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The use of optical scanning for analysis of casting shape

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Abstract

In the paper the use of optical scanning for inspection of casting shape and its accuracy was described. Optical system applied to digitization of objects determines all dimensions and shape of inspected object. This technology is used in quality control and reverse engineering. System is based on triangulation: sensor head performs projection of different patterns of fringes onto measured object and scanner tracks their distribution with two cameras. Basing on optical transform equations, a processing unit automatically and with remarkable accuracy calculates 3D coordinates for every pixel of camera. Depending on camera resolution the result of such a scan is a cloud of points with up to 5 million points for every image. In the paper examples of applications for castings with different designation was presented.

Keywords: Application of Information Technology to the Foundry Industry, Quality Management, Non-Destructive Testing

1. Introduction

Coordinate measuring technique in its assumptions is different from traditional metrology making measurements of three dimensional object much more effective. Its result is first of all shorter time of measurement, while keeping high quality and precision. Intensive development of computer science opened new computation possibilities for coordinate measuring technique. Fast programming options give a great deal of flexibility and thus it can be used for both: single workpiece inspection as well as batch production. Measurement is based on determination of workpiece position in coordinate system and its description by means of set of coordinates. After collecting data in any position computation software transforms obtained information into geometrical elements in coordinate system, composing on their base the whole inspected workpiece. Contemporary coordinate metrology can be practically executed as tactile or optical one, as well as combination of both these techniques.

2. Optical scanning

Optical scanning is based on photogrammetry, a method of obtaining data about shape and location of object from one or many images. Photogrammetric methods can be used to all applications where it is possible to take pictures of an object. In length metrology it is based on measurement of characteristic elements unambiguously coded on an object. In most cases they are either special markers or points, lines or fringes projected on object by a projector. First attempts to use photogrammetry in measurements come from middle of XIX century and were made by Laussedat, while first camera from that period was constructed by Meydenbauer and used to reconstruct buildings [1]. In 80-ties of XX century industrial application of photogrammetry became more common. Development of computer techniques enabled connecting images and building relations between them. A direct consequence of that was construction of optical scanner using projection of fringes.

Principal rule of photogrammetry is based on optical setup with a pinhole (fig. 1).

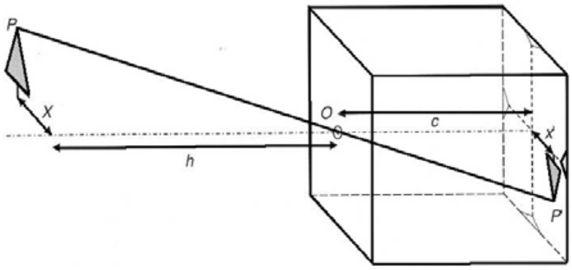

Fig. 1. Optical setup with a pinhole

Theoretically (ideal setup) center of projection is a point, common element for all rays, which are straight lines. In real devices there is a lens in center point while projection surfaces of images are not ideal planes. Besides an angle between these surfaces and optical axis is only very close to straight.

Measurement of geometrical relations between points collected from surfaces is performed by means of triangulation. It is a method utilizing triangles and their properties. Two ways of triangulation are used: active and passive. In active triangulation after projection of points onto the surface their network is detected by a line or area detector, what finally leads to information about object points. Locations of projector and detector are required (fig. 2).

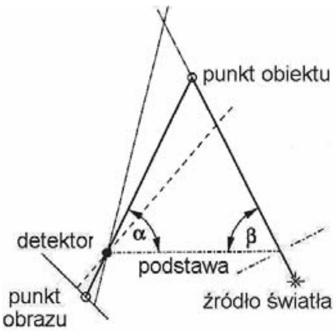

Fig. 2. Active triangulation

In passive triangulation (fig. 3) there are two detectors with known mutual location. Information about a point is written by both detectors what makes it possible to localize an object. Triangulation can take place between a camera and a projector as well as between two cameras. In the first case fidelity of data is biased by negative influence of temperature and there are 3 observations for 3 unknown data, so there are no redundant data, what is a negative issue, as it is impossible to eliminate potentially wrong data. Thus, quality of obtained measurement data is questionable. When triangulation between two cameras is considered, influence of temperature is eliminated, and for 3 unknown data there are 4 observations (positive redundancy of data). That is the most proper way to obtain good measurement data with very high fidelity.

