TEMPERATURE PICTURE OF A BUCKET TOOTH AND ITS' SERVICE LIFE

TEMPERATUROWY OBRAZ ZĘBA ŁYŻKI I JEGO CYKL OBSŁUGOWY

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Abstract:
The shape and the geometry of a bucket edge, its material and the material of a mechanical tooth are the key influences on the efficiency and energetic demands of mining processes with bucket wheel excavators. If the excavator units are often changed due to wear or breaking down, it increases the cost of the mining process, of course. It also reduces the service life of the machine and therefore it reduces the efficiency of the whole technological unit [TU] as well. Consequently, all wear causes not only changes to the shape and geometry or material features of the digging unit, but it also increases energy demands of the mining process, as mentioned. The presumption is – increased wear of digging units raises cutting resistances and consequently the temperature goes up due to higher friction and wear. Therefore, the picture of the temperature is the scale for measuring wear.

Key words: *thermography, service life, bucket wheel excavator*

Słowa kluczowe: *termografia, cykl obsługowy, koparka wielonaczyniowa*

INTRODUCTION

Heading stopes of the open-pit mines for brown coal are moved to more difficult geological conditions. It more often causes problems with breaking clay and claystones loose. Consequently, it affects efficiency parameters and service life, and therefore the construction and design of the digging units are affected, too. First of all, mining units are the most affected elements because they lack any absorption of digging forces during their mining service. The result of such performance is obvious. It is the destruction of teeth and buckets in very certain cases. Sometimes, it also causes damage to the whole boom of a bucket wheel excavator. A high abrasiveness of digging material accompanies the force effects in the sandy clay with pockets and claystones.

Consecutively, all wear changes the shape and geometry or material features of the digging unit but it also increases the energetic demands of the digging process. We presume that increasing wear of digging units raises cutting resistance and consequently the temperature goes up due to higher friction and wear. picture of the temperature is the scale for measuring wear.

The aim of the thesis is to determine an appropriate method for evaluation and definition of connections with the service parameters. It would enable simple technical and economical measurements or tests under the given conditions in the open-pit mines. Then, we would review the service wear of these digging units of bucket wheel excavators in connection with the measured temperature picture during the digging process.

SUGGESTED WORKING METHODS AND PROCESS OF EXPERIMENTAL MEASUREMENTS

The working methods have to fulfil the defined aims. Firstly, we focus on the evaluation of results from experimental measurements and finding possible connections. There are actually outputs to results of possible functional connections:

- Temperature = f [wear, geometry of an edge, geological conditions – index JKS and digging restrictions or efficiency and energetic demands]
- Wear = f [wear, geometry of an edge, geological conditions – index JKS and digging restrictions or efficiency and energetic demands]
- Service life = f [1/wearing speed]

The entity rests in determination of correlations between the temperature rise of an edge [°C] and the wear of the edge [by weight %] or between the energetic demands [kWh.m^{-3}r.z.] and the wear [by weight %] at a given geometry of edges [construction of disconnecting tool] and geological conditions represented with the index JKS [UCS - united classification of sediments] or the digging resistances, efficiency and energy demands. It is actually about all the given technical and service parameters.

There is a limit which influences the in-situ measurements. The bucket wheel excavators are in service in va-

rious open-pit mines with different mining and geological conditions and the measurements have to be done under strict mining rules and processes. The measurements are difficult to prepare, to arrange and to evaluate. Therefore, the measuring processes were realized only in the locations where the mining rules allowed to do such actions in certain times. Moreover, the economical management of the mining company had to agree with the measurements and modified conditions for such processes. As a result of such circumstances, it is obvious that for example the verification of wearing speed under strict mining rules and conditions would require regular measurements beginning form assembling of new digging components till their exchange. Then, we would gain precise explicit service data. The measurements took place in three locations: Severočeské doly a.s. – Doly Bílina, Severočeské doly a.s. – Doly Nástup Tušimice and Vršanská uhelná, a.s. The realization of the task was done under modified conditions and we had to solve the key connections with maximal evidential definiteness which is necessary to the total solutions of given aims.

