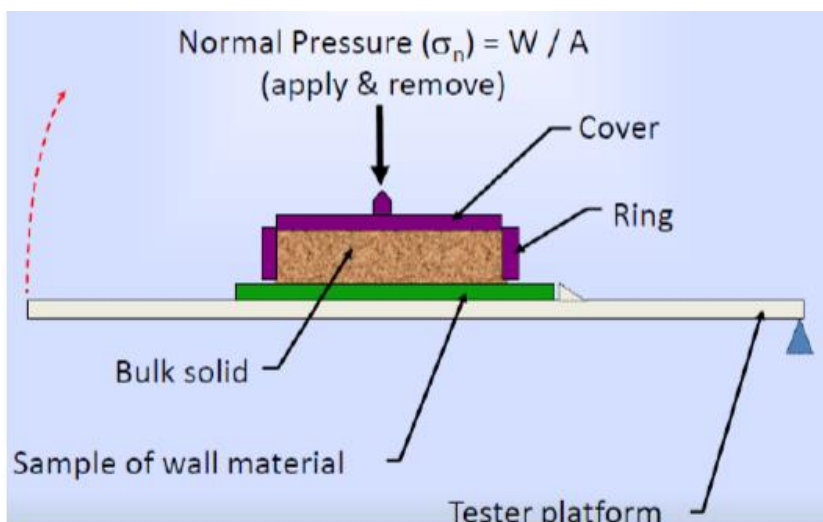


Figure 31. Test for wall friction angle

The starting point – the ore trajectory

The starting point is the point at which the ore leaves the discharge pulley. It is important here to identify this position as at this point mechanical interaction between ore and belt is lost, and the ore acts like a projectile with initial velocity subject only to the action of gravity (excluding the effects of air resistance).

The *ore trajectory* is fundamental in the design of the chute as it defines the flow of ore and the requirements for first impact point and the path followed by the ore until it lands.

There are numerous examples available in literature defining the methodology to be followed in establishing the ore trajectory. The methodology described below is based on the CMA lecture course. There are recent papers presented at Beltcon by Mr David Hastings which are excellent references to other methodologies and which also give a comparison of the different methods against actual results established by high speed photography. The theory being proved by the practical.

The methodology proposed in the CMA Diploma Course is as follows:

- Establish the area of ore flowing over the head chute
- Establish the depth of ore flowing over the head chute
- Establish the centroid of area of the ore flowing over the head chute.

The condition of ore flowing over the head chute is represented below for a typical three-roll idler set. Note that the troughed form now flattens out and the area of the trapezium formed when flattened should be equal to that of the troughed configuration.

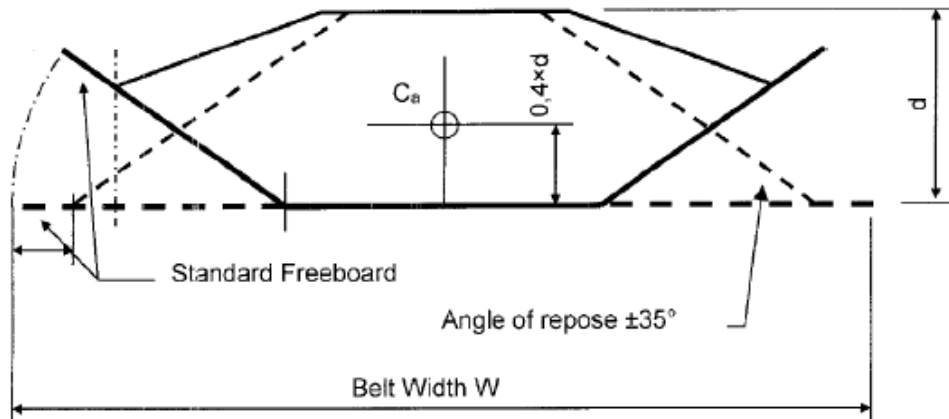


Figure 32. Loaded belt profile at the discharge

For a belt loaded to 100% of CEMA and based on normally accepted free-board dimensions, the width of ore on the flattened belt may be found from:

$$W_{wet} = (0.9 \times W - 50) \times 10^{-3} \quad (2)$$

Where

W = belt width in mm

W_{wet} is the wetted area in metres

(Note that units are mixed in order to simplify calculations).

The centroid of area of the trapezium is accepted as 40% of the height yielding

$$C_a = 0.4 \times d \quad (3)$$

Setting the area of the troughed belt equal to the area of the trapezium resulting from the flattened belt yields

$$d = \left(\frac{W_{wet} - \frac{W_{wet}^2 - 4A}{\tan \alpha}}{2} \right) \times \tan \gamma \quad (4)$$

Where

A is the cross section area of 100% loading in m²

And γ is the angle of repose (typically 34°–37°)

With this, a profile can be defined that the centroid of ore would follow around the head pulley and along its trajectory with upper and lower boundaries following this path.

