INDUSTRIAL UTILIZATION OF SINGLE-IMAGE PHOTOGRAMMETRY

VYUŽITÍ JEDNOSNÍMKOVÉ FOTOGRAMMETRIE V PRŮMYSLU

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Abstract

Single-image photogrammetry is today only a marginally used surveying method. In the project of diagnostics of rotary kilns a non-contact method is searched, which may help and speed up the overall surveying and evaluating work. Thus also a possibility is looked for to use the single-image photogrammetry during the survey.

Abstrakt

Jednosnímková fotogrammetrie je v dnešní době okrajově využívanou měřickou metodou. V projektu diagnostiky rotačních pecí se hledá bezkontaktní metoda, která by pomohla a urychlila celkové měřické a vyhodnocovací práce. Hledá se tedy možnost využití jednosnímkové fotogrammetrie při těchto měřeních.

Key words: Photogrammetry, rotary kiln, diagnostics.

1 INTRODUCTION

Photogrammetry is a scientific and technical discipline, dealing with finding out reliable information on physical objects and environment by recording, measuring and interpreting images. [1]

Roots of photogrammetry go back far before the invention of photography. Already Aristotle constructed an ancestor of camera, so-called camera obscura. The first who put into practice the central projection, which is a basic imaging method of photogrammetry, was Leonardo da Vinci (1452-1519). He described the phinole camera, allowing to redraw shapes of observed objects using the central projection. Jan Keller (1571-1630) equipped the camera with a converging lens and so camera clara occurred. The gradual development led to the emergence of photography, from which the photogrammetry has split off. Photographs are used to capture a variety of events from the life of man. Photogrammetric images, however, serve to surveying purposes. [2]

Since its emergence to the present day the photogrammetry has undergone various stages of development, which reflected the knowledge of its time. Currently, digital technologies are mainly used, which greatly accelerate the entire process of collecting, processing and subsequent evaluation of photogrammetric images.

Single-image photogrammetry is a type of photogrammetry, when only a single photogrammetric image enters into the process and after performing its evaluation plane coordinates of the captured object are obtained. At present, the single-image photogrammetry is applied in archaeology, architecture and civil engineering, but also in surveying profiles, verticality and straightness of vertical mine workings. [2]

2 PROJECT OF INDUSTRIAL UTILIZATION OF SINGLE-IMAGE PHOTOGRAMMETRY

Photogrammetry is a non-contact surveying method, increasingly used not only in geodesy. Using it we are able very quickly to record a current condition and size of a captured object. Therefore an idea arose to use this method for diagnostic measurements of rotary kilns, when it is necessary to work under the full kiln operation.

Considering all the technical conditions, the decision was made to use the single-image photogrammetry. The rotary kiln design does not enable to locate two cameras so that two images of the same object are taken at a moment.

The rotary kiln can be described as a long rotating tube with a diameter of about 4 meters and inclination of about 2% (Fig. 1). Through the length of 75 metres a special material for production of cement or other loose materials are gradually mixed and dried or kilned. Due to it the kiln temperature may be even 400˚C, which embarrasses diagnostic measurements. The whole equipment rotates at about 5 revolutions per minute, and therefore a suitable method is searched that is relatively precise and safe and capable to capture the object condition at a given moment.

Fig. 1 Rotary kiln for cement production

2.1 Theoretical preparation

In order to enable the use of an ordinary digital camera (non-surveying one) for photogrammetry purposes, it must be calibrated. The calibration is essential to determine constructional and technical features of the camera, without which it would be impossible to make any evaluation.

The calibration was performed on a school test flat field using the PhotoModeler 4 program. This program allows to create a custom calibration field and perform a manual calibration.

It was also necessary to provide additional equipment needful to accomplish measurements. These were a reduction pad that lets camera to be mounted on a tripod, holders and targets, thanks to which a scale is inserted into image, marking spray resistant to very high surface temperatures, halogen lamp and finally tripods, fixing the holder of targets and halogen lamp.

The entire theoretical preparation was conducted on the basis of a visit to a cement mill. However, measurements were carried out in another manufacturing plant. So the rotary kiln differed in some constructional details, which slightly affected the whole course of measurements.

2.2 Workflow

Conditions, under which the imaging was carried out, were very difficult. The kiln rotated on its own axis at 5 revolutions per minute, which is 12 seconds per revolution. Due to the uneven distribution of content the kiln shook at irregular intervals, causing vibrations of both the concrete pillars, on which the kiln is located, and also handling platforms around the kiln itself. Another factor that negatively affected the workflow was the temperature of the kiln shell, which affected to a great extent the air circulation in the given area.

This was followed by choosing the most suitable types of aids. It was necessary to determine, which of the possible reflective tape targets best reacts to the camera flash. After the practical test under these conditions the Leica reflective tape targets were selected (in Fig. 2 the two in the middle).

