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Simulation of HD 325-6 Dump truck Tires Performance of Angoran Lead and Zinc Mine

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ABSTRACT

The mining industry is one of the most influential industries in the economy of any country. Today, mining companies are attempting to reduce the costs of mining operations by using different sciences. Tires are one of the expensive and dangerous components of mining dump trucks, and because they are used in certain conditions, they are always prone to premature failure, but this can be prevented with methods. Dump truck load and speed are among the most effective and controllable operating parameters in improving tire life performance. The simultaneous effect of these two variables can be checked in the form of ton-kilometer per hour index and through its analysis, tire life can be improved. The purpose of this research is to manage the ton-kilometer per hour index, investigate its effect on the performance of the HD 325-6 dump truck tires in the Angoran lead and zinc mining complex. Due to the uncertainty of operational parameters, Monte Carlo simulation using MATLAB software has been used to control the failure of tires of the studied dump truck. This research was conducted by collecting and analyzing operational data in 10 work cycles in Sep. 2023. The results of the investigations show that there is a 21.6% probability of passing the TKPH limit of Tianli TUE400 tire. Therefore, it is suggested using tires with TKPH greater than 170 for the mentioned dump truck. In addition, the life of the tires is less than their nominal life, which can be caused by the poor conditions of the ramps.

KEYWORDS

Dump truck, TKPH, Tires Performance, Monte Carlo Simulation

I. Introduction

The mining industry is one of the most important economic pillars of a country. Open-pit mines produce more than underground mines for various reasons, including the use of high-capacity machines. Some of these machines, which are used for loading or transporting minerals, require special consumables and equipment, which imposes a very high operating cost on mines. Among these consumables, we can mention the tires used in mining dump trucks. The rate of wear and tear of these tires and determining the appropriate time to replace them are of great importance in the management of the machinery fleet. This cost of production affects the safety and efficiency of transportation machinery. Depending on the type and size of the dump truck, the cost of tire consumption of integrated mining dump trucks can account for 15-35 percent of the operating cost of the machines (Asadi, 2019). In some sources, this cost is reported to be approximately 20-30% of the operating cost of the mine (Sarkar, 2012). Tire performance mainly depends on how the tire characteristics (material, size, air pressure, etc.) interact with operating conditions (road, load, travel distance, and speed). Weather conditions are also considered other factors that affect the life of tires. The multiplicity of effective factors, the complexity of the interaction mechanism between them, and the selection of inappropriate operational strategies by managers can lead to early tire failure, accidents, waste of resources, and reduced profitability. For example, not adjusting the tire air pressure can cause a 10% increase in fuel consumption and improper tire wear of mining dump trucks (Pascual, 2019). The average life of a tire in mines is lower than the amount recommended by the manufacturing plants. The lifespan of dump truck tires depends on the load pressure on the wheels. The main factor in changing a normal load is the wheel position on the dump truck and haul road in the open pit mine. Determining the maximum amount of load loaded on the tire in different working conditions increases the life of the tire and prevents its premature failure (Dadonov et al., 2019). In 2013, Meech and Parreira presented a model for predicting mining tires wear and tear for a virtual mine. This model uses fuzzy logic to relate tire wear with dump truck speed and load (Meech and Parreira, 2013). The research Pascua et al. for reduce the consumption of tires in a medium-scale open-pit mine in northern Chile in 2019, showed that an allocation program for the transport fleet and the selection of suitable tires for dump trucks, resulted in a 7.3%

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reduction in consumption (Pascual, 2019). In 2020, Asadi and Sayadi have reviewed the operational parameters of Gol Gohar Iron Ore mining trucks aiming at improving the useful life of tires. In this research, operational data were collected in 55 work cycles in the winter of 2020. The results showed that the tires are in good operating conditions, while the life of the tires is considered half of their nominal life (Asadi, 2019). The purpose of this research is to manage the ton-kilometer per hour index, investigate its effect on the performance of the HD 325-6 dump truck tires in the Angoran lead and zinc mining complex. This research was conducted by collecting and analyzing operational data over 10 work cycles in Sep.2023. For this purpose, the operational TKPH index for the types of tires used in the mine were determined and analyzed. After calculating the aforementioned index, the performance of the studied dump trucks will be checked using MATLAB software and the results will be analyzed.

