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Escuela Académico Profesional de Ingeniería Industrial
Escuela Académico Profesional de Ingeniería Mecánica

Tesis

Times Optimization in the Installation of Loading Pipes in Underground Mining Operation

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Times optimization in the installation of loading pipes in underground mining operation

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***Abstract*— Economic policies and the crisis caused by COVID-19 have harmed mining production, with minimal, slow, and conservative investments. An alternative to improve this is underground mining, which represents 43% of worldwide operations; however, the limited production and the number of accidents are limiting, so the procedure for the optimization of times and the time of exposure of workers to danger during the installation of loading tubes were evaluated. For this, the current and improved PAD and POD were analyzed (after the modification of the bit and loading tube), evidencing that in the current procedure, it takes 91 minutes for the installation, with an advance of two and a half cycles. In contrast, in the improved situation, it takes 23 minutes, reaching three cycles, concluding that there is an optimization of 68 minutes per cycle. The time of exposure to danger is also reduced by 2.8 hours.**

Keywords*— *Loading tubes, underground mining, optimization of times

I. INTRODUCTION

Currently, Peru is considered the second producer of silver and copper worldwide; on the other hand, it is considered the third producer of zinc; it is also considered the producer of gold, tin, and lead in Latin America; and it is also the second molybdenum producer, due to mineral deposits from the Andes Mountain range that runs longitudinally across Peruvian territory [1], taking into consideration the above, it must be taken into account that Peru's economy will grow or decrease as the price of minerals grows, positively impacting the growth of mining investment [13]

The Ministry of Energy and Mines states that the economic policies of the last governments of Peru and the crisis due to the widespread COVID-19 pandemic have caused a negative impact on mining production, so it will be subject to the economic reserves from previous campaigns, … "Global economic activity continues to be affected by the prolongation of the supply shocks and lower consumer confidence due to high global inflation. It expects global growth of 2.8 percent in 2022 and 2.7 percent in 2023." [2], so how to act in the face of this future panorama? Underground mining has a promising future, which is why important mining companies such as the Newmont-Cajamarca Company will go from being an open pit mine to one of underground operations, so an increase is foreseen. of 15% in gold production, another clear example of this change is Chinalco-Toromocho. Alfredo Pacheco, general manager of Los Quinuales, states that 43% of mining operations in the world use underground mining as an operating method, for a total of 12% of world production [3].

Despite what has been stated, it is worth mentioning that underground mining exploitation is the one that generates the greatest number of accidents, since in the last seven years more than twenty accidents have been generated each year, as stated [4]. It is a fact that not only does it affect the victim's family because it is an irreparable loss, but it also affects the company, generating economic losses that must be paid to the beneficiaries. On the other hand, it also generates work stoppages during the investigation of the accident.

Underground mining makes possible an increase in productivity since it mitigates the current negative effects due to the situation in which the country finds itself. This is because it incurs minimal investments. On the other hand, however, this type of mining exploitation exposes workers to accidents due to their prolonged stay under the drilled benches during the placement of loading tubes and the loading of explosives.

II. MATERIALS AND METHODS

Seven cycles are identified in underground mining: drilling, loading explosives, blasting, ventilation, debris removal, and sanitation, shotcrete, and bolting. The proposal for time optimization was given in the second cycle, the same one that includes the explosive load, in strict compliance with the following: according to the Buenaventura integrated system in explosives and blasting E-COR-SIB-07.04, Version 02 [5].

Those responsible for supervision must ensure that all workers have the specific safe work procedures for the tasks to be performed, since many mining companies, mainly in informal mining, use PPE little or inadequately, reducing occupational health and safety in mining [11], considering the medium and/or high risk that is closely related to explosives and blasting. In places where explosives and/or diesel equipment are used, workers are required to use self-rescue respirators, which protect against carbon monoxide gases. The driller makes the first holes in the lower part of the mesh, and then, while the driller drills the other end, the assistant places the loading tubes in the holes already made, drilling is understood as the act of opening cylindrical holes in the rock intended to accommodate explosives for their subsequent explosion [14]. Once the installation of the forty-six loading tubes on one front has been completed, the drilling machine is backed out, giving way to those responsible for loading explosives and the spark gap. Once the front is loaded with the explosives and the gelatin, the fuse is extended to a distance of no less than 100 meters, which is united into one. The person responsible for the drilling and his assistant carry out the loading of the drills and the sparking of the work under your responsibility. The person responsible for supervision must ensure that all workers are removed from the area no later than thirty minutes before sparking. The driller and assistant must always perform sparking at the established schedule; failure to comply with this is considered a high-potential incident [6]

According to the geomechanical classification of rock and terrain types, in fractured or altered terrain [10] the one known as “Panizo” this one has a core of greater deformation, which is surrounded by an area of fractured rock, having the core of deformed material that is often thin [12], so, the drilled holes become clogged, affecting the installation of the explosives. since explosives are loaded at different depths within the column of explosives. To reduce these problems, PVC tubes called loading tubes are used, improving the level of performance.

