Electronic Engineering and Informatics
G. Izat Rashed (Ed.)

doi:10.3233/ATDE240111

Based on the Analysis of Influence of Large Forgings Three Dimensional Size Research of Non-Contact Measurement Method

Jiangping CAO[a], Kaiqiang XIE[a1], Meng ZHAO[a], Jing LIU[a], Mengzhi SUN[a], Yuhui HAO[a], Tao JIANG[b], Shengli YUAN[c]
[a]*National Institute of Measurement and Testing Technology, Chengdu 610056, China;*
[b]*Erzhong (Deyang) Heavy Equipment Co., Ltd. Deyang, China*
[c]*Chengdu jiujin technology co., LTD, Chengdu, China*

Abstract. To meet the practical application requirements of in-situ measurement methods and technologies for large forgings in China, two types of non-contact measurement methods are studied in this paper, including laser scanning measurement and structured light measurement. Based on the measurement principles of the two methods, the corresponding measurement system prototypes are designed. The feasibility of the two types of non-contact measuring systems designed is verified in the measurement experiments of large forgings, and the measurement differences between the two types of methods are compared according to the test results. The results show that the two methods meet the accuracy requirements of three-dimensional dimension measurement of large forgings, and the overall difference of measurement accuracy between the two methods is small. It is necessary to refer to other performance requirements for selection in practical application.

Keyword. Dammann grating; Parallel recombination simulated annealing algorithm; Adaptive light source; Industrial measurement

1. Introduction

High temperature forging is steel rolling equipment, hydropower, nuclear power units and other heavy equipment core components are the main mode of production. Large forgings production level is to measure a country the basic symbol of the levels of mechanical manufacturing [1]. Hot forging cannot directly contact measurement, in most cases is to use other indirect comparison way to calculate the size. Eventually caused by measuring accuracy limit waste material is 5% ~ 10%. High precision non-contact measuring way has very realistic significance for promoting the manufacturing industry. At home and abroad in recent years, the study of the solution also only stay in simple artifacts, single parameter detection. Due to the influence of site conditions at the same time, it is not suitable for large forgings hot mature technology and practicability in measurement device[2].Some products abroad also has great limitations on use, plus the

[1] Corresponding author: Kaiqiang XIE, National Institute of Measurement and Testing Technology, e-mail: jiangping@my.swjtu.edu.cn

introduction of the expensive and technical barriers, cannot be applied to domestic manufacturing of large forgings. Laser scanning technology and structure light measurement technology for large size three-dimensional topography measurement of two kinds of key technologies, is currently the most appropriate tests of large high temperature forging application requirements. Laser scanning measurement by laser beam sweep measured target to get the size of the object to be tested measurement [3].Its basic working principle is through the laser emission interval shaping laser pulse, swing Angle control point to measure target, by scanning and receive target return to the surface of the laser echo signal is point cloud coordinates calculating [4].Structure light measurement technology is a kind of non-contact computer vision technique, the working principle of this technology is composed of laser array structure light projection device in lattice or network generated on the object to be tested, lattice or network on the object being measured modulation distortion, recanalization of lattice in the image coordinates of digital modeling and cross section analysis to obtain the required forgings dimension data [5].

Above all, laser scanning and the structure light measurement is to realize the high temperature forging size of 3 d non-contact measuring method for two kinds of mainstream. This article is based on two kinds of measuring principle, respectively, the technical implementation, according to the corresponding technical difficulties in study and design the prototype measurement system. For comparing the difference between the two methods of measuring performance, the high temperature forging is measured at the same time using two methods, through comparing the measured data, provide a reference for the selection of measurement method in practical application.

2. Laser Scanning Measuring Mechanism Analysis

2.1 The basic working principle

The basic principle of laser scanning measuring optical module for launch laser to the surface of measured target, after receiving optical module to collect the information returned by the photoelectric detector receives, target is obtained through signal processing and data acquisition of information. The laser scanning measuring the basic steps are as follows:

(1) light source emission laser shaping pulse interval, such as swing Angle by scanning device to measure the goal;

(2) laser signal meet target surface return becomes the laser echo signal, and collected by the receiving optical system to the photoelectric receiving module;

(3) the laser echo signal by photoelectric conversion and weak signal detection circuit, calculate the moment of the laser echo signal and the signal strength;

(4) information transfer laser pointing Angle scanning agencies;

(5) the laser echo signal and point to point cloud coordinates calculating Angle information.

2.2 The key parameters are calculated

Laser energy, power, and the calculation of optical parameters such as effective receiving caliber is the premise to realize laser scanning measurement. Echo received power formula is as follows:

$$P_r = \frac{P_s K_s K_r A_s A_r \rho T^2}{\pi^2 R^4 \theta_t^2 \sin^2(\theta_s / 4)} F_s F_r \quad (1)$$

With Ps As the laser power, θt for laser divergence Angle, Ks system for launch transmittance, Kr for receiving system transmittance, T for one-way atmospheric transmittance, ρ for target reflection coefficient, As for the target effective reflection area, Ar is receiving aperture size, θs for the reflected light divergence Angle, the Fs laser beam intensity distribution function for launch, Fr for receiving light intensity distribution function, R for target distance.