Note however, that in the case of the ore stream comprising mainly large lumps (greater than say, 150 mm), it is normal to calculate d as a function of the lump size and typically as 60% of the lump size.

The point (R) at which the ore stream leaves the belt can now be defined.

Define

$$R = r + h + C_a \text{ in m (5)}$$

Where

r = pulley radius over lagging (m)

h = belt total thickness (m)

C_a = depth to center of area of ore burden (m)

At the point of separation, the ore has the same velocity of the belt V (m/s)

And define factor K

$$K = \frac{S^2}{g \times R \times \cos \alpha} \text{ (6)}$$

Where

α = angle of inclination of the belt at the discharge pulley.

The location of the drop points with their dependency on belt speed is now defined as

For $K > 1$ Drop Point is at T

For $K < 1$ Drop point is at C

$$\theta = \sin^{-1} \frac{S^2}{g \times R} \text{ (7)}$$

Where θ , the angle between the horizontal and the drop point is defined as the release angle.

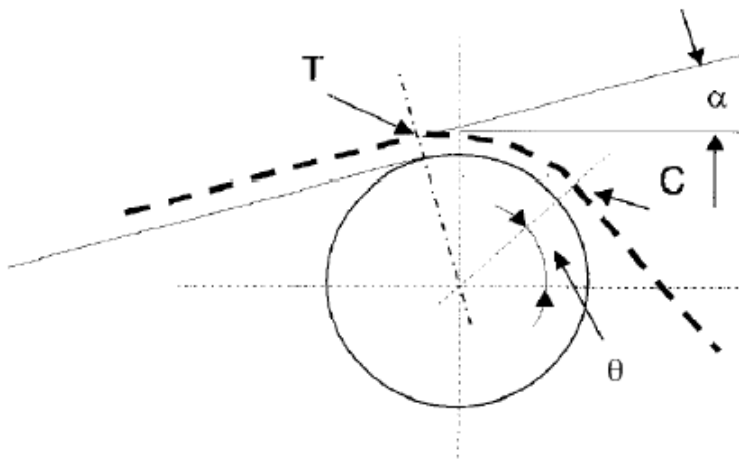


Figure 33. Point of discharge

In the case of slow moving belts where the release angle is calculated as being less than the angle of repose of the ore, it is normal to reckon the release angle as being between 3–5 degrees greater than the angle of repose of the ore.

Plotting the ore trajectory can now be done

- From the drop point determined above extend a line along the inclination θ determined
- Decide on set-out spacing.

$$L = S \times t \quad (8)$$

where t are time intervals (typically seconds) and mark out

- At each spacing along the line of the release angle drop a vertical of distance

$$H = \frac{g \times t^2}{2} \quad (9)$$

- Join each end point to plot the trajectory of the center area of the ore.

The upper and lower bounds of the trajectory will follow the upper and lower bounds of the ore about the center of area for a fall of about 2.5 m. Thereafter air-drag and wind may result in deflection of the ore stream.

The sketches below indicate the difference in ore trajectory for fast and slow belt speeds.