According to the EXSA practical blasting manual, “to start a drill loaded with a sensitive breaking explosive or a blasting agent, a bait is used” [7], being a set made up of a cartridge of dynamite, emulsion, or hydrogel that is sensitive to the detonator, which has an inserted detonating cord used to activate the detonation of the main explosive charge.

Generally, the equipment used for drilling is hydraulic drills, these are sophisticated equipment and in many cases robotic, for which hydraulic energy is used for the transmission, and control of forces and movements in drilling. During the experimentation [15], the drill bit model "B" SR35 X 51mm was used with a bar length of 14 feet, used for the 46 drilling points in front of 4m by 4m [7] (see figure 1), the same ones that consider average explosive loads according to the details in table I and II.

Fig. 1. Detail of drilling distribution points on a front, by Rojas 2018, Drilling Mesh Standard for Ramp 4m x 4m [7]

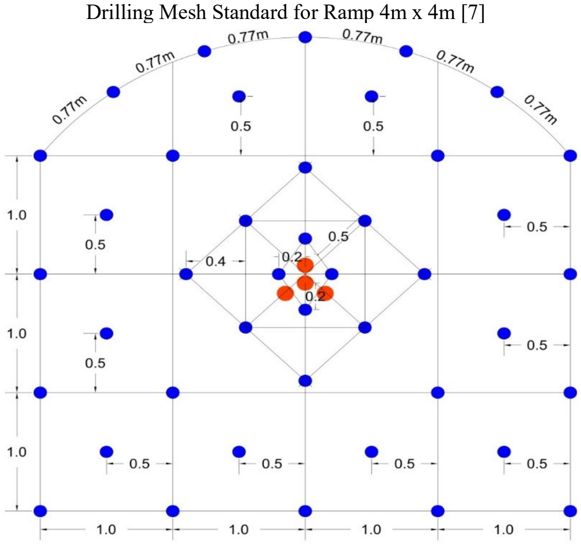


TABLE I. THE TABLE SHOWS THE DETAILS OF THE EXPLOSIVE LOAD DOSAGE FOR THE ADVANCED FRONT, JUMBO, [8]

Explosive charge dosage table for advance front: Jumbo						
Description	***N° Tal.***	***Average load per drill.***				
		E-3000 1"X8"	***E-65%1 1/4"X8"***	***ANFO***		
				Parts/drill. An	***Kg/drill***	***Total Kg***
Start	4		4	3/4 parts	3.45	13.8
Ayu. Start	4		4	3/4 parts	3.45	13.8
Production	18		18	2/3 parts	3.07	55.26
Squarers	4		4	1/2 parts	2.3	9.2
Ring gear	7	7/Tal.				
Drag	5		12/Drill			
TOTAL	**42**	**49**	**90**			**92.06**

TABLE II. HOLE DISTRIBUTION: LOADED AND RELIEF DRILLS

CONTENT	
Relief drills	
Loaded drills	
Hole distribution	
Description	UND.
Boot relief	4
Relief	4
Startup help	4
About Ay. relief	4
Squarers	4
Production Tal.	14
Ring gear	7
Drag	5
Loaded drills	42
Relief drills	4
Total	46

The aforementioned aspects gave rise to the analysis, modification, and implementation during the installation of the loading tubes, for which the procedure was proposed to optimize loading installation times in underground mining exploitation as well as significantly reduce exposure. Due to the danger to the workers during the aforementioned pipes, the improvement began after the perforation of the forty-six points marked on the mesh starting the explosive loading cycle, under the following procedure: clean to avoid friction and blockages, drain the hole with compressed air, sheath the drilling (install the loading pipes), place the cartridges, place the detonating cord [16].

Application: After drilling the front, the drilling machine was stopped, the drill bit with which the forty-six points were drilled was changed with the modified drill bit (innovation proposal), the modified loading tube was manually placed on the drilling bar of the equipment, the drilling column was placed in each of the drilled holes on the front, the bar was moved with the loading tube attached until it reached the top of the drilling, and the drilling rod, the loading tube was stuck in the drilled hole. This is because it is stuck in the steel support of the life of the equipment, preventing the loading tube from returning with the drilling rod.