High temperature forging take 10 m and 50 m distance measuring range, calculation of laser beam divergence Angle is 0.3 mrad, pulse repetition frequency is 100 KHZ, receiving caliber Dr To 50 mm.

2.3 measure implementation

Laser scanning measuring system adopts modular design, mainly by the laser, launch receiving light path, scanning structure, photoelectric receiving module, time interval measurement module, laser returned intensity measurement module, data acquisition module, etc.

Considering the form of laser wavelength, pulse, pulse energy, pulse repetition frequency, size limit factors, such as light source adopts 1550 nm narrow pulse width fiber laser. The laser receiving optical path design goal is to achieve efficient laser signal received at the same time try to reduce the interference of background light, receiving light path design is shown in figure 1.

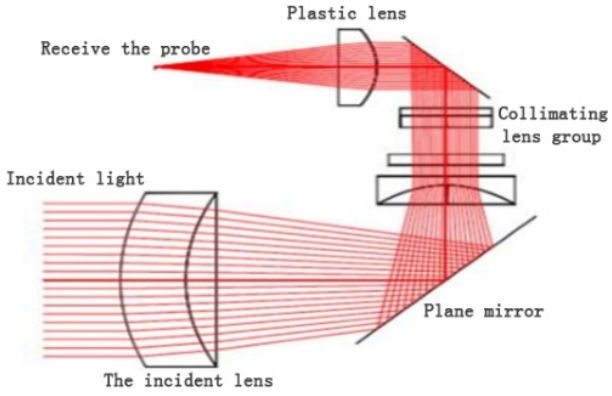


Figure 1. Receiving light path

Scanning mechanism is composed of scanning mirror and optical precision motors, received by scan mirror laser echo signal, and passed to the laser signal receiving light path, optical precision motor drive in accordance with the program scan mirror change point laser [6].

Choose the SCADA system for the overall control, emission control, receiving control, receiving signal processing and photoelectric signal measuring, environmental control, data storage, clock synchronization, command and control system.

3. Structure Light Measurement Mechanism Analysis

3.1 The basic working principle

Structured light projector with laser as light source, laser after divergent lens hole formed by grating planar lattice onto forgings, forming different forming round or oval spot. Based on shanmugaratnam diffraction grating design theory, combined with genetic algorithm and simulated annealing algorithm is the parallel combination of simulated annealing algorithm to optimize the grating equation. The algorithm to learn from the intrinsic parallelism of genetic algorithm, the parallel simulated annealing searching from many initial points, and integrated into the group and the concept of genetic operators of genetic algorithm, make it become a highly efficient global optimization algorithm.

In practical industrial applications, the projected pattern compared with surface under test through low or the image will cause the projection feature point is difficult to measure. In order to solve this problem, this paper selects the power for 100 mw, 532 nm wavelength green laser, designed the emission intensity of automatic adjustment ability of adaptive lighting system. Adaptive lighting system by real time image contrast, real-time adjust the laser power emission intensity to ensure the project design and surface under test contrast is always in a reasonable range. Image preprocessing to get contrast step as shown in figure 2.

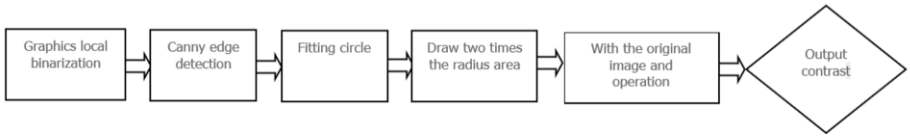
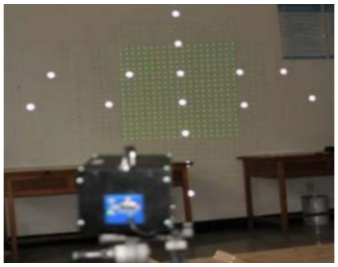
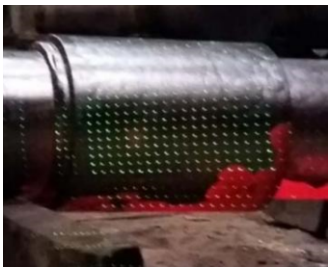


Figure 2. Image preprocessing

The output power of the laser in the light source system varies linearly with the voltage. The upper computer sends the control signal to the MCU according to the real-time contrast data, converts it into digital signal and sends it to the D/A conversion chip to generate the output power to adjust the TTL signal. The final projected pattern effect of the projector is shown in Figure 3.