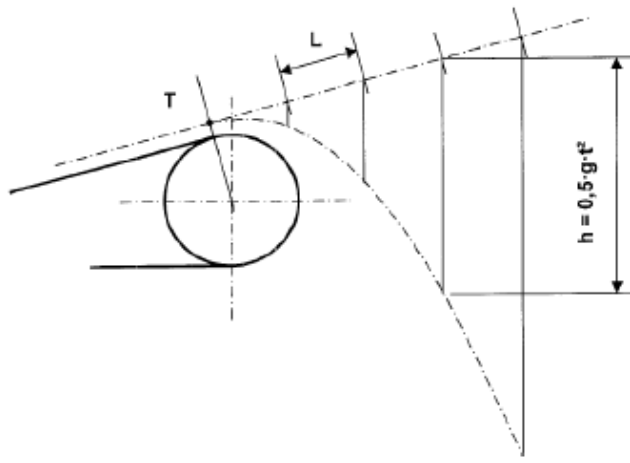


Figure 34. Trajectory at fast belt speed

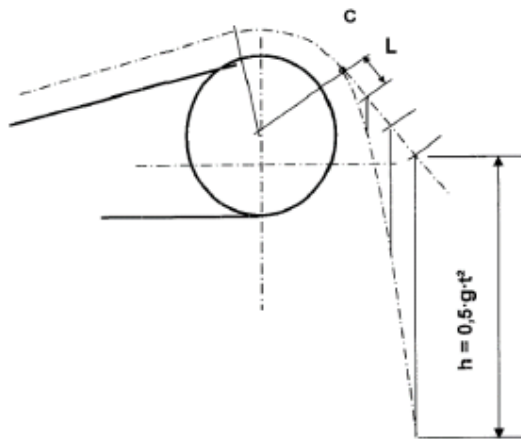


Figure 35. Trajectory at low belt speed

Knowing the ore trajectory, the flow pattern and the point of first impact can be determined. This is critical in the design of the Hood. The Hood directs the flow of the ore towards the Spoon. The ore is intercepted at a tangent. The Hood should be designed such that it has the same radius of curvature at the point of impact as the trajectory, i.e. the impact angle should be as small as possible.

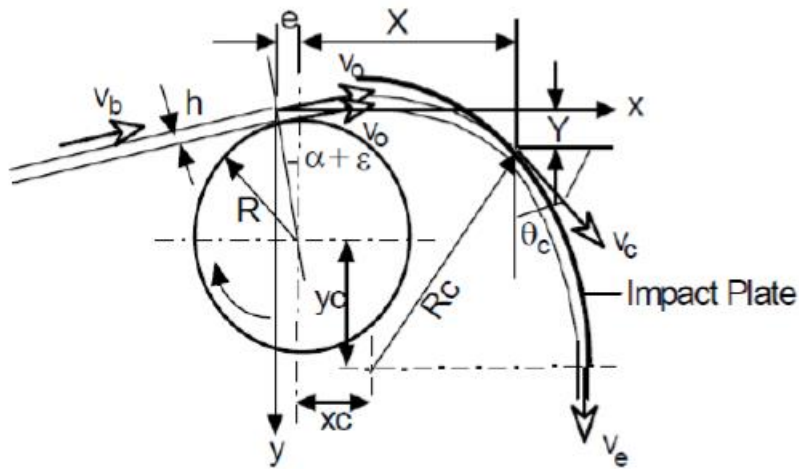
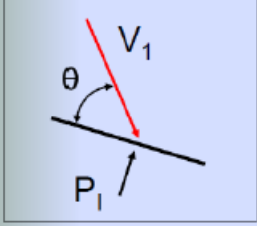


Figure 36. Hood design

Prevent plugging at impact points

The chute face must be sufficiently smooth and steep to allow sliding and hence clean-off of the stickiest ore that it has to handle.

The impact pressure at any point that the ore stream impacts the chute face is given by:

$$\text{Impact Pressure} = \frac{\gamma V_1^2 \sin^2 \theta}{g}$$


- γ = Bulk density
- V_1 = Impact velocity
- θ = Impact angle
- P_1 = Impact pressure
- g = Acceleration (gravity)

Figure 37. Formula for impact pressure

The velocity following an impact with the chute surface may be calculated from

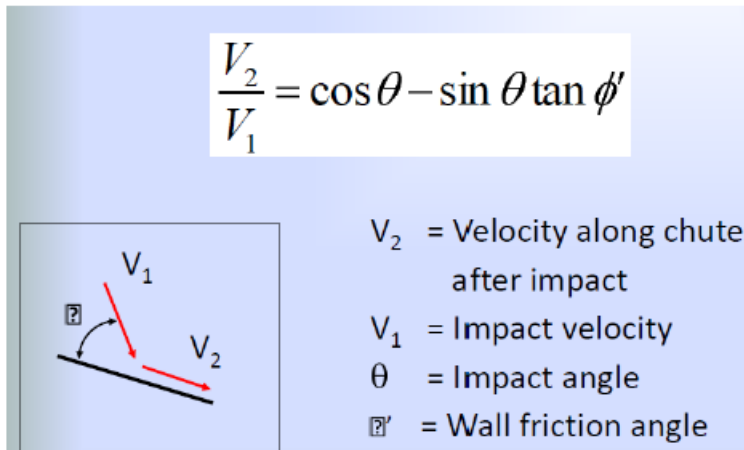


Figure 38. Velocity after impact

Stagnation and hence plugging will occur when $V_2 = 0$ m/s.

It is critical that the velocity at the point in question be accurately estimated.

As the ore moves through the chute it may be subjected to different acceleration forces such as sliding along the chute plates or free falling through the vertical section of a chute.

Minimize abrasive wear of chute surface

A critical aspect in the efficient design of transfer chutes is the wear that is imposed on the chute surface by the abrasive nature of ore flowing on the chute surface.

a. Wear on chute bottom

Consider the generalized case of flow through the Spoon as indicated in Figure 21.