The thesis contains 11 short-term measurements and 3 long-term measurements on the bucket wheel excavators TC2. These measurements cover three different geometries of edges and geological conditions. Data from the years 2008 and 2009 are worked. The given correlations are important for the prognosis of the consumption of edges and for determination of an optimal geometry in given mining and geological conditions.

It is necessary to say that bucket wheel excavators are in service in various open-pit mines and in different mining and geological conditions. Moreover, different types of machines have hourly capacity, drag forces and different uncoupling tools are mounted to them – buckets of various shapes and cutting geometry.

Following types of bucket wheel excavators were included into the measuring processes:

− those which independently work in relatively homogenous environment, however different to each other, ie. classes A, B, C in accordance to JKS [UCS]
− have small scattering Q_t [theoretical capacity] according to manufacturer
− are located in different places
− have different shape and geometry of the edge or teeth

The above mentioned conditions reduce the types of bucket wheel excavators. The machines which work primarily in the coal roof of the surface layer fulfil these conditions. The type TC 2 belongs to this group. The model **KU 800** is the most common one and its' theoretical hourly capacity after the reconstruction of the wheel engine is approximately 5300 až 5500 m^3h^{-1}s.z. **K2000** is another model with its capacity Q_{th} = 5 500 m^3h^{-1}s.z. Finally, there are two new machines **SchRs 1550** a **SchRs 1320**.

Basic parameters of the uncoupling tool at the bucket wheel excavators KU 800.11, KU 800.14

Bucket – production number [p.n] 0-02-01969/ with teeth p.n. 2673.

The teeth are made from abrasion-resistant steel VP7 with following chemical structure:

C   = 0,32 %
Cu = 0,00 %
V   = 0,20 %
Mn= 1,60 %
Ni = 0,00 %

W   = 0,00 %
Si   = 0,80 %
Mo= 0,60 %
B   = 0,006 %
Cr   = 1,00 %
Zr   = 0,00 %

Long-time strength of the steel VP7 = 1500 MPa.

Front cutting geometry:

− side clearance angle = 18°
− angle of the cutting edge = 25°
− rake angle = 47°

This geometry is marked as geometry 1 in the final part of the thesis [fig. 1].

Fig. 1. Geometry 1
Rys. 1. Geometria 1

The geometry of individual teeth on the bucket is influenced with the position of a tooth on the bucket and it varies in the angle of the cutting edge and the rake angle. They are signed for particular positions as 1-1 … 1-8 in accordance with given rules "wear of edge-tooth'.

Basic parameters of the uncoupling tool at the bucket wheel excavators KU 800.18, KU 800.19

Bucket – p.n 000158-0000-0-Z2 with angular edges or the bucket p.n. 000080-0001-0-Z5 with exchangeable angular edges.

They are angular edges with welded abrasion-resistant layer of material with thickness of 9÷12 mm. Material of the welded layer: Corthal OA 78

Front cutting geometry:

− side clearance angle = 18°
− angle of the cutting edge = 47°
− rake angle = 21°

This geometry is marked as geometry 2 in the final part of the thesis [fig. 2].

Fig. 2. Geometry 2
Rys. 2. Geometria 2

*Basic parameters of the uncoupling tool at the bucket wheel excavators **KU 800.20, SchRs1320 4x30***

The bucket is fitted with teeth system ESCO Super V which consists of an adaptor, toothed cutter head and a stop pin. The adaptor is welded to the banding of the bucket. The toothed cutter head is mounted to the adaptor, it is type V39VYH. The stop pin protects against loosing the head. The material of the tooth is unknown.

Front cutting geometry:
- side clearance angle = 18°
- front angle of the cutting edge = 47°
- rake angle = 55°
- side angle of the cutting edge = 32°
- sloped angle of the cutting edge = 62°

This geometry is marked as geometry 3 in the final part of the thesis [fig. 3].

