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FRICTION COEFFICIENT OF DIAMOND WIRE SAW

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In order to estimate the diamond wire saw upon quarrying of dimension stone, it is necessary to know the value of a friction coefficient on the driving pulley of the saw. Therefore the numerical value of the friction coefficient between diamond wire and coating of a driving pulley was determined in experimental way. The experiments were conducted under different working conditions. The resulting average value of the friction coefficient upon working in wet and muddy conditions amounted to $\mu = 0.32$.

Ključne riječi: Arhitektonski kamen, Dijamantna žična pila, Koeficijent trenja

Za proračun dijamantne žične pile pri eksploataciji arhitektonskog kamena potrebno je poznavati vrijednost koeficijenta trenja na pogonskom kotaču pile. Zato je eksperimentalnim putem određena brojčana vrijednost koeficijenta trenja između dijamantne žice i obloge pogonskog kotača. Pokusi su provedeni za različite uvjete rada, a dobivena prosječna vrijednost koeficijenta trenja pri radu u mokrim i blatnim uvjetima iznosi $\mu = 0,32$.

Introduction

The efficiency of a diamond saw upon quarrying of dimension stone comprises professional choice and its professional usage. In order to make the right choice it is necessary to know the exact procedures of diamond wire saw estimate. The estimate of diamond wire saw by any of the procedures (Dunda, 1996) requires the numerical value of friction coefficient on the driving pulley. Since the figure from the reference literature regarding this coefficient is not real, its numerical value was defined in experimental way.

Theoretical contemplations

The friction coefficient between diamond wire and driving pulley depends on the kind and condition of their surfaces in contact, specific wire pressure on the pulley, wire speed and working conditions. The groove of the pulley is covered by rubber coating in order to increase the friction coefficient μ and the durability of diamond wire.

In the articles about stone cutting by diamond wire saws I have not found any data referring to the value of friction coefficient on the driving pulley. The only exception is the literature source (Kartavii, 1988) according to which the pulling factor $e^{\mu\alpha}$ of diamond wire saw upon looping cutting method amounts to 1.4 with an enclosing angle $\alpha = 180–220^{\circ}$. This means that the friction coefficient between diamond wire and the coating of driving pulley is $\mu = 0.09–0.11$.

These figures seem to be unrealistic if we consider the fact that the friction coefficient of a steel rope on the brim of a cast iron pulley amounts to $\mu = 0.12–0.14$, and $\mu = 0.16–0.18$ if the pulley is coated in wood or leather (Arar, 1962). According to the mining regulations (Regulations about technical standards upon transportation of people and goods through mining shafts) the calculated friction coefficient between the steel rope and the Koepe driving pulley should amount to $\mu = 0.25$. The real friction coefficient must be determined on the coating sample for a particular case and it must not be less than 0.45, which is to be proved by the test report. The friction coefficient between the rubber belt conveyor and driving drum varies from 0.1– smoothly turned wet drum surface up to 0.5 – ceramic coating with groover, work in dry atmosphere (Treščec, 1983).

The friction coefficient between diamond wire and rubber coating of a driving pulley as well as the pulling factor $e^{\mu\alpha}$ should be considerably higher than the one between the steel rope and the pulley of cast iron. The rough surface of diamond beads in contact with the coating of driving pulley enables (provides) a high and stable friction coefficient. Besides adhesive also the intensive hysteresic friction is present, because the protrusive diamond grains are pressed into the friction coating of driving pulley. The coating surface is periodically deformed. The ratio of losses upon deformation to the work on the passed path represents hysteresic friction component. The penetration of diamond grains into the coating of driving pulley prevents the wire gliding and causes their intensive wearing out. Therefore a rubber coating is put into the groove of a driving pulley and can be easily replaced.