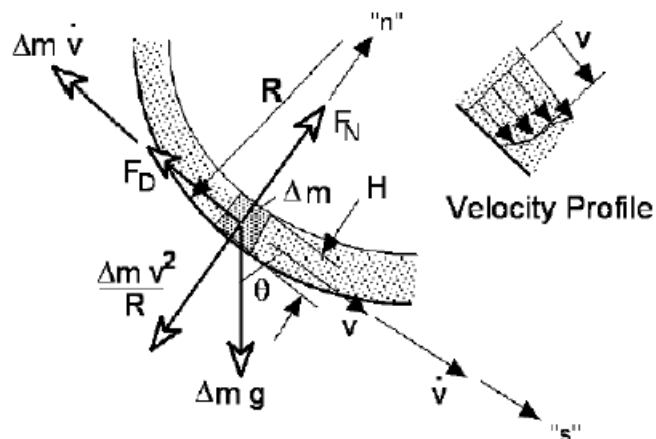


Figure 39. Flow through Spoon

An abrasive wear factor W_c may be determined as:

$$W_c = \frac{Q_m \times g \times K_c \times \tan \phi}{B} \times N_{wr} \quad (12)$$

W_c has units of N/ms

N_{wr} is the non-dimensional abrasive wear number and is given by

$$N_{wr} = \frac{S^2}{R \times g} + \sin \theta \quad (13)$$

The various parameters are

ϕ = chute friction angle B = chute width (m)

$K_c = \frac{V_s}{S}$ ratio V_s = velocity of sliding against chute surface

Q_m = throughput kg/s R = radius of curvature of the chute (m)

S = average velocity at section considered (m/s)

θ = chute slope angle measured from the vertical

The factor $K_c < 1$. For fast or accelerated thin stream flow, $K_c = 0.6$. As the stream thickness increases, K_c will reduce. Two particular chute geometries are of practical interest, straight inclined chutes and constant radius curved chutes.

b. Wear on chute side walls

Assuming the side wall pressure increases linearly from zero at the surface of the stream to a maximum value at the bottom, then the average wear may be estimated from

$$W_{csw} = \frac{W_c \times K_v}{2 \times K_c} \quad (14)$$

K_v and K_c are as previously defined. If, for example, $K_c = 0.8$ and $K_v = 0.4$, then the average side wall wear is 25% of the chute bottom surface wear.

c. Impact wear

Impact wear in transfer chutes may occur at points of entry or at points of sudden changes in direction.

For ductile ores the greatest wear occurs when impingement angles are low, say 15° – 30° . For hard, brittle ores the greatest impact damage occurs at steep impingement angles of the order of 90° .

Minimize the wear of the belt

A critically important aspect in the design of transfer chutes is that of reducing the effects that the ore stream has on belt wear and damage.

The transfer of ore onto the belt is illustrated in the figure below.

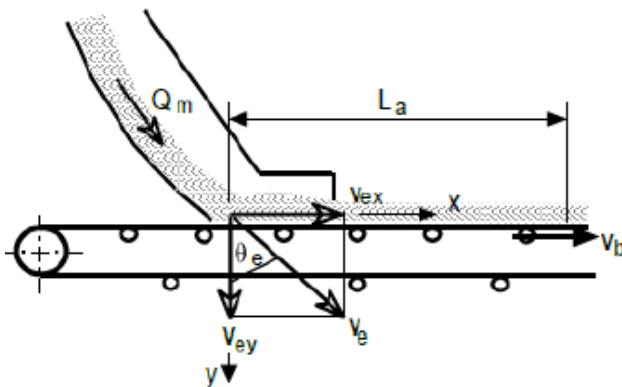


Figure 40. Feed onto the belt

The primary objectives are to:

- Match the horizontal component of the exit velocity as closely as possible to the belt speed
- Reduce the vertical component of the exit velocity so as to reduce abrasive wear due to impact
- Load the belt centrally so that the load is evenly distributed in order to avoid belt mistracking and spillage.

The following formulae have been developed as a means of estimating belt wear at a transfer point:

$$P_{vi} = D \times V_{ey}^2 \quad (15)$$

Where

D = bulk density

V_{ey} = vertical component of the exit velocity

Abrasive wear parameter W_a :

$$W_a = \mu_b \times D \times V_{ey}^2 \times (V_b - V_{ex}) \quad \text{kPa} \cdot \text{m/s} \quad (16)$$

Where

μ_b = friction coefficient between the bulk solid and the conveyor belt

V_b = belt speed

The wear will be distributed over the acceleration length L_a .