II. ANGORAN LEAD AND ZINC MINE

The Angoran lead and zinc mine is located in Mahenshan City, 135 km west of Zanjan City. It is located at 36°37'N and 47°24'E, with an elevation of sea 3100 above meters level. Due to its location in a mountainous region, it has very harsh and long winters and mild summers, with a minimum temperature of -30°C in the winter and a maximum temperature of 22°C in the summer. Precipitation is generally high, and snow falls from early November to April. The reserve of this mine consists of two parts, carbonate and sulfur, and is pear-shaped with the deep expansion of the sulfur part. Most of the carbonate reserve has been extracted. The production capacity of the said mine is 800,000 tons per year, with an average grade of 25-30% zinc and 3-6% lead. It is considered one of the largest metal mines in the country. Based on the design, the Angoran mine is mined in an open pit. The final slope of the mine is 45 degrees in waste rock and 35 degrees in mineral matter. The height of the stairs is 10 meters (except for the highest horizon, which is 15 meters high) and with a slope of 74 degrees in the tailing and 60 degrees in the mineral (Ghadimi, 2022). In the current transportation system, the extracted minerals are transported to high-grade, medium-grade, low-grade, and tailing dumpsites around Kavak by means of dump trucks from the ramp of the open pit mine. Due to the impossibility of the lateral expansion of the cavity due to the topographical limitations, especially the falling schists on its western side, the depth advancement of the levels causes the working spaces of the machines to be limited (Tedin Mansouri et al., 2016). In Fig. 1, a view of the loading and unloading system of the Angoran mining complex is shown.

The TKPH index is actually a rating for tires that are rotating with a certain amount of load and speed, how much heat it can withstand. On the other hand, according to the definition of the Michelin company (a tire manufacturer), TKPH is the ability to perform the work of a tire and is a function of the maximum internal temperature allowed for the operation of the tire. TKPH calculation is a series of engineering calculations that are done according to the amount of load, speed and conditions in which the tire is used. TKPH are calculated both for operational conditions and for tires (EARTHMOVER, 2016). In this research, the load distribution on each tire is assumed to be normal and homogeneous. But the amount of load distribution on the front and rear axles is different, and its values are provided in the handbook of the company that manufactures dump trucks. Table number one shows the load distribution values on the front and rear axles of the HD 325-6 dump truck.

Fig. 1. A view of the loading and unloading system of Angoran mining complex

III. TKPH

Table 1. Weight distribution on the front and rear axles and the weight of the dump truck HD 325-6 (Komatsu, 1987)

Dump truck	Empty Weight	gross vehicle weight	Weight distribution			
			Empty		loaded	
			Front axle	Rear axle	Front axle	Rear axle
HD 325-6	28.7	60.775	48 %	52%	32 %	68 %

In order to calculate TKPH, operational parameters related to the studied dump trucks have been collected. These data include tonnage, speed, distance, road slope and also the annual average temperature for ten work cycles were measured in Sep. 2023. All the data were collected from the same work shift so that the temperature conditions of the environment, operator, etc. are almost the same. The mentioned data is presented in table number two. In table number two, TKPH calculations based on tonnage and speed are presented. It should be noted that the average return cycle of dump trucks is 4.4 km, the average annual temperature is 22°C and the road slope is 8%.

Table 2. Calculation of TKPH based on load and speed

Cycle	Load	The amount of load on each front axle tire (ton)	The amount of load on each rear axle tire (ton)	Speed (Km/h)	TKPH
1	29.9	8.132	6.847	18	146
2	30.1	8.148	6.864	18.6	152
3	29.6	8.108	6.821	20.4	165
4	30.5	8.180	6.898	21.6	177
5	30	8.140	6.855	19.8	161
6	28.5	8.020	6.728	21.36	171
7	29	8.060	6.770	24	193
8	29.6	8.108	6.821	22.8	185
9	30	8.140	6.855	19.2	156
10	32	8.300	7.025	18.12	150

A. TKPH TIRE

The TKPH of the tire can be different depending on the type of design, i.e. the size and pattern of the tread, as well as the materials used to make it. Tire manufacturing companies provide this index and it will have a different number for each tire of different size and design (Komatsu, 1987). The specifications of the tires used in the Angoran mining complex are presented in Table 3.