Due to the fact that hysteresic friction is present, the friction coefficient should be higher than it is in the above stated examples. On the other hand, the diamond wire is not in contact with the coating of a driving pulley along the entire angle of wire encirclement on the pulley but it is touched by the beads intermittently. Therefore the friction coefficient for the specific enclosing angle should be lower than it would be if the rope were coated by diamond layer continuously and if it permanently were in contact with the coating of driving pulley. Since I was not able to obtain the data referring to the friction coefficient between the diamond wire and the coating of driving pulley from the coating manufacturer (because they did not determine this), I experimentally determined the real friction coefficient of diamond wire and coating of driving pulley.

Experimental work

In order to determine the value of friction coefficient of diamond wire on driving pulley I used the well-known method of coefficient determination (Šindler, 1991).

The driving pulley of diamond wire saw is fixed on the axle outside of the machine mechanism. A diamond wire with weights of the mass $G = 7$ kg hanged on its endings, is coiled round such a fixed driving pulley (Fig. 1). In this way the initial tension of the wire is achieved, unlike the machine procedure whereby the tension is enabled by means of a tension mechanism. In this way the initial

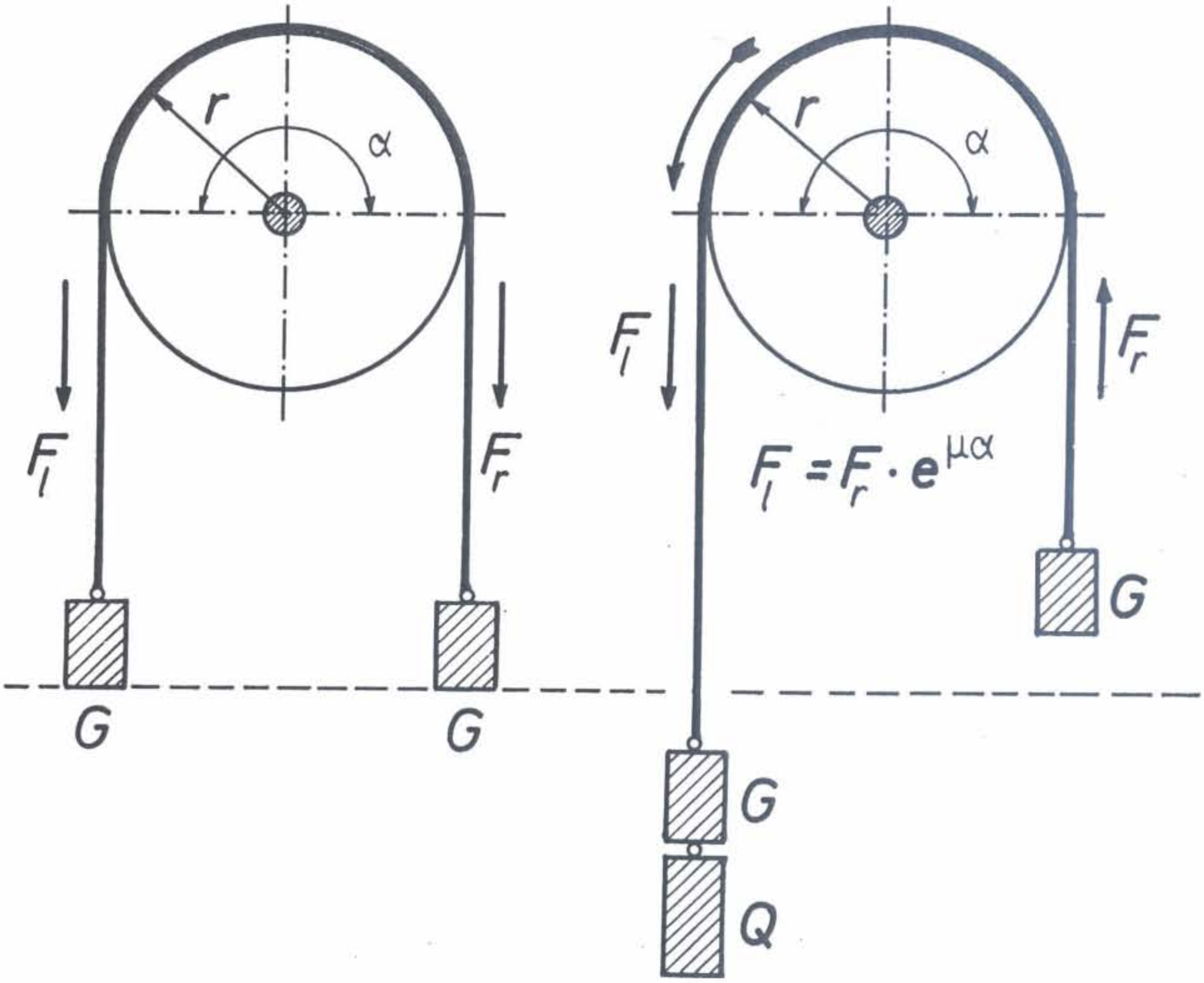

Fig. 1. The experimental determination of friction coefficient on the driving pulley.

pressure force is realized. Both weights have the same mass, placed in the same plane which provides the balance between the left and right sides of the wire. The right side is stressed by the force $F_r = g \cdot G$
and the left side by same force of the same intensity
$F_l = g \cdot G$.

$$F_r = F_l = g \cdot G = 9{,}807 \cdot 7 \approx 69\ \mathrm{N} \qquad (1)$$

whereby
$g = 9{,}807\ \mathrm{m/s^2}$ gravity
$G = 7$ kg weight mass.