The wear parameter may then be expressed as

$$W_a = \mu_b \times D \times V_e^3 \times K_b \quad (17)$$

Where

$$K_b = \cos^2 \theta_e \times \left(\frac{V_b}{V_e} - \sin \theta \right) \quad (18)$$

θ_e = chute slope angle with respect to vertical at exit.

K_b is a non-dimensional wear parameter. It is plotted in Figure 13 for a range of v_b/v_e values.

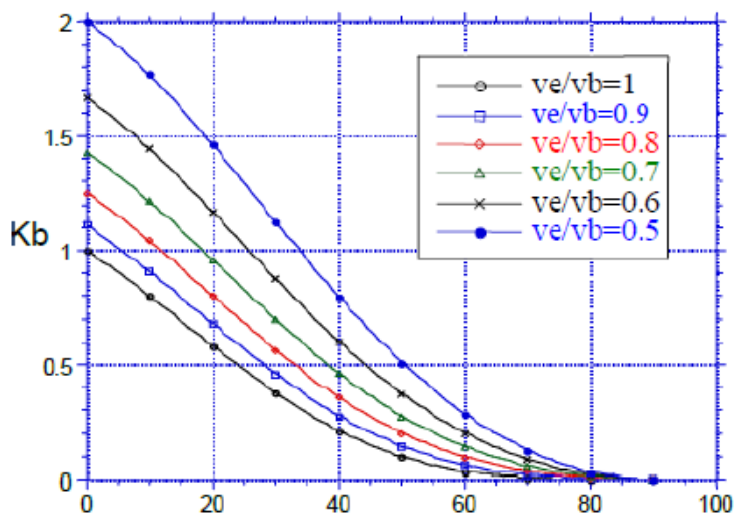


Figure 41. Non-dimensional wear parameter versus slope angle

As shown, the wear is quite severe at low chute angles but reduces significantly as the angle θ_e increases. For the chute to be self-cleaning, the slope angle of the chute at exit must be greater than the angle of repose of the bulk solids on the chute surface.

It is recommended that $\theta_e \geq \tan^{-1} \mu_e + 5^\circ$ (19)

4.2 Hypothesis

In order to decide Oyu Tolgoi mining industry's chute design problem, after reviewing related theories and formulas we are trying to raise following hypothesis based on data of Oyu Tolgoi transfer chute.

Installation of chute was wrong and has geometrical error

Not accurate stream flow.

Not convenient flow rate.

High bulk density ore.

Not suitable conveyor velocity.

Ore morphology

Ore size distribution

Ore shape (impact area)

4.3 Calculation

OT chute parameters

$Cdc = 7100$ Flow rate t/h

$D = 1.75$ bulk density t/m³

$S = 3.78$ conveyor velocity in m/s

$W = 1800$ belt width in mm

$\alpha = 4.79072 \cdot (3.14/180) \cdot \arcsin(38/455)$; inclination of pulley at discharge in radian

$\gamma = 60 \cdot (3.14/180)$ repose angle in radian

$r = 0.6$ pulley radius in m

$h = 0.039$ belt total thickness in m

$g = 9.81$ gravity acceleration m/s²

$h_1 = 1.587$ belt to rockbox in m

$\theta_2 = 30$ wall friction angle degree

$$A = \frac{2.5 \times Cdc}{3600 \times S \times D} = 0.7454 \quad (1)$$

$$W_{wet} = (0.9 \times W - 50) \times 10^{-3} = 1.57 \quad (2)$$

$$C_a = 0.4 \times d = 0.9623 \quad (3)$$

$$d = \left(\frac{\sqrt{Wwet - \frac{Wwet^2 - 4A}{\tan \alpha}}}{2} \right) \times \tan \gamma = 2.4058 \quad (4)$$

$$R = r + h + C_a = 1.6013 \quad (5)$$

$$K = \frac{S^2}{g \times R \times \cos \alpha} = 0.9127 \quad (6)$$

$$\theta = \sin^{-1} \frac{S^2}{g \times R} = 65.47 \quad (7)$$

$$L = S \times t = 1.258 \quad (8)$$

$$H = \frac{g \times t^2}{2} = 0.53 \quad (9)$$

$$P_i = \frac{D \times V_1^2 \times \sin \theta_2^2}{g} = 58.4491 \quad (10)$$

$$V_1 = \sqrt{\left(\frac{S^2}{2} + g \times h_1 \right)} = 4.7658 \quad (11)$$

$$\theta_2 = \tan^{-1} \frac{V_1}{S} = 51.6063 \quad (12)$$

$$\frac{V_2}{V_1} = \cos \theta - \sin \theta \times \tan \phi' = 0.3367 \quad (11)$$

$$W_c = \frac{Q_m \times g \times K_c \times \tan \phi}{B} \times N_{wr} = 5008.5135 \quad (12)$$

$$N_{wr} = \frac{S^2}{R \times g} + \sin \theta = 2.3705 \quad (13)$$

$$W_{cSW} = \frac{W_c \times K_v}{2 \times K_c} = 3186.909 \quad (14)$$

$$P = \frac{F}{A};$$

$$F = Q_m \times V_1 = 9399 \quad (15)$$

4.4 Result

Our study suggested following results.