The research sought to evaluate the procedure for optimizing times in the installation of loading tubes in underground mining exploitation and obtained a significant reduction in the exposure to danger of workers during the installation of loading tubes in underground mining exploitation. In this proposal, the data obtained was quantified and compared with the data collected from workers in the area, as well as the practical experience gained during the years of work in the mining sector of one of the researchers, who proposed the modification of the conventional drill bit used for drilling processes. On the other hand, the modification of the loading tube used in mining exploitation was also proposed, to which a longitudinal cut has been made.

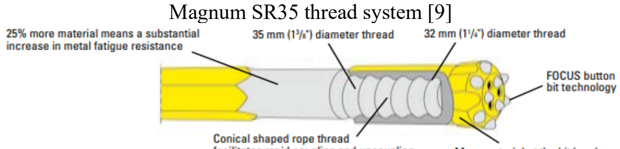
The generation of the results was obtained after the Pareto analysis, current and improved Process Analytical Diagram (PAD) and the Process Operation Diagram (POD), time observation, and a pilot test that was developed in SENATI-Huancayo, with which the evaluation of the cost-benefit relationship was validated. Proposed with a pilot test developed in the environments of SENATI-Huancayo, Peru, with the Jumbo 282 EPIROC two-arm equipment.

The details of the modification of the drill bit and loading tube are presented below:

A. Original design

Bench drill bit. Tool used for drilling surfaces (banks) during mining exploitation. It is available in different dimensions on the market. For this proposal, a "B" SR35 X 51mm drill bit has been used [9]. See Figure 4.

Fig. 2 . Graphic representation of the drill bit attached to the drill rod Magnum SR35 thread system [9]



Explosive loading tubes. They are plastic implements that are placed in the drilled holes to facilitate the loading of explosives to the top of the drilling, having a length of 2.80 m, with a variation in diameter depending on the drill bit to be used. See figure 3

B. Modification

With the help of a lathe, a notch was roughened to the contour of the drill bit. This notch is 4 mm with a 35° inclination towards the teeth or cutting inserts of the drill bit, having a depth of 2 mm. See figure 4

A roughing angle was made to the skirt of the drill bit to facilitate the fitting of the loading tube insert, allowing it to enter the drilling without difficulty.

After the work carried out in modifying the drill bit, there is a 4mm notch with a 35° inclination and a roughing on the skirt of the drill bit. See figure 7

Fig. 3. Charging tubes for loading explosives

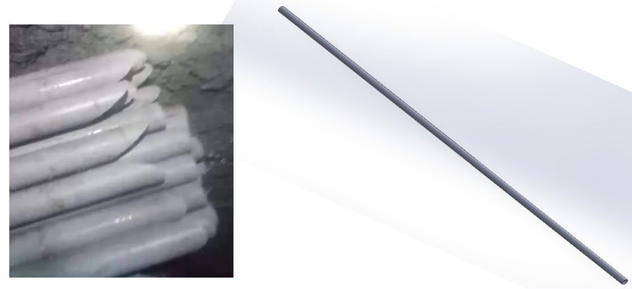
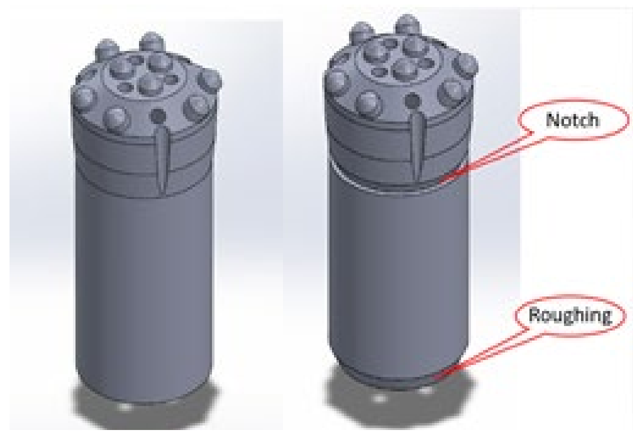
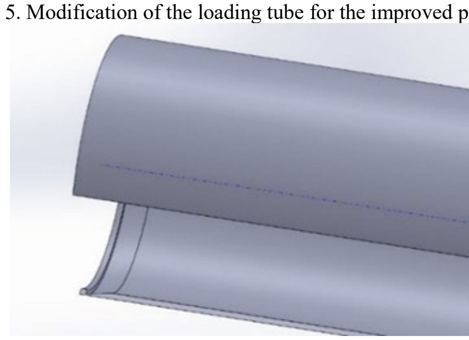