Fig. 3. Geometry 3
Rys. 3. Geometria 3

Simultaneous measurements
- Determination of service capacity on the basis of data from conveyor scales
- Per unit energetic consumption
- Wear of teeth and edges of the wheel bucket
- Digging resistances with indirect method
- Laboratory test of taken ground samples
- And others non-specified

EXPERIMENTAL MEASUREMENTS AND THEIR EVALUATION

The Picture 4 compares a new tooth with an old one to increase knowledgeability. The temperature picture was acquired with thermography.

The thermovision measurement is provided to find out:
- Determination of working capacity on the basis of data from conveyor scales,
- Spatial arrangement of the temperature on the teeth surface of the digging units,
- Percential number of temperatures on the selected surfaces of teeth surface,
- Temperature loading of a bucket tooth.

Many other quantities and data are necessary to be checked to find out basic connections between surface temperature of bucket teeth and their spatial arrangement on the surface. This data might influence the temperature loading of teeth on the uncoupling tools. There are following thermovisual data – physical, mechanical and technological features of the dug material and the features of the mining machine and the mining conditions in general. Thermographs are shown on the fig. 5, 6 and 7.
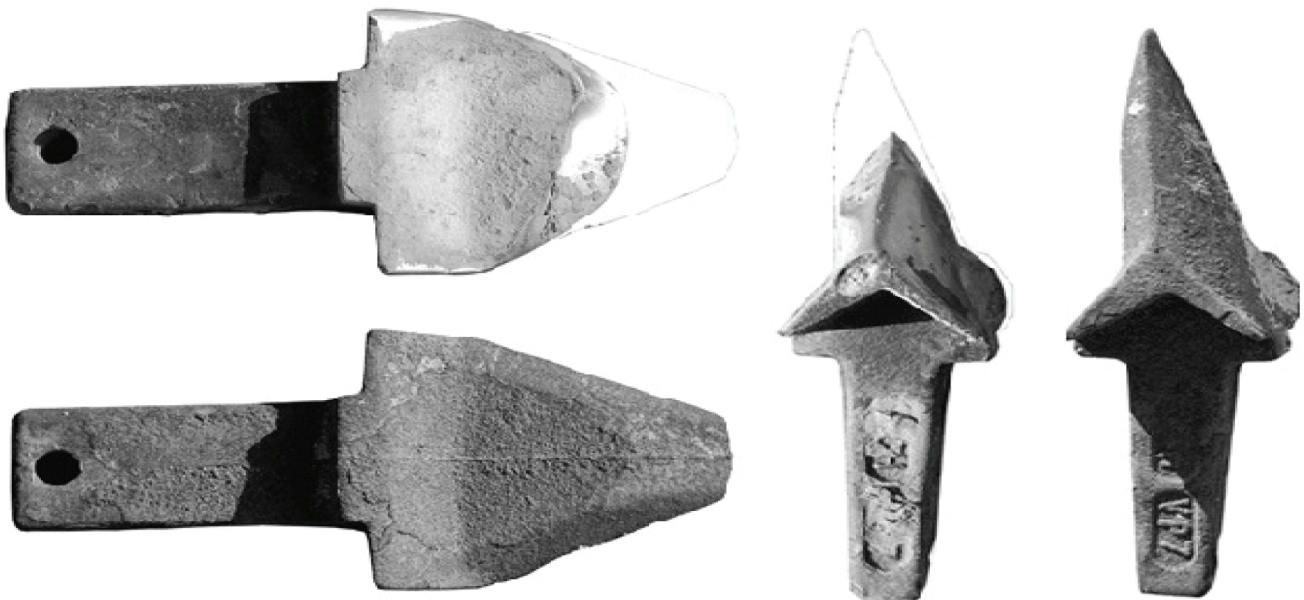