1.75t/m³ bulk density ore conveyed into CVB-001 discharge chute of cross sectional area of 0.7454 by 3.78 $\frac{m}{s}$, 5° inclined conveyor. As we defined factor K is lower than 1 so its low speed belt. Horizontal release angle was 65.47°. Ore accelerated by gravity and traveling height as 1.587m and velocity was 4.6758 $\frac{m}{s}$. Also impact angle was 51.6063. Impact pressure at first impacting point was 572.80118Pa (formula we used was assumed size distribution is low and impacting area big). After impacting the chute sliding velocity was 1.6 $\frac{m}{s}$. Abrasive wear on chute bottom was 49kPa at width of 2.23m, 89.7kpa at width 1.22m. Average side wall wear was 31.2kpa.

If area of impact to under 184.29mm² get wears the liner because of the maximum strength is 500 MPa.

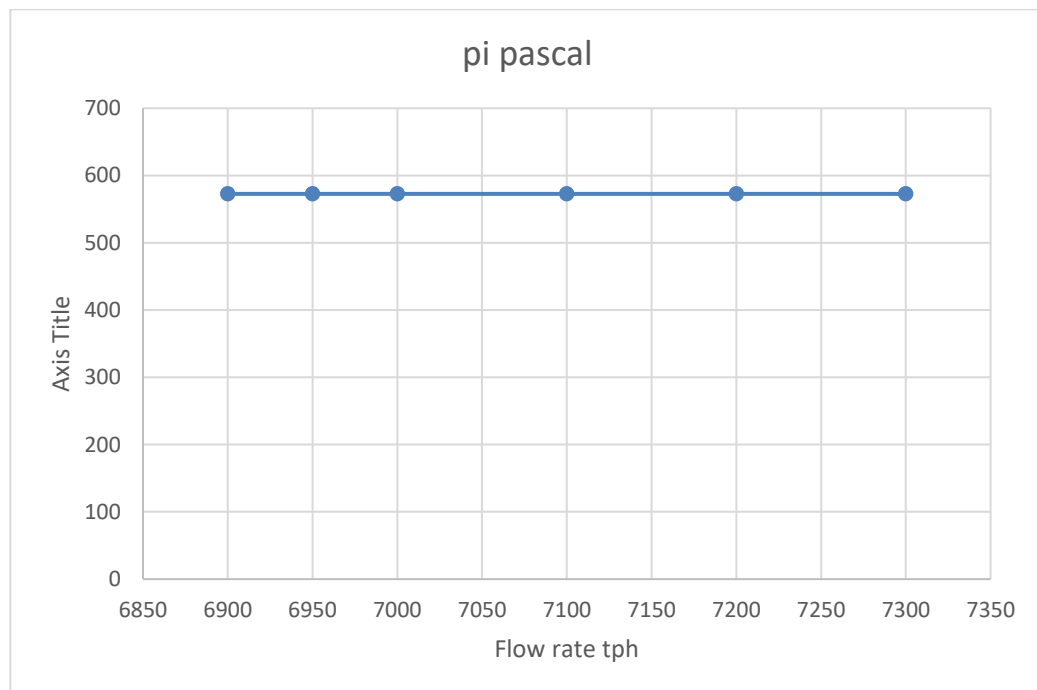


Figure 42. PI pascal

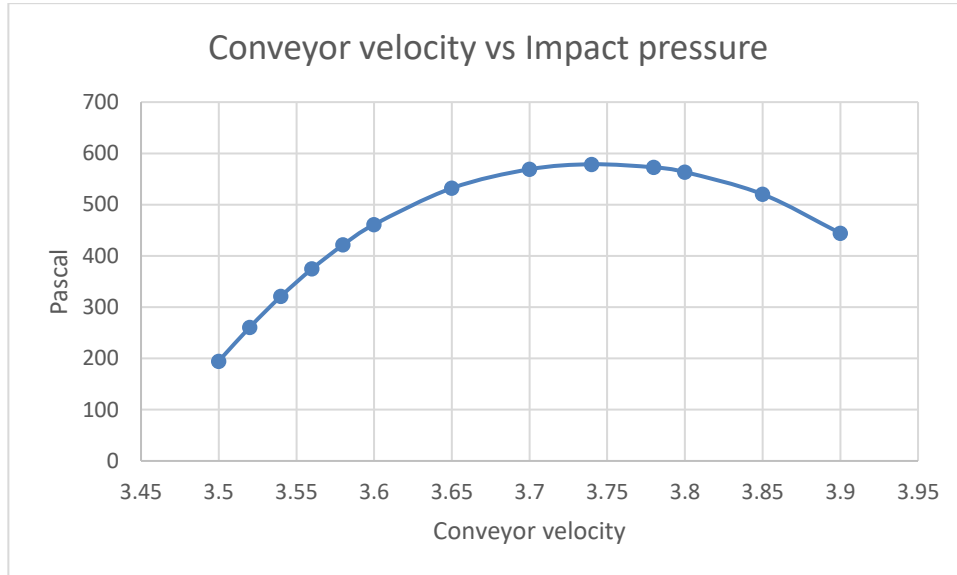


Figure 43. Conveyor velocity vs Impact pressure

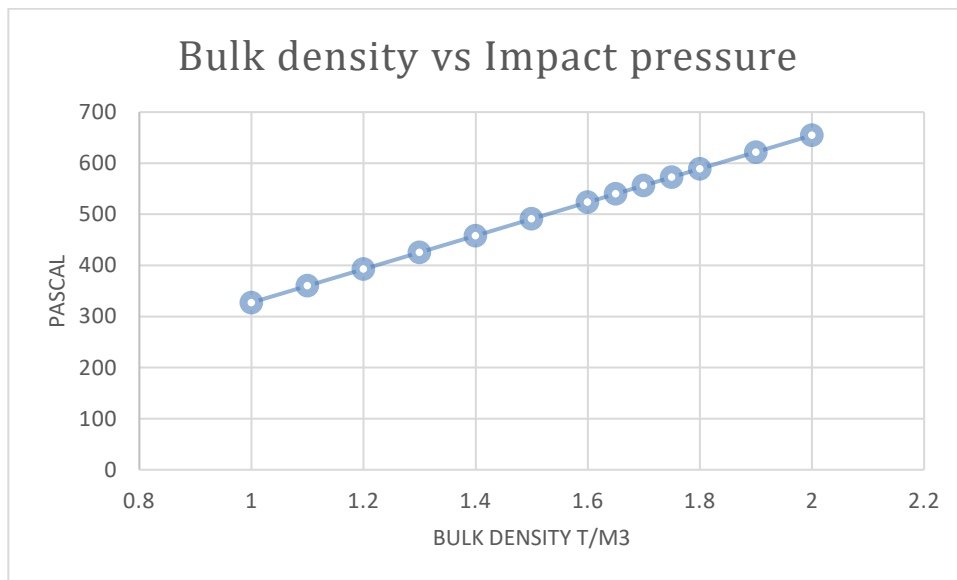


Figure 44. Bulk density vs Impact pressure

According to graph if we decrease the bulk density of material or changing the velocity of conveyor the impact pressure can be less. Also repose angle is high as mentioned before

common repose angle. Chute design of neck was symmetrically narrowed than chute hood then abrasive chute wear and side wall wear is higher.

Chapter 5 Conclusions

5.1 Conclusion

1. Copper was one of the first metals to be used by humans. This powerful metal has been a major influence in metallurgy, technology, economy and history.