Fig. 4. Comparison between the original drill bit and the modification made



The modification of the loading tube consisted of forming an insert at one of the ends, the same one that helped it fit into the modified drill bit. See figure 5

Fig. 5. Modification of the loading tube for the improved process



A longitudinal cut was made to the tube, and then a 25-millimeter-wide tape was extracted. The loading tube insert allowed it to be attached to the drill bit, preventing it from disengaging during entry into the drilling already carried out. On the other hand, the cut in the tube facilitated its installation on the drilling rod. The modified loading tube was left with an insert in one of the tube ends and a longitudinal cut. See Figures 6 and 8.

Fig. 6. Difference between the original loading tube and the modification made is that the longitudinal cut facilitates its attachment to the drilling rod, and the insert ensures that it is fixed to the drilling bit.

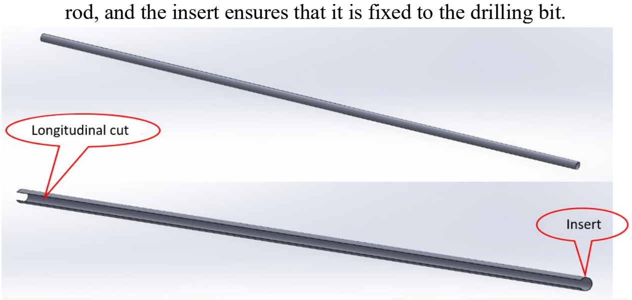
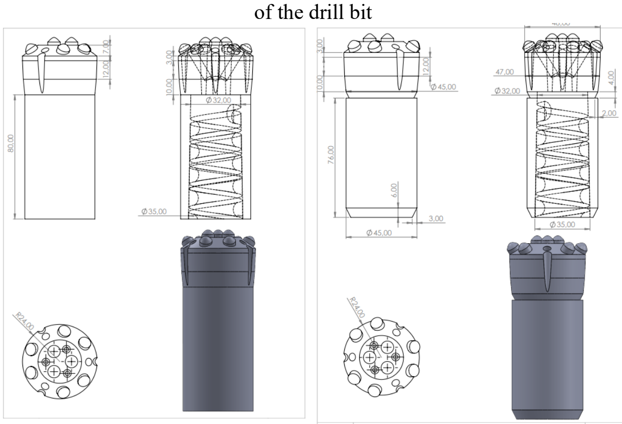


Fig. 7. Drawings of the original drill bit and drawings of the modification of the drill bit



C. Application

The modified bit was installed in the drill rig, and then the loading tube was fitted to the drill rig bar, ensuring that the insert was engaged in the notch of the modified bit. The machine was responsible for introducing the loading tube into the drilled hole, with which it was left installed when the bar was retracted.

The loading tube was installed on the drilling bar; for this, the tube with the cut was pressed on the drilling bar of the equipment, which remained wedged. The drilling machine introduced the loading tube to the previously drilled hole, leaving it installed for later filling with explosives.

D. Results

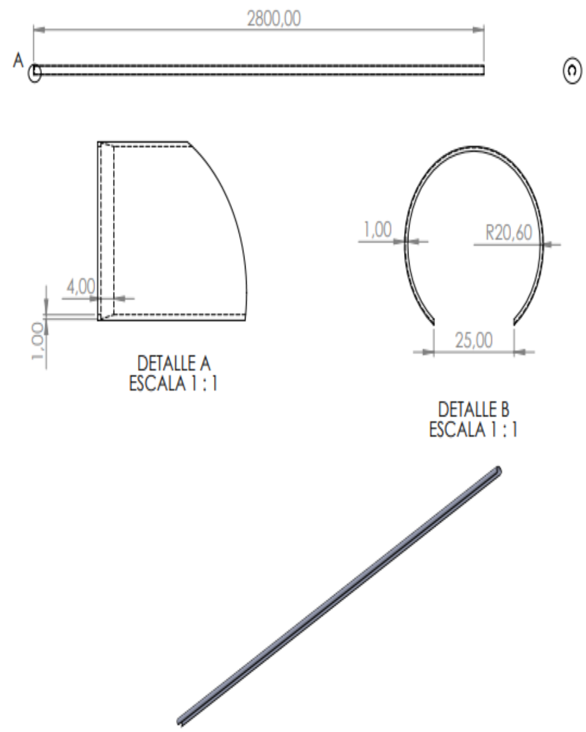
After the implementation of the modifications made to the loading tube and the drill bit, a comparative table is presented in which the current process and the improved process are explained.