Table 3. Brands used in Angoran mining complex (Off-The-Road-Tires, 2016)

Brands	Techking	Tianli	Triangle	Tianli
Type	ETDT2	TUE400	TB526S	EUE402PRO
TKPH	275	170	297	180

B. ADJUSTMENTS

After determining each operational TKPH and tire before comparing the two, adjustments should be made on one of them to determine the appropriateness of the desired tire in a specific operational condition. For this purpose, based on the instructions provided by the tire manufacturing companies, these adjustments are applied. For example, Michelin and Magna companies have provided the same adjustments that are applied to the operational TKPH. Yokohama Company has also applied its own adjustments on TKPH operations. If Bridgestone, Techking and Triangle companies have applied their adjustments on TKPH tires. In addition, Goodyear Company has not provided an adjustment for tires or operational TKPH (Asadi, 2019). In this research, adjustments of Yokohama Company are used for Tianli tire so.

$$TKPH = TKPHop \times k_t \times k_g \quad (1)$$

In this relation, $TKPHop$ is operational TKPH, k_t is the temperature coefficient and k_g is the adjusted coefficient for the slope. If the ambient temperature of a mine during the year is lower than T_c is 22°C, equation (2) will be used; otherwise equation (3) will be used. Table No. 4 is also used to determine the coefficient k_g.

$$k_t = \frac{55}{55+[0.5\times(38-T_C)]} \quad (2)$$

$$k_t = \frac{55}{55+(38-T_C)} \quad (3)$$

Table 4. Coefficients of front and rear axles in different slopes (Asadi, 2019)

Road slope	Front axle	Rear axle
-1	1.01	1
-2	1.02	0.99
-3	1.02	0.98
-4	1.03	0.98
-5	1.04	0.97
-6	1.05	0.97
-7	1.06	0.96
-8	1.06	0.96
-9	1.07	0.95
-10	1.08	0.95

In order to apply the adjustments of Techking and Triangle companies, the following methods should be used:

a. If the distance covered in each cycle is less than 5 km, the operating TKPH will be increased by 12%.

b. If the ambient temperature is different from 38°C, the operating TKPH is modified using the coefficients presented in Table No. 5.

Table 5. Correction coefficients of TKPH score of tire at different temperatures (Sayadi and Khalsi, 2019)

Temperature (°C)	Bias tires		Radial tires	
	cross-section			
	> 27 in	> 30 in	> 27 in	> 30 in
< 14	1.144	1.120	1.240	1.216
14	1.144	1.120	1.240	1.216
22	1.096	1.080	1.160	1.144
30	1.048	1.040	1.080	1.072
38	1	1	1	1
40	0.988	0.990	0.980	0.982
46	0.952	0.960	0.920	0.928
50	0.928	0.940	0.880	0.892

C. COMPARISON OF TKPH

By determining the operational TKPH of each cycle and adjusting it, it is time to evaluate these two indicators. In this way, the performance of the used tires will be evaluated. This review is presented in the form of charts number 2 to 4. These graphs include operational TKPH (brown color), tire TKPH (blue color) and 80% tire TKPH (green color). So,

- Considering that the average return cycle of dump trucks is 4.4 km, the TKPH of technical and triangle tires should be increased by 12%. In addition, taking into account the average annual temperature of 22°C, the calculated TKPH is modified again using Table No. 5. Therefore, the values of TKPH for Technig and Triangle brands are calculated as 357 and 386, respectively.
- Given that, the operating TKPH values are less than 80% of the TKPH of Techking and Triangle tires. It can be said that from the economic point of view, the mentioned tires are not suitable for use in the operating conditions of Angoran mine.

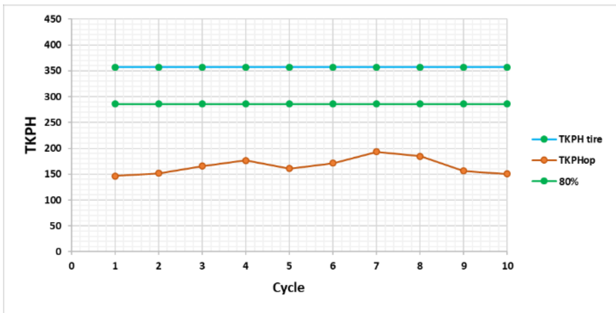

Fig. 2. Operational TKPH and Techking tires

Tables are No. 2, 4 and Equation No. (1-2) have been used to calculate Tianli tires adjustments by equation (1-1). The average operating TKPH adjusted for Tianli tires is calculated as 153, which is greater than 80% of the TKPH value of the said tire. Therefore, the TUE400 model is not suitable for the operating conditions of Angoran mining complex, and models with a larger TKPH should be used, as shown in Fig. 4.