(a)lattice structure light projection effect



(b) Workpiece surface contrast results

Figure 3. Projection pattern

3.2 Three-camera photogrammetric system

The three-camera camera system is mainly composed of a high-resolution digital camera and its fixed bracket, image acquisition accessories and measurement software. Three

professional-grade industrial cameras are fixed on the stand, the cameras are controlled to shoot images synchronously, and the 3D coordinates of the feature points in the images are obtained through data processing. In terms of hardware configuration, the three cameras all use the German industrial camera SVS11002, and the lens uses Nikon 24mm prime lens.

Three camera system internal parameters by free to move in multiple locations calibration of three-dimensional control point set, taking photographs for more than three camera calibration plate image to build structure light field of photogrammetry structure parameters calibration, finally the calibration algorithm is used to calculate the structural parameters of the precise value [7-9].For internal and external camera parameters calibration is not accurate, and other reasons caused by the nuclear line not strictly by the condition of the same name as, for like a point on the photo 2, nuclear line for a given distance range selection on photo 1 potential as some of the same name. A nuclear equation for:

$$k_1 x - k_2 y - cf = 0 \tag{2}$$

The potential of the same name as the point to the nuclear line:

$$\frac{\left|k_1 x - k_2 y - cf\right|}{\sqrt{k_1{}^2 + k_2{}^2}} < \varepsilon \tag{3}$$

On photo 1 can be obtained p' with the method of potential of the same name as on photo 3 points. In the process of exact match set a distance threshold ε', Choose the potential of the same name from different image point are combined, if the distance between two points is less than the threshold ε',Will the two same name like points and the points on the photo 1 p' as a potential image point with the same group.Potential as two two points in the group with the same combination, through the collinear equation can be calculated three object space point coordinates, OP12, OP13, OP23.OP12 is photo 1 and 2 photos of the same name as forward intersection of object space points and the remaining two points and so on. Actually get three party may not be for the same points, but through two two parties the distance between the point of maximum the MaxD to describe the aggregation degree between the three. In order to ensure the correctness of the match to the secondary.

3.3 Coordinate measuring

After complete corresponding points matching coordinates, three camera coordinate measuring may be regarded as a combination of two cameras binocular vision measurement model [10, 11].On camera in the system of two combinations, three calculating to get the coordinates of the binocular measurement system for the Pi (Xi, Yi, Zi), I = 1, 2, 3.Party set content for the real coordinates of point P (X, Y, Z), as a result of solving three coordinates and the actual object space coordinates are not overlap, by optimizing solution, to meet the objective function is shown in the following type:

$$F = \min(\|P - P_1\| + \|P - P_2\| + \|P - P_3\|) \tag{4}$$

Will take place on type are:

$$\begin{aligned} F = &\min\left[(X - X_1)^2 + (X - X_2)^2 + (X - X_3)^2\right] \\ &+ \min\left[(Y - Y_1)^2 + (Y - Y_2)^2 + (Y - Y_3)^2\right] \\ &+ \min\left[(Z - Z_1)^2 + (Z - Z_2)^2 + (Z - Z_3)^2\right] \end{aligned} \tag{5}$$

Parties point coordinates can be represented as:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{1}{3}\begin{bmatrix} X_1 + X_2 + X_3 \\ Y_1 + Y_2 + Y_3 \\ Z_1 + Z_2 + Z_3 \end{bmatrix} \tag{6}$$

4. The Experimental Contrast

In order to compare the differences of two measuring methods, at the same time using two kinds of measurement system for large forgings for measurement, and according to the calculating results of contrast analysis of the performance measurement. Large forgings measurement field is shown in figure 4. Laser scanning system and the structure light measurement system for forging surface point cloud data is shown in figure 5.

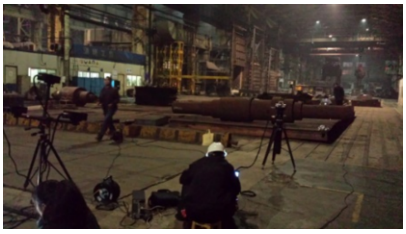
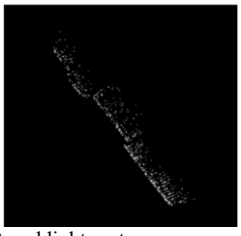
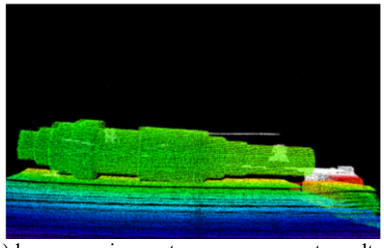


Figure 4. Large forgings dimension measurement field



(a)structured light system measurement results



(b) laser scanning system measurement results

Figure 5. Large forgings surface point cloud

In order to compare the two methods of measuring level difference, based on point cloud data, respectively, the diameter of the misalignment of calculating forging size. Forging the shaft diameter is measured with a laser tracker for reference. Comparing the results as shown in tables 1, 2.