By force increase by means of weights on one side enables the preponderance of this side in the moment when the friction between the wire and driving pulley will not be able to prevent wire gliding i.e. decreasing of the load. The load on this side was increased by slow strewing of steel grains in the hanged container. These steel grains are usually used as free abrasives on frame saws in the sawing plants of dimension stone. Thus, according to the formulae about the transmission of pulling force from the driving pulley of a diamond wire saw to the diamond wire (Dunda, 1991), if the wire starts gliding down the stiff driving pulley, the ratio between the forces is:

$$F_l = F_r \cdot e^{\mu\alpha} \qquad (2)$$

whereby
F_l – tension of the left wire arm outgoing on the driving pulley
F_r – tension of the right wire arm incoming from the driving pulley
e – base of natural logarithm
μ – friction coefficient between diamond wire and coating of driving pulley
α – angle of wire encirclement on the pulley (in ark measure)

Since the gravity acts on both sides, the load increase on the left side (G+Q) causes wire gliding down the driving pulley as soon as this load reaches the value $G \cdot e^{\mu\alpha}$. This means that the condition for wire gliding is:

$$G + Q = G \cdot e^{\mu\alpha} \qquad (3)$$

i.e. pulling factor is:

$$e^{\mu\alpha} = \frac{G+Q}{G} \qquad (4)$$

whereby
Q– additional load on the left side.

Wire gliding started when the load Q = 14.9 kg was added on the left side. The value Q = 14.9 kg was adopted as an average value in ten measurements of the start of wire gliding. The pulling factor in this moment was:

$$e^{\mu\alpha} = \frac{G+Q}{G} = \frac{7+14.9}{7} \sim 3.13$$

Angle of wire encirclement on the pulley was $\alpha = 180^0$ or in ark measure $\alpha = \pi = 3.14159$. The value of the base of the system of natural logarithms is $e = 2.718$, so:

$$e^{\mu\alpha} = 3.13 \rightarrow \mu\alpha \cdot \log e = \log 3.13 \rightarrow$$

$$\mu = \frac{\log 3.13}{\alpha \cdot \log e} = \frac{0.4955}{3.14 \cdot 0.4342} = 0.3634 \sim 0.36$$

Approximately the same rounded figure was obtained by force measurement by dynamometer in the moment of imbalance. The truthfulness of the received data regarding the value of friction coefficient between diamond wire and coating of driving pulley was thus additionally confirmed.