Fig. 4. Comparison of a new and a wear tooth
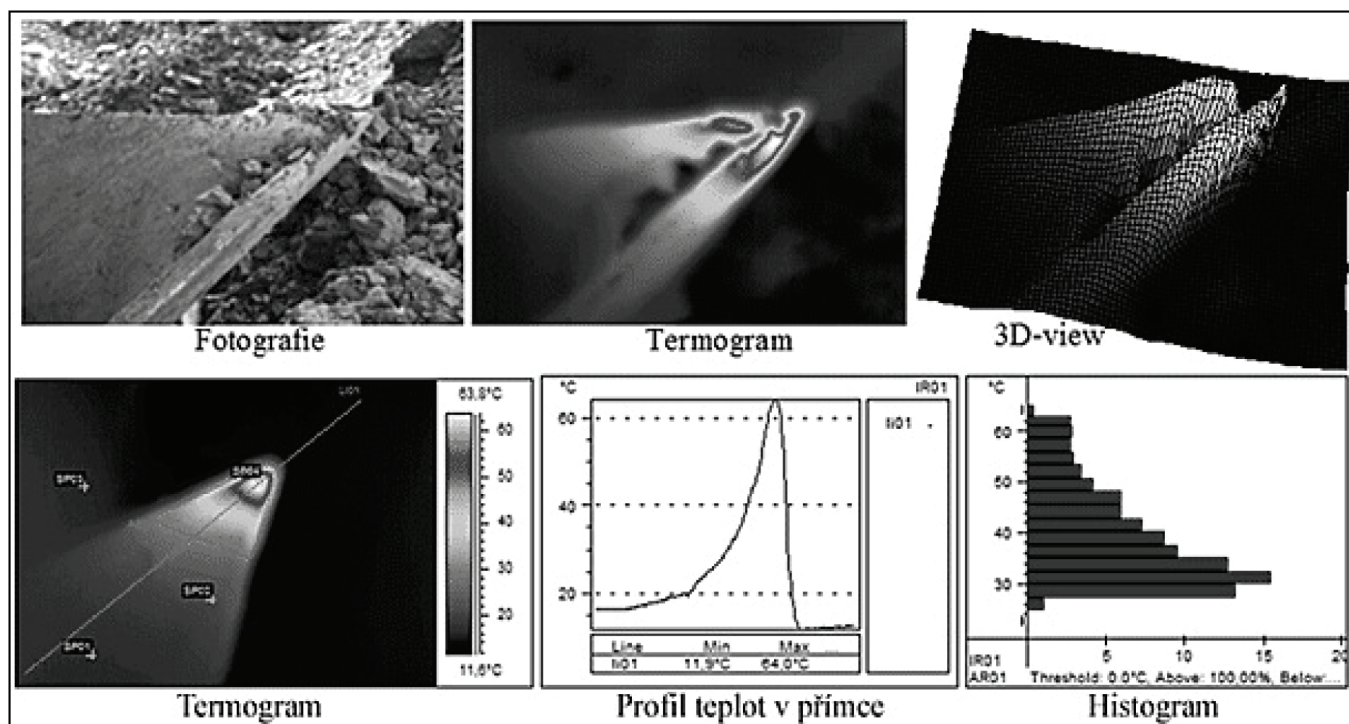**Rys. 4. Porównanie nowych i zużytych zębów**

Fig. 5. The analysis of thermograph with the surface temperature of a bucket tooth
Rys. 5. Analiza termograficzna temperatury powierzchni zęba

The thermographs were evaluated, some accompanying measurements and laboratory tests of ground samples were undertaken and we come up with following results:

− The energetic demand of the process is in the relations from 0,395 kWh/m3 to 0,890 kWh/m^3. The average energetic demand is 0,6398 kWh/m^3.
− The warm of edges is from 1,0°C to 135,0°C. The average warm of edges is 26,3°C.
− The wearing of edges is from 1,290% to 23,280%. The average wearing of edges is 9,573%.
− The influential level is 95% and it proves that the position of a tooth influence statistically the energetic demand of the process (p-value = 0,757).
− The energetic demand of the processes undertaken in the geological conditions marked with index JKS is statistically connected with these conditions. The correlation between the energetic demand and JKS index is not statistically influential.