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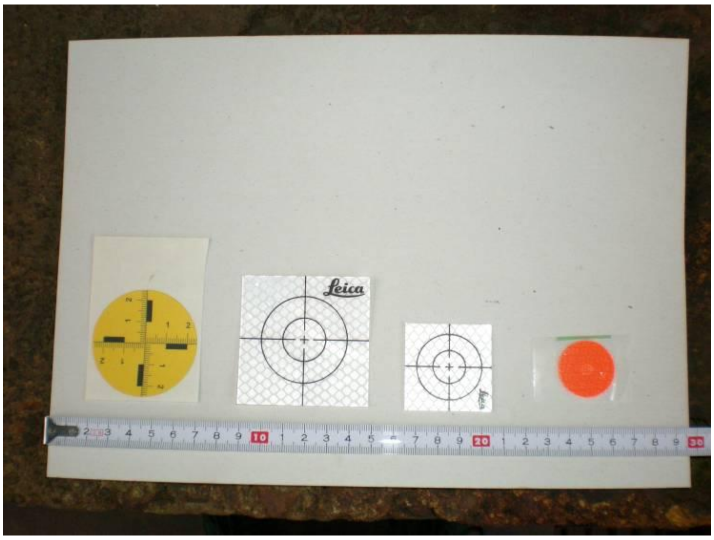

Fig. 2 Test of tape target

The following parts and characteristics of the rotary kiln should be measured in a photogrammetry way:

Diametrical clearance between the bearing ring and kiln shell, tooth clearance between the ring gear and pinion and clearance between stop-blocks on the shell.

1. Diametrical clearance – is determined indirectly by recalculation. The kiln shell fits close to the bearing ring (Fig. 3), which provides rolling the kiln. The bearing ring is made of more resistant material and less react to temperature changes of the kiln content than its shell. Due to these changes the kiln shell expands or contracts. Regarding the different lengths of their perimeters they have different peripheral velocity. The bearing ring can choke or release the shell. Neither of these conditions is ideal for the rotary kiln operation. So the aim was to determine the difference in the distances of the point marked on the bearing ring and the kiln shell and then calculate the difference between the highest point of bearing ring and the highest point of kiln shell.

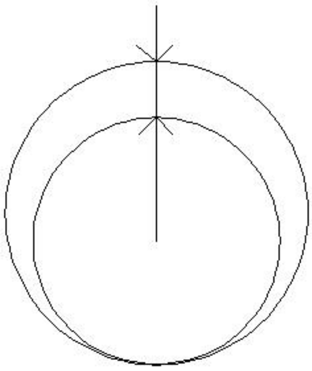

Fig. 3 Diametrical clearance

First, it was necessary to set up the tripod for the camera and the tripod with reflective tape targets. Then it was necessary to indicate the point on the bearing ring and on the kiln shell that will be imaging. The line that should be used for the evaluation must be thin and clear. The test of an ordinary school chalk showed that this indication method is not appropriate. The resulting line was to vague and duplicated deposits of waste grease on the bearing ring. Therefore the white and silver sprays were selected (Fig. 4). The formed lines were clearly visible, however, their contours were not clearly defined.

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Fig. 4 Test of spray visibility

Based on the theoretical preparation the sequence of activities before measurements should be as follows: To form a visible and, if possible, direct line using a marking spray at the bottom of the bearing ring and kiln shell, where both parts fit the most. The initial condition of the formed line should be captured by the camera. Then an image of the formed line was taken after 5 and then after 10 revolutions of the bearing ring. In the resulting pictures then the original line would be clear, which due to uneven rotation of the bearing ring and kiln shell split into two. Among the images of „0-phase“, „5-phase“ and „10-phase“ should be also a visible trend of different rotation of these parts.

However, the practical surveying part did not run according to the above theoretical template. Using the camera flash a short time was achieved during which the image originated. The line, which should be then evaluated, was not blurred, but the reflective tape targets which brought the scale into the photogrammetric image, were overexposed. Therefore, various combinations of camera settings, use of flash and halogen lamp were used. First, it was necessary to set up the tripod for the camera and the tripod with reflective tape targets. Then it was necessary to indicate the point on the bearing ring and on the kiln shell that will be imaging. The line that should be used for the evaluation must be thin and clear. The test of an ordinary school chalk showed that this indication method is not appropriate. The resulting line was to vague and duplicated deposits of waste grease on the bearing ring. Therefore, various combinations of camera settings, use of flash and halogen lamp were used.

Fig. 5 Illustration of image used for calculation of diametrical clearance

2. Tooth clearance – changes during the kiln rotation (the eccentricity of ring gear is caused by the eccentricity of kiln shell at a given point). It is therefore necessary to know, at what turn phase the ring gear is. The ring gear and pinion induce the rotation of the entire kiln on its axis.