The above stated experiment was conducted when both of the contiguous surfaces were dry. The function of the diamond wire is substantially disturbed by a constant water inflow, which is necessary for wire cooling and cut rinsing. This is the reason why the obtained data regarding the value of friction coefficient cannot be used upon calculations of diamond wire saw. It is necessary to use more negative value with lower friction coefficient i.e. the friction coefficient upon wet conditions, which correspond to real working conditions of diamond wire saw.

Therefore, in order to determine the real friction coefficient with wet contiguous surfaces and to see the difference between coefficient values in different working conditions, the entire experiment was repeated. There was a constant water inflow on driving pulley including dust adding, which appears by stone cutting in a quarry, so that the working conditions were almost identical if not even worse than those on the working site. The obtained average value of friction coefficient between diamond wire and coating of a driving pulley in such wet and muddy working conditions amounts to $\mu = 0.32$. This value is only by 0.04 different from the value obtained in experiments conducted in dry conditions.

Analysis of the results

The obtained figures regarding friction coefficient show that there is no large difference between dry and wet conditions. It is considerably smaller than the one on rubber belt conveyors, whereby $\mu = 0.1$ for smoothly turned drum – wet surface, and $\mu = 0.3$ for smoothly turned drum – dry working conditions. This can be explained by the higher influence of hysteresic friction which appears on diamond wire saw. The hysteresic friction depends less on the condition of the contigenious surfaces than on their material.

The friction coefficient, obtained in such real, bad conditions is considerably higher than it was quoted in reference literature (Kartavii, 1988).

In both experiments (wet and dry conditions) the friction coefficient was determined in repose, so it can be considered as a static friction coefficient. The value of a static friction coefficient is important upon determination of the starting working conditions when the resistance is high because of the start-up of the machine. Upon working a diamond wire saw has a high speed (up to 45 m/s). Therefore the friction coefficient will be different than the coefficient which was experimentally determined in repose. Upon belt transmission the friction coefficient between the belt and the belt reel is increased together with the speed increase (Decker, 1980). Speed increase of rubber belt conveyors causes the increase of the friction coefficient, so that upon the belt speed of 0.2 m/s the friction coefficient is approx. 20% lower than upon the speed of 5.2 m/s (Trešćec, 1983). Accordingly, the friction coefficient between diamond wire and coating of a driving pulley during the operation of the saw will be higher than it was determined during the experiment in repose. This is an additional safety factor, if the experimentally determined static friction coefficient is adopted upon the estimate of diamond wire saw.

Conclusion

According to the experimental determination of friction coefficient and analysis of the obtained results it can be concluded that the average friction coefficient of $\mu = 0.32$ can be applied upon estimate of a diamond wire saw.

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REFERENCES

Arar, I. (1962): Transportna sredstva u rudarstvu. Tehnička knjiga, 463 pp., Zagreb.

Decker, K. H. (1980): Elementi strojeva. Tehnička knjiga, 542 pp., Zagreb.

Dunda, S. (1991): Neujednačenost prijenosa gibanja dijamantne žične pile za eksploataciju blokova arhitektonskog kamena (Ununiformity of Motion Transmission of a Diamond Saw Cutter for the Exploitation of Dimension Stone Blocks). *Rud.-geol.-naft. zb., 3*, 77–84, Zagreb.

Dunda, S. (1996): Theoretical Development of the Estimate of Diamond Wire Saving Plant. *Rud.-geol.-naft. zb., 8*, 103–109, Zagreb.

Katavii, N. G., Sichev, J. J. & Woluev, J. V. (1988): Oborudovanie dla proizvodstva oblicovochnih materialov iz prirodnovo kamna. Mashinostroenie, 239 pp., Moskva.

Šindler G. and Valić B., (1991): Materija, čestice i međudjelovanja. Školska knjiga, 127 pp., Zagreb.

Trešćec, I. (1983): Teorija, proračun i primjena transportera s gumenom trakom. Zavod za produktivnost, 392 pp., Zagreb.