		Energetic demand [kWh/m^3]	JKS index
Pearson Correlation	Energetic demand [kWh/m^3]	1,000	0,057
	JKS - index	0,057	1,000
Sig. (1-tailed)	Energetic demand [kWh/m^3]		0,313
	JKS - index	0,313	

−There is a statistically influential positive correlation between the energetic demand and the warming of a tooth.

Correlations

		Energetic demand [kWh/m^3]	Warming [°C]
Pearson Correlation	Energetic demand [kWh/m^3]	1,000	0,234
	Warming [°C]	0,234	1,000
Sig. (1-tailed)	Energetic demand [kWh/m^3]		0,022
	Warming [°C]	0,022	

− The Post Hoc analysis showed that the position of teeth can be divided into three similar groups in accordance with their warming. The lowest warming is identified for the positions of edges 1-1, 1-5 and 1-8. The second group contains positions of edges 1-2, 1-4 and 1-7. The highest warming belongs to position of edges 1-3 and 1-6. The medians of teeth warming can be considered as the same in these groups.
− The correlation coefficient between the warming of teeth and index JKS is 0,461. This value corresponds with a middle positive correlation which was evaluated as statistically influential.
− The influential level is 95% and it proves that the position of edges influences their wear.
− There is a weak correlation between the wear and JKS [UCS] index. See the table with results. There is no statistical influence of index JKS [UCS] on the wear of an edge.
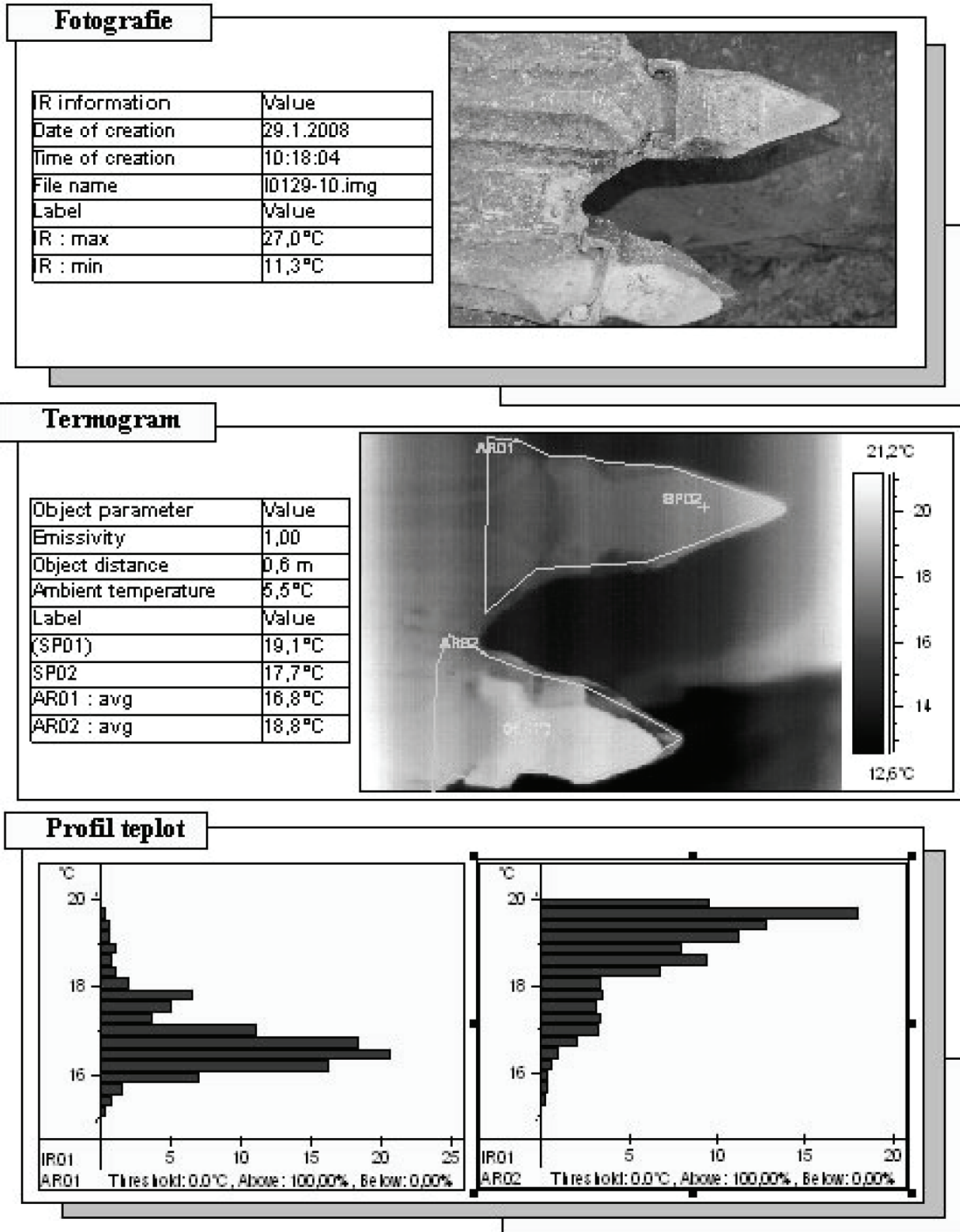
Fotografie