2. Mongolian copper mining development began when an international geological team discovered Erdenet -Ovoo in early 1970s, as well as when a Mongolian and Russian joint venture Erdenet was established in 1976.

3. The Oyu Tolgoi is one of the most exciting developments in copper mining after the Erdenet mining industry. It contains huge reserves and resources that greatly support the economy of Mongolia. However, in order to improve effectiveness and productivity of its processes OT faces many problems. One of them is belt conveyer primary crusher's transfer chute problem.

4. The transfer chute problem occurs not only at Oyu Tolgoi, but throughout the world. Globally, mining industries in many countries have chute design problems. Researchers have been studying these problems for years considering different aspects of it. According to the researchers one of these aspects of chute problem could be the influence of the ore property. While altering ore mechanical property problem with transfer chute could be reduced.

5. Regarding the Oyu Tolgoi transfer chute, when we calculated the influence of ore mechanical property to the chute perforation, the ore causes 572 Pa pressure to the chute linear and there is no possibility to perforate chute linear when using Hardox 500. Following the results of this calculation we raised a hypothesis that we need to study morphological properties of ore. According to our calculations and study, the ore has high pressure impact for a small area, specifically smaller than 184,3 mm². area. During the ore crashing process sharp, apical, spiky parts were carried to the chute and these parts cause the chute perforation and cause the problem to chute linear.