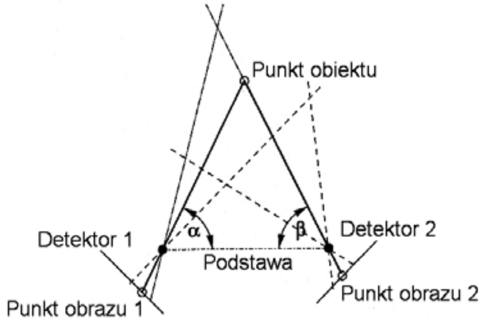

Fig. 3. Passive triangulation

A vital part of data collection process is also projection of fringes onto a measured surface (fig. 4). Coding of fringes means that identical points have identical coding in cameras. Coding of light is performed basing on phase shifting or Gray code [2].

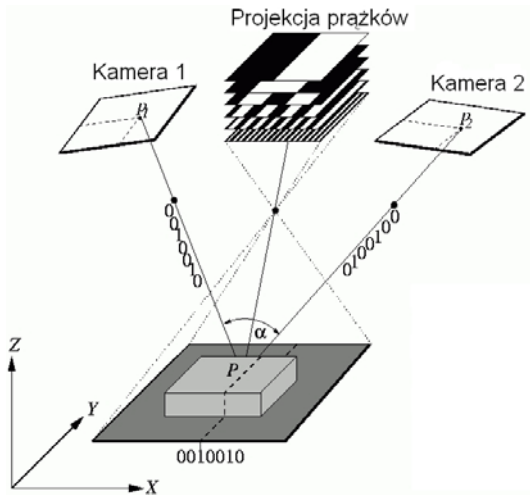

Fig. 4. Projection of fringes

101	123	149	232	230
81	88	225	180	182
144	227	177	162	95
211	185	164	99	45
202	173	92	42	35

Fig. 5. A detail of workpiece in gray scale

When the image is obtained its transformation takes place. In 8-bit system an image is divided into 256 shades of gray, which are connected with every pixel of an image respectively. Practically, it means that to every shade of gray a number meaning brightness is assigned, where low value means dark shade while high value stands for light ones (fig. 5). Shade of gray scale changes with every pixel, and a number from that scale can be presented in a function of pixels formed in a line. Because while scanning it is necessary to precisely determine edges, a question arises, where between white and black a border of material is located. Computation algorithms determine it where gray scale gradient is the highest, i.e. where transition curve is the most steep.

3. Inspection of workpieces

In measurements optical scanner ATOS was used, which is based on the use of two cameras and projection of fringes according to Gray code. This scanner enables for measurement of the whole workpiece. That technology is widely used in car industry, in reverse engineering and applications connected with quality analysis and control (first part inspection, assembly, manufacturing and optimization of tools, monitoring production, inspection of suppliers). Main merits of that measuring technique are:
- scanning and visualization of the whole workpiece in 3D and its comparison with CAD data,
- fast measuring process comparing with traditional measurement systems with touch probe, e.g. tactile coordinate measuring machines,
- high resolution and accuracy, often surpassing requirements for particular applications,
- mobility of systems enabling for measurements in different locations and places.

The use of such methods will further increase in the future with decrease of manufacturing time, development of production and decrease of feedback loop in its monitoring.

ATOS is based on triangulation [3]: sensor head makes projection of different patterns of fringes onto inspected object and scanner observes their run with two cameras. Basing on optical transform equations, processing unit automatically and with high accuracy calculates 3D coordinates for every pixel of camera. Depending on camera resolution a result of such a scan is a cloud of points with up to 5 million of points for every single image [4].

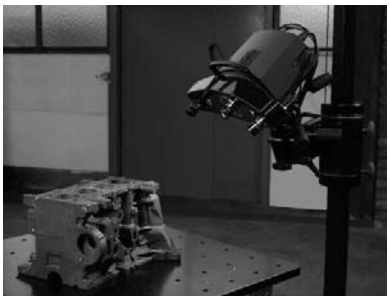

Fig. 6. ATOS at work

Geometrical configuration of the system and parameters of distortion of lenses are calibrated by means of photogrammetrical method. During measurements a user can position a measuring head on a stand in front of a measured object with no necessity to use additional workpiece mounting technology (fig. 6). Markers located on a workpiece or in its surrounding are used as reference points.

Analysis and inspection of workpieces by means of ATOS ensures a significant potential for optimization of products and production procedures. Workpieces are scanned and obtained data are laid over a CAD model. Fitting is based on characteristic points, as bores, long bores, areas or points on edges with specifications included in RPS system. These specifications are taken either from a drawing or directly from a CAD file. After fitting deviations are calculated regarding all single measurement points in reference to nominal shape. As density of the collected points is very high, deviations can be visualized as color plot. Such a representation allows for a fast and accurate analysis of an object. Color plot of deviations is particularly useful for analysis of workpiece during its trial phase, first part inspection and measurements during production, as well as to verify process.