IR information	Value
Date of creation	29.1.2008
Time of creation	10:18:04
File name	I0129-10.img
Label	Value
IR : max	27,0°C
IR : min	11,3°C

Termogram

Object parameter	Value
Emissivity	1,00
Object distance	0,6 m
Ambient temperature	5,5°C
Label	Value
(SP01)	19,1°C
SP02	17,7°C
AR01 : avg	16,8°C
AR02 : avg	18,8°C

Profil teplot

Fig. 6. Analysis of thermograph - the starting state of teeth before their service life
*Rys. 6. Analiza termograficzna - stan wyjściowy zęba przed cyklem obsługowym*

Fotografie

IR information	Value
Date of creation	29.1.2008
Time of creation	12:22:12
File name	I0129-24.img
Label	Value
IR : max	91,3°C
IR : min	10,5°C
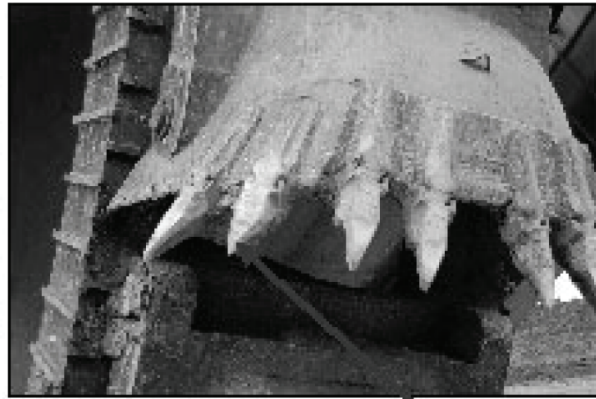
Termogram

Object parameter	Value
Emissivity	1,00
Object distance	2,4 m
Ambient temperature	5,5°C
Label	Value
(SP01)	91,3°C
SP02	79,6°C
SP03	63,9°C
SP04	45,9°C
SP05	29,9°C
SP06	21,8°C