6. Resulting from above mentioned inference we concluded that in order to reduce transfer chute linear perforation, it would be a better practice to change the morphology of ore therefore to widen chute linear contacting area. In order to achieve these goals, it's needed to reduce ore particle size at the previous process (stage) or at the primary crushing process. Solving transfer chute problem needs further careful studies on changing and researching chute geometrical design and chute body material.

5.2 Suggestion

There are still a number of open issues for future research in improvement of chute design. The further researchers are needed to enrich combined experimental and theoretical study on changing chute geometrical design and chute body material in a more efficient ways.

REFERENCES

- Arnold, P. C. & Hill, G. L. 1989, 'Predicting the discharge trajectory from belt
- Arnold, P. C. & Hill, G. L. 1990a, 'Feeding coal to and from belt conveyors', *International Coal Engineering Conference*, Institution of Engineers Australia, Sydney, Australia
- Arnold, P. C. & Hill, G. L. 1990b, 'Predicting the discharge trajectory from belt conveyors', *Bulk Solids Handling*
- Arnold, P. C. & Hill, G. L. 1991a, 'Conveyor transfer chute performance and design', *Paper for Presentation at 'Bulk 2000'*, Institute of Mechanical Engineers London, U.K.
- Arnold, P. C. & Hill, G. L. 1991b, 'Design of conveyor chutes with special attention to blockage, wear and conveyor direction change', *End of Contract Report, NERDDP project No. 1188*
- Arnold, P. C. & Hill, G. L. 1993, 'Transfer chutes engineered for reliable performance', *National Bulk Materials Handling Conference*, Institution of Engineers Australia, Yeppon, Australia
- Benjamin, C. W., 1999 'Rapid design approach to the zero-spillage transfer chute', *Australian Bulk Handling Review, June/July*
- Benjamin, C. W., 2001, 'The use of parametric modeling to design transfer chutes and other key components', *BELTCON 11: International Materials Handling Conference*, Johannesburg, South Africa
- BFGoodrich Engineering Handbook: Conveyor and Elevator Belting, 6th edition, BF Goodrich Company.

Booth, E. P. O. 1934, 'Trajectors from conveyors – method of Calculating them Corrected', *Engineering and Mining Journal*

BTR Conveyor Belt Manual, BTR Belting Limited

C.E.M.A – Belt Conveyors for Bulk Materials, 1997, 5th edition, Conveyor Equipment Manufacturers Association

Colijn, H. & Conners, P. J. 1972, 'Belt Conveyor Transfer Points', *Transactions of conveyors', Third International Conference on Bulk Materials, Storage, Handling and Transportation*, Institution of Engineers Australia, Newcastle, Australia

Dunlop Rubber Co., 1982, Dunlop Conveyor Manual, Dunlop Industrial Handbook

Goodyear Handbook of conveyor and Elevator Belting Section 11: Trajectory of Material Discharged over Conveyor Head Pulley, 1976

Korzen, Z. 1984b, 'On the discharge process of belt conveyors', *f+h – fordern und heben*

Korzen, Z. 1989, 'Mechanic of belt conveyor discharge process as affected by air drag ', Bulk Solids Handling

M.H.E.A – *Guide to the Design of Transfer Chutes and Chute Linings*, 1989, The Mechanical Handling Engineers Association

M.H.E.A – *Recommended Practice for Troughed Belt Conveyors*, 1986, The mechanical Handling Engineers Association

Roberts, A. W. 1997b, 'Notes on conveyor discharge', Belt Conveying, Master of Engineering Practice Module Course Notes, Centre for Bulk Solids and Particulate Technologies

Roberts, A. W. 2001, 'Chute design considerations for feeding and transfer', BELTCON 9: International Materials Handling Conference, South Africa



Sabrina, William E., Stahura, Richard P., and Todd-Swinderman R. (1992). Chute Problem Checklist. *Bionic Research Institute*. Chute Design Conference. 1992.

Shortt, G. et al. *Diploma Course in the Design and Operation of Belt Conveyors*. Johannesburg: Conveyor Manufacturers Association of South Africa.

Snow, C. L. 1991, 'Degradation control in transfer chutes', Bionic Conference, Johannesburg, South Africa.

Stuart-Dick, David and Royal, T. Anthony. (1991). Streamlined Design of Chutes to Handle Bulk Solids (1991). *Bionic Research Institute*. Chute Design Conference. 1991. *the AIME*