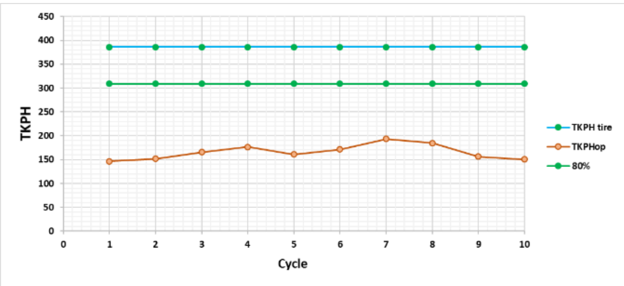

Fig. 3. Operational TKPH and Triangle tires

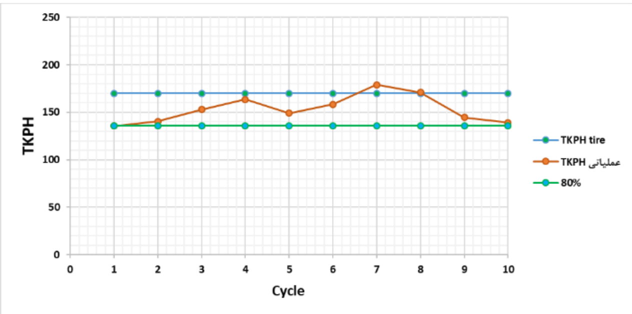

Fig. 4. Operational TKPH and Tianli TUE400 tires

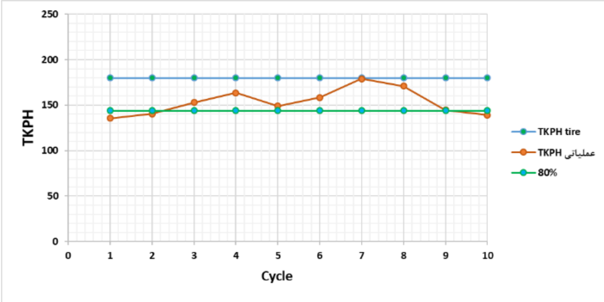

Fig. 5. Operational TKPH and Tianli TUE402PRO tires

IV. SIMULATION OF OPERATIONAL TKPH

Monte Carlo simulation is a computational algorithm that uses random sampling to obtain results. In general, the Monte Carlo method refers to any technique that provides approximate answers to quantitative problems through statistical sampling. This method is mostly used to describe a method for propagating the uncertainties in the model input to the uncertainties in the model output. Therefore, this method is based on repeated sampling of a random process; that is, it continuously samples the input data under the distribution function of that data and creates random numbers under the same distribution. This is because random numbers are an important part of this method. This work is repeated and observed until the desired result is obtained (Mohamed et al., 2019). In the first step, the relationship between the variables should be determined, so the Eq. (4) is used for simulation.

$$TKPH = T \times V \times k_1 \times k_2 \quad (4)$$

In this regard, T is the load tonnage, V is the speed of the dump truck, and k1 and K2 are adjustment coefficients that are determined from the manuals of the tire manufacturing company. The general method of simulation is that in MATLAB software, a general matrix will be formed to perform calculations and the rows and columns of this matrix will include different values until the equation (1-4) for each tire is calculated separately. The rows of the matrix include the number of simulation repetitions, and the columns of the matrix include various values such as load, speed, ambient temperature, etc. According to the number of repetitions, equation (4-1) will be calculated, and the values that exceed the allowed amount of TKPH of the tire will be obtained. By dividing the values above the allowed amount by the number of repetitions, the probability of exceeding the allowed limit will be calculated. In the following, according to Table 6, the distribution of load and speed variables are determined from the collected data. By determining the probability of each interval, the desired data for simulation is produced in such a way that it follows the mentioned function.