E. Current process

Once the drilling of the drilling mesh points has been completed:

- The drilling assistant is responsible for placing the loading tubes.
- One of the factors that affect the installation time of the loading tubes is the type of terrain, which takes longer in fractured or altered "C" class terrain.

Fig. 8. Drawing of the modified loading tube



- In fractured or altered terrain, the loading tube is inserted as far as it will go, and it can get stuck at different points; consequently, there is no optimal blasting.
- Another risk in the installation of loading tubes is that they break due to the force exerted at the time of installation.
- Despite the cleaning (blow blasting) done by the drilling equipment, debris generally remains, requiring cleaning with tools (corrugated iron spoon) made by hand (spell).
- During the installation of loading pipes, drilling assistants are exposed to danger, greatly influenced by the type of terrain in which they are working.
- The looser the terrain, the more complicated the installation of the loading tubes is therefore the longer the helpers are exposed to danger.

F. Improved process

After drilling the points of the drilling mesh, the drill bit is changed, and the loading tube is attached to proceed with its installation:

- The installation of the loading tubes is done by the drilling team.

- The installation is not as complicated as manual installation since the team installs it with the same force that it uses for drilling.

TABLE III. HOURS TO COMPLETE THE CYCLE OF UNDERGROUND MINING EXPLOITATION

Necessary hours to complete the cycle of underground mining exploitation in sandy or fractured terrain.

Drilling	1	2	3	4	…	42	43	44	45	46	**Total minutes**
Installation of loading pipes in sandy terrain.	1.75	1.75	1.75	1.75	…	1.75	1.75	1.75	1.75	1.75	91.00
Improved method	0.50	0.50	0.50	0.50	…	0.50	0.50	0.50	0.50	0.50	23
Optimized time	1.25	1.25	1.25	1.25	…	1.25	1.25	1.25	1.25	1.25	68.00

Cycles in the current process	2 cycles and a half	Work hours	12 hours
Total optimized hours, approx.	3 hours approximate		
Cycles in the improved process	3 cycles	Work hours	12 hours

- The loading tube does not break since it enters with the drilling rod support of the same equipment.
- Cleaning is not necessary since it enters again with a drill bit, clearing the debris found in the drilling.
- The assistant simply places the loading tubes on the drill rod of the rig and attaches the insert to the notch of the drill bit.
- The assistant is not exposed to danger during the installation of the loading tubes since he is away from the removed ground.
- This process helps the loading of explosives to be efficient, obtaining optimal blasting, thereby optimizing times and reducing the risk when installing the loading tubes.

The innovation projects the reduction of time in one of the underground mining exploitation processes. With the reduction of time in this second process, it is possible to drill more fronts and consequently make a significant advance during exploitation, which is translated into profit for the company.

On the other hand, the non-exposure to the danger of the assistants generates confidence in underground mining exploitation, which promotes this method for future exploitations. Likewise, it should be stated that the life (safety) of the workers is invaluable, and all companies seek their promotion and the application of processes that ensure the integrity of their collaborators.

As evidenced in Table 3, the current process; During the installation of loading tubes, it takes approximately 91 minutes, according to what was stated by those interviewed for the development of this project, for the same reason that during a work shift of two and a half cycles are achieved, however with the improved process the installation of The loading tubes take 23 minutes, achieving an optimization of 68 minutes per cycle, with a total of more than 3 hours during the workday, for the same reason that two and a half cycles are achieved, however with the improved process the installation of The loading tubes take 23 minutes, achieving an optimization of 68 minutes per cycle, with a total of more than 3 hours during the work day, which is why it is possible to complete the 3 cycles unlike the 2 and a half carried out in the actual process. See table III

On the other hand, Peru is a country dedicated to mining exploitation, and the demand would be significant since it helps to optimize times and promote the safety of collaborators during mining exploitation. On the other hand, it does not generate any environmental impact.

III. CONCLUSION

It is concluded that there is an optimization of 68 minutes per drilling cycle, achieving compliance with three complete cycles with the implementation of the project.

With the proposal, the installation of the loading tubes is carried out by the team and not by the assistant; consequently, they are no longer exposed to danger.

The proposal mainly benefits the mining exploitation process (companies) since, with the proposed method, it is possible to optimize mining exploitation, which is extremely attractive in the mining sector in general. On the other hand, the exposure time of assistants to danger is reduced by 2.8 hours, so from this perspective, it also benefits companies since one of their priorities is to ensure the safety of their collaborators.

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