Profil teplot

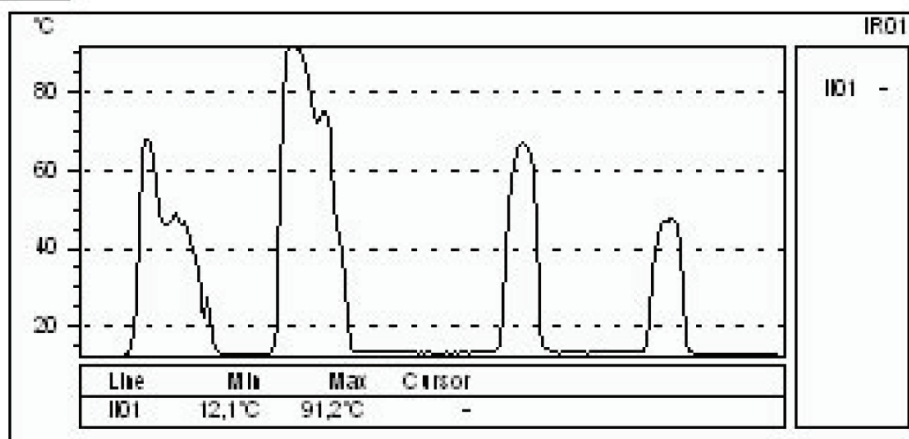| Line	Min	Max	Cursor
II01	12,1°C	91,2°C	-
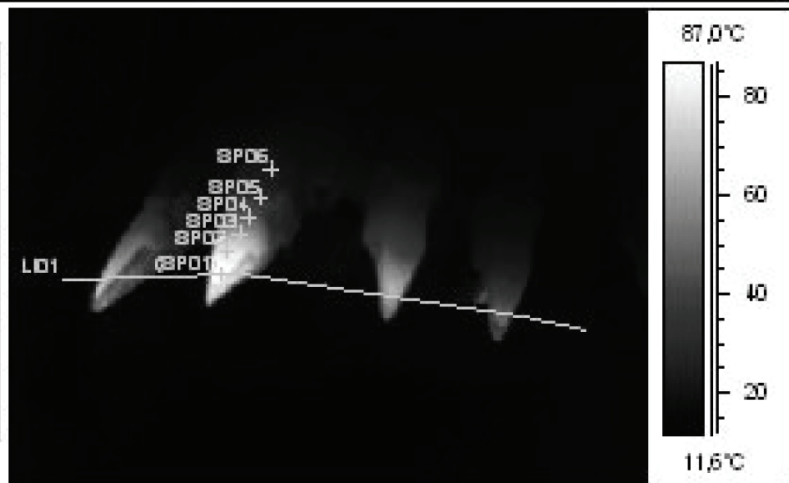
Fig. 7. Analysis of thermograph – working temperatures of teeth
Rys. 7. Analiza termograficzn - temperatura pracy zęba

SUMMARY

To sum up, we introduced the process of the work which has been done so far. We managed to do some experimental measurements and their analysis and evaluation which have brought particular final results. On the other hand, the solution is not the finalized, but it was our duty to inform public about the gained knowledge which was acquired with this non-standard way. The process enabled us to work under the working conditions of brown coal open-pit mines and to do simple technical and economic measurements. These measurements are the basis for relevant consideration of service steps within the wear of digging units on bucket wheel excavators.

In other words, we have managed to do following actions so far:

− We determined machines which will undergo the measurements of edges and teeth, consequently, the cutting geometries were selected,
− We determined dates and length of measurements,
− We created measuring methods to control the temperature picture of a tooth – edge with a thermovisual camera,
− We created measuring methods to find out the abrasive wear of the bucket edge and tooth,
− We measured the uncoupling resistances, capacity and energy consumption and other thermovisual measurements; we measured new teeth and old teeth at the end of their working life,
− We made laboratory tests of ground samples which were taken right from their capping,
− We calculated particular JKS [UCS] indexes on the basis of the analysis mentioned above. If there were no samples available, the analysis was made on the basis of values according to the mining and geological model of the mining company,
− We determined some basic correlations and connections between the results acquired from in-situ measurements.

Our future steps should lead to:

− To find out, verify and confirm the connections between the wear rate of the uncoupling tools and the temperature picture in the given mining and geological conditions (index JKS and digging resistances, capacity and energetic demands) on the basis of the worked set of working measurements,
− In-situ measurements to verify the data for different bucket wheel excavators and their uncoupling tools,
− To work on a method to find out the wear of uncoupling tools from their first work to a necessary exchange,
− To use the result for construction planning of new bucket wheel excavator or their maintenance and control systems.

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