In the next step, the matrix will be formed for simulation in MATLAB software, and the overview of this matrix will be as follows.

Table 6. Probability of distribution of tonnage and speed in four categories

Tonnage Classification	Number	Possibility(%)	Speed Category	Number	Possibility (%)
28-29	1	10	17-19	3	27
29-30	4	40	19-21	3	29
30-31	4	40	21-23	3	32
31-32	1	10	23-25	1	12
Total	10	100	Total	10	100

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{115} \\ a_{21} & .. & .. & .. & a_{215} \\ & & \cdots & & \\ a_{n1} & .. & .. & .. & a_{n15} \end{bmatrix} = \begin{bmatrix} Load1 & Speed1 & T1 & Techking & \text{triangle} & Tianli \\ Load2 & Speed2 & T2 & Techking & \text{triangle} & Tianli \\ .. & .. & & .. \quad .. & .. & .. \\ Load\ n & \text{Speed n} & \text{Tn} & Techking & \text{triangle} & Tianli \end{bmatrix} \quad (5)$$

In the last step, after calculating the relation (4-1) 10,000 times, the number of cases whose operating TKPH will be greater than the tire TKPH will be determined and the probability will be calculated by dividing this number by 10,000. In Table 7, the probability of TKPH distribution in the simulation process is presented, and the best number and probability in the third category is between 160-180. Fig. 6 shown the abundance distribution of Tianli tire.

Table 7. Probability of TKPH distribution in the simulation process

Category	Number	Probability(%)
120-140	94	2
140-160	1778	33
160-180	1912	36
180-200	1356	26
200-220	176	3
Total	5316	100

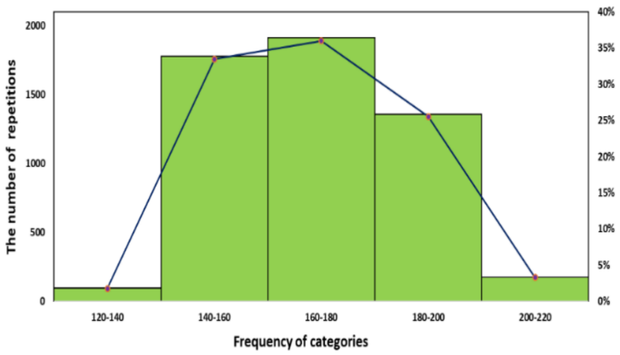

Fig. 6. Tianli tire abundance distribution diagram

THE EFFECT INCREASE OF TEMPERATURE ON THE POSSIBILITY OF EXCEEDING THE PERMISSIBLE LIMIT OF THE TIRE

The temperature of the tire is considered the most important factor in the failure of dump truck tires (Asadi, 2019). The higher the operational TKPH number is, it means that the heat generated in the tire will be higher, so we must control the TKPH to prevent thermal problems such as splitting or bursting of the tire. This control can be done by reducing the number of cycles or by reducing the average weight on the tire. In the codes prepared in the MATLAB software environment, the TKPH values of the studied tires have been evaluated. As shown in table number 8, at a temperature of 22 degrees Celsius, Tianli brands ETDT2 and EUE402PRO have 21.6 and 6.7% probability of passing the limit, respectively. Also, ETDT2 and TB526S models were not damaged.

Table 8. The percentage of the probability of exceeding the permissible limit of tire

Tire brand	EUE402PRO	TB526S	TUE400	ETDT2
TKPH index	180	297	170	275
Probability	6.7	0	21.6	0

Fig. 8 shows the relationship between changes in ambient temperature and the probability of exceeding the limit of Tianli tire. At a temperature of 22°C, for increasing the value of TKPH from 170 to 180, the temperature created in the tire decreases by 31%.