4. Examples of casting measurements

Optical measurement scanner is used for analysis of castings and casting processes. It can be also used for statistical quality control of sand cores [5] and to verify wear conditions regarding foundry tools (chills and boxes) by means of comparison of actual shape with CAD model. Basing on detected deviations from nominal dimensions it is possible to correct tools to obtain their proper shapes after repair corresponding to nominal values and thus allowing production of workpieces according to drawings and specifications. Scanning of reflective surfaces (metallic, ground, polished etc.) requires their initial preparation to get appropriate and not distorted signal. To do this optical system is appropriately adapted, or surface is coated with sprayed chalk powder what significantly reduces or even eliminates all the glosses.

One of the most common application of ATOS in car industry is quality control of car engine block castings. The image of scanned truck engine block was shown on figure 7.

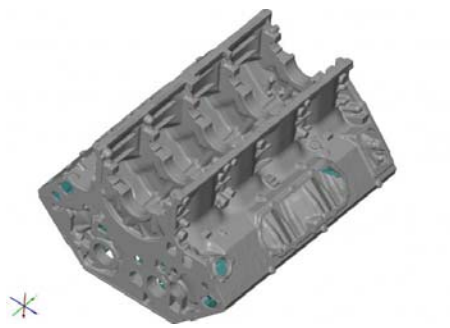

Fig. 7. Scanned truck engine

Number of points obtained during that measurement allows to create a color plot and meaningful visualization of deviations. Negative deviations (real points below nominal data) are marked with blue color, the bigger is deviation the darker gets the shade. In contrary, positive deviations (real points above nominal data) are marked with green, yellow, and finally red colors, each of them with a number of shades. This visualization enables an operator to concentrate only on the greatest deviations, that are the most important and clearly seen, where the biggest risk of reject takes place. It is also a very user friendly way of description being time saving in industrial environment particularly comparing with tactile coordinate measurements.

Further examples concern machine elements. It is than a good tool to inspect all kinds of casings. An example of this is shown on the following drawing (fig. 8), where water pump casing is presented.

Fig. 8. Water pump casing scan

Also in this case a color plot of deviations makes quality control of workpieces fast and effective. The use of optical scanner in foundry shows that way its great helpfulness. With short measurement time that together with presentation of results for even very complex parts reaches less than an hour it is a useful tool in quality control. Short time of measurement is particularly important in batch production, because it enables for a fast reaction when any discrepancy occurs and - as a result of that - it strongly influences on quality of manufactured goods reducing number of rejected workpieces and risk of sending a faulty element to a customer.

Another application is manufacturing big castings basing on their miniature models. An example of miniature created by a sculptor was shown on figure 9.

Fig. 9. A scanned model and real workpiece

Basing on that measurement points were collected and than a magnified image of workpiece was generated. Data obtained that way served to create die to make a casting of a monument.

5. Conclusions

Optical digitization by means of ATOS measuring system is a part of an advanced production cycle in development of workpieces and manufacturing processes of many different elements. Already now it enables for shortening a measurement time, reduction of costs and quality amendment, increasing competitiveness of a manufacturer. In the future that technology will be used more and more often to automated inspection tasks thanks to further integration in manufacturing process and availability of very powerful data processing system. An important application already now is measurement of small workpieces made from different materials, where such an optical system - with certain accuracy - enables to measure and check in a more complex way than e.g. a coordinate measuring machine. Naturally, a range of application of 3D optical scanner is immense and goes far beyond mechanical engineering, comprising even so distant scopes of industry as designing furniture [6, 7] or analysis of historical objects [8].

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Wykorzystanie skanowania optycznego do analizy kształtu odlewów

Streszczenie

W artykule opisano wykorzystanie skanowania optycznego do kontroli dokładności wykonania odlewów. System optyczny stosowany do digitalizacji obiektów określa wszystkie wymiary i kształt badanego przedmiotu. Technologia ta wykorzystywana jest w kontroli jakości i w inżynierii odwrotnej. System bazuje na zasadzie triangulacji: głowica sensora dokonuje projekcji różnych układów prążków na obiekt mierzony a skaner obserwuje ich przebieg dwoma kamerami. Opierając się na równaniach transformacji optycznej, jednostka przetwarzająca automatycznie i z dużą dokładnością oblicza współrzędne 3D dla każdego piksela kamery. Zależnie od rozdzielczości kamery, wynikiem takiego skanu jest chmura do 4 milionów punktów dla każdego pojedynczego pomiaru. W artykule pokazano przykładowe zastosowanie skanera optycznego do pomiarów odlewów o różnym przeznaczeniu.