A special spray was bought to indicate the turn phase on the gear wheel and pinion. The imaging was to be performed according to the same pattern as the imaging for the evaluation of diametrical clearance. Both mechanical parts are covered with a thick layer of grease, which prevents their marking. During imaging it was necessary more than ever before to take into account a time delay of image occurrence. All the more was hindered by the fact that the kiln gear teeth were accessible only through a small hole, not allowing to see the turn phase of gear wheel or pinion.

Fig. 6 Gear wheel and pinion

Fig. 7 Highlighted gearwheels

3. Clearance between the bearing ring and stop-blocks - on the kiln shell "stops" are welded, defining the bearing ring movements. A frequent phenomenon is an axial run-out of the bearing ring, which reveals itself as an unequal clearance between the stop-blocks and the bearing ring during a revolution.

The camera was again attached to a tripod and a reflective tape target was attached to a magnetic stand on a protective structure at the bottom of the bearing ring.

During the imaging the flash was used without extra lightening. This enables to see the centre of the reflective tape target, while the parts being imaged remained unlit.

Fig. 8 Bearing ring with a stop-block

3 EVALUATION

During imaging the distances between the camera and the reflective tape target and between the reflective target and the imaged object were measured by a tape measure. To check it the total distance was measured between the camera and the object.

The evaluation was gradually tested using three programs, which were Topol 3.002, MicroStation SE/V8, PhotoModeler Pro5. Neither of these programs were able to fully provide an evaluation function of generated images. Unexpected complications arose already while uploading the images and finding a suitable evaluation method. Moreover, it was necessary to recalculate the image divergence. This step is induced by that the reflective tape target = scale was not in the same plane as the imaged object, but in front of it. It was therefore necessary to measure also the distances between the camera and the reflective tape target and the object. The evaluation thus becomes time-consuming and non-effective.

4 CONCLUSIONS

The use of photogrammetry to determine the diametrical clearance, tooth clearance and clearance between the bearing ring and stop-blocks would be very practical and elegant under conditions, when all parts are in motion. Photogrammetry would be the most appropriate, as it captures the state at a given moment. If a more suitable and especially accurate evaluation method is found than the one used, this photogrammetric method would be very fast and effective. To obtain images, it takes a relatively short time, the operation of equipment need not be limited and the work can be done by one person only.

The only problem, persisting from the beginning, was the need to measure the time of a revolution to take a photo at a given moment. Watching the revolution phase using a stop-watch and taking photos early enough is very difficult. The only acceptable variant, excluding the fallible/slow human factor, is a high-quality camera. It would allow to generate more images per second and select the most appropriate image to be processed.

REFERENCES

[1] http://www.vugtk.cz/slovnik/3867_fotogrammetrie

[2] http://igdm.vsb.cz/ Sylaby- Fotogrammetrie

RESUMÉ

Fotogrammetrie je bezkontaktní měřickou metodou, která si stále více hledá své místo nejen v geodézii. Proto vznikla myšlenka využít tuto metodu při diagnostických měřeních rotačních pecí. Vzhledem k tomu, že tato měření probíhají za plného provozu pece, byla by to velmi elegantní a hlavně bezpečná měřická metoda.

Rotační pec je v podstatě dlouhé otáčející se potrubí, které má v průměru cca 4 metry a sklon cca 2%. Na délce 75 metrů se uvnitř postupně mísí a vysouší nebo vypaluje speciální materiál pro výrobu cementu nebo jiných sypkých hmot. Díky tomu má povrch pece i 400˚C, což velmi znesnadňuje diagnostické měření. Celé toto

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rotující zařízení se otáčí rychlostí kolem 5 otáček za minutu a proto se hledá vhodná metoda, která by byla relativně přesná a bezpečná.

Použití fotogrammetrie při určování diametrální vůle, zubové vůle a vůle mezi nosným kruhem a stop-bloky by bylo velmi praktické a elegantní, protože jsou všechny tyto části v pohybu. Fotogrammetrie by byla nejvhodnější, protože zachytí stav v daném okamžiku. Pokud by se našel vhodnější a hlavně přesný způsob vyhodnocování, než který byl použit, byla by tato metoda velmi rychlá a efektní. Pro získání fotografií stačí relativně málo času, není omezen provoz zařízení a práci může vykonávat jeden člověk.

Jediný problém, který od začátku přetrvával, bylo měření času otáčky pro vytvoření fotografie v daném okamžiku. Hlídání fáze otáčky na stopkách a focení s dostatečným předstihem je pro jednoho člověka náročnější. Jedinou přijatelnou variantou, ze které by se vyloučil omylný/pomalý lidský faktor, je kvalitní fotoaparát. Díky němu by bylo možné vytvořit více snímků za 1s času, což by umožnilo si vybrat nejvhodnější snímek pro zpracování.

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