Table 1. Laser tracker and comparison of structure light measurement (mm)

The serial number	Structured light system	Laser tracker	deviation
Shaft section1	493.09	491.64	1.45
Shaft section2	880.02	877.70	2.32
Shaft section3	961.99	963.20	1.21
Shaft section4	460.80	458.32	2.48

Table 2. Laser tracker and laser scanning system to measure contrast (mm)

The serial number	The laser scanning system	Laser tracker	deviation
Shaft section1	492.26	491.64	0.62
Shaft section2	875.43	877.70	2.27
Shaft section3	965.91	963.20	2.71
Shaft section4	460.64	458.32	2.32

Comparison results show that the structure light measurement system of the maximum error of measurement is 2.48 mm, the average measurement error is 1.865 mm. Maximum error of measurement and laser scanning measuring 2.71 mm, the average measurement error is 1.98 mm. Measurement data by comparison of the two, both the level of measurement precision can satisfy the requirements of large forgings measures of relevant indicators, the precision of laser scanning measurement is slightly less than a structure light measurement, but overall accuracy of measurement was no significant difference [12]. In the practical application of the applicability of the laser scanning measurement, can be applied to objects of different shapes, sizes and materials, and a large amount of data can be obtained in a short period of time. Structure light measurement equipment prices are relatively low, the operation is relatively simple, but the application of environmental requirements higher, although in this paper, the design of adaptive environment light source system, additional calibration operation will to some extent influence the efficiency of detection.

5. The Conclusion

Laser scanning with structured light measurement is suitable for two kinds of large forgings three-dimensional measurement way of two kinds of non-contact measurement [13].Based on these two basic measuring principle, this paper researches on the related technology, and in view of the measuring system is the key technical problems in the design of structure puts forward the corresponding solutions. After the complete measuring system is set up by these two methods is verified by the experiments in the large forging, the feasibility of measuring field. According to the experimental results comparing the two measuring the level of performance at the same time, to verify the difference on the measuring accuracy of the small. Need in practice according to the measuring efficiency and environment, such as cost, and the size of the data volume and the actual demand to choose the appropriate measurement method.

PROJECT FUNDING

Sichuan province regional innovation cooperation projects(2022YFQ0084)

REFERENCE

[1] Shao-min Nie, shu-kui li. Large forgings hot online measurement research were reviewed [J], Metal processing: hot working,2008(11) : 22-25. DOI: CNKI: SUN: JXRG. 0.2008-11-011

[2] Zheng Chen, mechanisms influence. Based on photogrammetry in high temperature forging at elevated temperature detection technology research [D], Zhengzhou: information engineering university, 2012.

[3] Tongqun Ren, Based on laser vision of rapid measurement of three dimensional shape [D], Tianjin: tianjin university, 2005.

[4] Jiangping Cao, Zhen Yu, Analysis of online 2D laser displacement Sensor influenced by environmental changes [J]. MEIM2022, Proc. of SPIE Vol. 1260 126000X-1-126000X-5.

[5] Zheng Chen, gui-ping huang, Feng Xin. Three camera structure light photogrammetry in artificial logo image point automatic matching with the same method [J], Surveying and mapping engineering,2013, 22(01): 28-30+34. DOI:10.3969/j.issn.1006-7949.2013.01.008

[6] Jiangping Cao, Yunchang Zhang, Research on lightweight design of metal structure based on ANSYS [J]. CAMMIC 2022,1225963 (17 May 2022); 63.1-63.

[7] Gui-ping Huang, High temperature forging size photogrammetric system external parameters calibrationmethod[J],Journal of surveying and mapping science and technology,2013, 30(03): 260-263. DOI: 10.3969/j.issn.1673-6338. 2013.03.010

[8] Jiangping Cao, Gang Li, C shape and high precision measurement method research,The Chinese test,2022 1) supplement, 29-32.

[9] C.S.Fraser. Design and implementation of a computational processing system for off-line digital close-range photogrammetry. ISPRS journal of photogrammetry & remote sensing.2000.55(2):94-104

[10] Graham L C. "Synthetic interferometric radar for topographic mapping". Proc. IEEE[J]. 1974. 62(6)

[11] Honghong Lu, Ming Yin, Luofeng Xie, et al. Research on 3D reconstruction technology of blade based on surface structured light[J]. Chian Measurement and Test, 2019, 45(2):134-138.

[12] Long Guo, Jun Ma, Ming Li, et al. Non-contact measurement of ice shape in icing wind tunnel based on 3D scanning technology[J]. Chian Measurement and Test,2018, 44)9): 18-22.

[13] A. Gruen. H. Kahmen. Optical 3-D measurement techniques II. Wichmann Verlag:1993