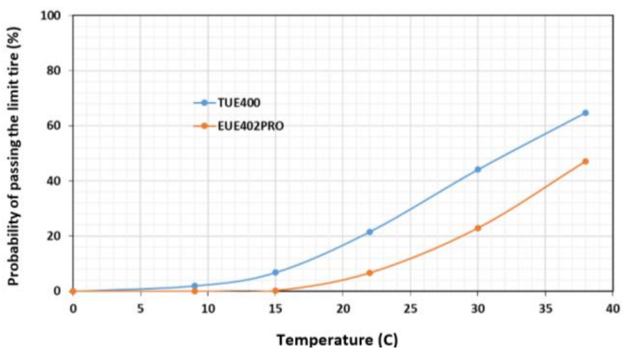

Fig. 7. The effect of temperature changes on the possibility of exceeding the permissible limit of the tire

V. CONCLUSION

The purpose of this research is to manage the TKPH index and investigate its effect on the performance of HD 325-6 dump truck tires in Angoran lead and zinc mining complex. MATLAB software has been used to control the failure of tires of the studied dump trucks. This research has been done with the help of collecting and analyzing operational data in 10 work cycles. Dump truck load and speed are among the most effective and controllable operating parameters in improving tire life performance.

- In this research, the performance of tires with Technig, Tranigle and Tianli brand were investigated.

- Considering that the average return cycle of dump trucks is 4.4 km, we will increase the TKPH of Technic and Triangle tires by 12%. Also, taking into account the average annual temperature of 22 degrees Celsius, the calculated TKPH has been modified using Table No. 5. Therefore, the values of TKPH for Technig and Triangle brands are calculated as 357 and 386, respectively. Considering that the operational TKPH values are less than 80% of the TKPH of Techking and Triangle tires. It can be said that from the economic point of view, the mentioned tires are not suitable for use in the operating conditions of Angoran mine.
- The adjusted operating TKPH value for Tianli TUE400 tire is calculated as 153, which is greater than 80% of the TKPH value of the said tire. Therefore, it is not suitable for the operational conditions of the mentioned mine. The results of the investigations show that there is a 21.6% probability of passing the TKPH limit of Tianli TUE400 tire. Therefore, it is suggested using tires with TKPH greater than 170 for the mentioned dump truck.
- Also, the life of the tires is less than their nominal life, which can be caused by the conditions of the ramps, poor skill and knowledge of the operators, poor monitoring and control of the tire pressure.

REFERENCES

Asadi, S. (2019). Analysis of the operational parameters of Gol Gohar 1 iron ore mine trucks with the aim of improving the service life of tires, Master's thesis of Tarbiat Modares University.

Sarkar, A. 2012. Regression and Failure Analysis of Dumper Tires: A Case Study for Iron Ore Mines. In Safety and Reliability. Taylor & Francis.

Pascual, R., Román, M., López-Campos, M., Hitch, M., & Rodovalho, E. (2019). Reducing mining footprint by matching haul fleet demand and route-oriented tire types. Journal of cleaner production, 227, 645-651.

Dadonov, M., Kulpin, A., Ostanin, O., & Suleimenov, E. (2019). Distribution of static normal reactions to wheels of open-pit dump trucks depending on the longitudinal and cross sections of the open-pit road. In E3S Web of Conferences (Vol. 105, p. 03009). EDP Sciences.

Meech, J. and Parreira, J. (2013). Predicting wear and temperature of autonomous haulage truck tires, IFAC Proceedings Volumes, 2013. 46(16): p. 142-147.

Pascual, R., Román, M., López-Campos, M., Hitch, M., & Rodovalho, E. (2019). Reducing mining footprint by matching haul fleet demand and route-oriented tire types. Journal of cleaner production, 227, 645-651.

Ghadimi, M, (2022). presenting a report on the geotechnical situation of Angoran lead and zinc mine, the second annual national conference of Iranian deposits, lead-zinc deposits and associated metals in Iran, Shahrood University of Technology.

Tedin Mansouri, A., Shakur Shahabi, R., Samimi Namin, F., Khani Khorshki, M.H., Kargar, B. (2016). Feasibility of transporting open pit mine tailings through existing underground excavations, Journal of Mineral Resources Engineering, 7(4), 25-38.

TECHNICAL DATA -EARTHMOVER tyres. (2016).

Komatsu HD 325-6. (1987). Off-highway truck,.

Off-The-Road Tires. (2016): p. 4, 10-12.

Sayadi, H., Khalsi, A. (2019). Parametric estimation of the costs of loading and unloading machines in Royaz mines, Organizational Management Research, 4/8: 23-44.

Mohamed, S., Rosca, M., Figurnov, M., & Mnih, A. (2020). Monte carlo gradient estimation in machine learning. Journal of Machine Learning Research, 21(132), 1-62.