The 3D Model in the Manufacturing Process of Forged Products

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In order to assess their dimensions early, forgings have previously been sized after heat treatment with a measuring string in the heat treatment shop. The forgings have then been transported to the machining shop followed by accurate remeasurement for marking, making the original measure pointless. To improve on this inefficient process, we have installed a three-dimensional (3D) laser scanner (Leica Absolute Tracker ATS600) which enables us to measure products quickly and accurately.
Marking and reporting with the ATS600 are essential. Firstly, the data acquired by ATS600 is polygonally-transformed using a computer. Next, the amount of excess material of the forgings is assessed by comparing the polygonal data with the computer-aided design (CAD) model of the product. Finally, according to the optimized dimension data, the product can be marked anywhere using a laser on the surface of the product. Furthermore, the marking instantly provides a paper reporting the maximum and minimum of the excess material at arbitrary points on the product. Consequently, using this device for measurement and ruling has successfully lessened operation time, resulting in shortening lead times.

KEYWORDS: ATS600, 3D MEASUREMENT, RULED LINE WORK, DIMENSIONAL MEASUREMENT, WFD TECHNOLOGY, THE SURFACE DEVIATION, DIRECT SCANNING CAPABILITY

INTRODUCTION

We manufacture forgings used in thermal power generation and industrial machinery. The production of steel forgings basically proceeds in the following order: casting, forging, heat treatment, and machining. In the past, steel forgings were measured on the dirt floor of the heat treatment shop after the heat treatment process. This was done to improve forging procedures for subsequent products through early dimensional confirmation. After that, the forged products were placed on a surface plate at the machine shop to take accurate dimensional measurements for ruled line work prior to machining. In other words, dimensional measurements were performed on the same product at both the heat treatment shop and the machine shop, wasting time and effort.
To solve this problem, Tokyo Boeki Techno Systems Ltd. introduced the Leica Laser Tracker ATS600 (hereafter ATS600), a three-dimensional measuring machine manufactured by Leica Geosystems. This paper reports on a case in which the ATS600 was applied to dimensional measurement, ruled line work, and grading of wrought steel products.

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MEASURING METHOD BY THREAD STRETCHING

In the heat treatment shop, the dimensions of steel forgings after heat treatment were measured by thread stretching. Figure 1 shows the procedure for thread tensioning a shaft-shaped product. First, a temporary center position is determined at both ends. A thread tension rod is applied to the center position on both ends, and the thread is stretched to the same distance A [mm]. Then, the distance B [mm] between the thread and the product is measured with a ruler at each position, and the distance A-B [mm] from the shaft center of the product can be calculated. This is done at 8 equally spaced positions. However, the measurement method using threads is not accurate enough to replace the ruled line work in the next process. Therefore, in order to confirm the center of the axis, another measurement is made in the next process, and the ruled line work is performed, which duplicates the previous work.

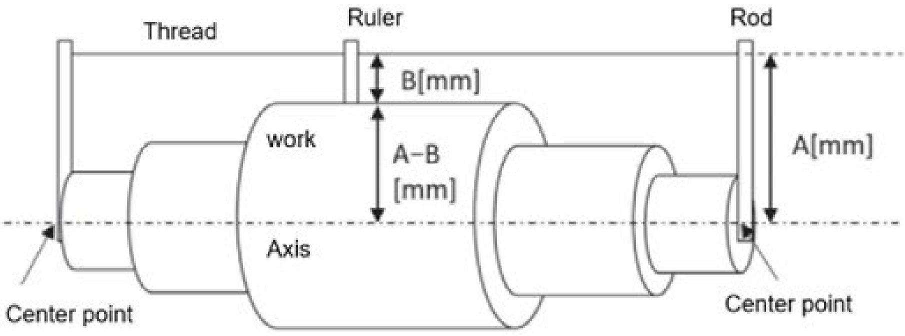

Fig.1 - The procedure for thread tensioning.

DIMENSIONAL MEASUREMENT WITH ATS600

The ATS600 is characterized by its direct scanning capability, which enables non-contact, non-marking measurement of a wide area up to 60 m from the tracker body in a single scan. This scanning allows taking the coordinates and performing polygonization of the product's surface topography even in areas that cannot be touched by humans. Direct scanning is based on Wave-Form Digitizer (WFD) technology, which, when combined with reflector measurement, enables measurement work on large products.

Fig.2 - ATS 600 Main unit.

Tab.1 - Chemical composition (%wt) of the A357 and C355 alloy.

Specifications of ATS 600	
Absolute accuracy	< ±300 μm
Reflector measurement (radius)	0.8 - 80m
Non-contact measurement Measuring range(radius)	1.5 - 60m
Ambient operating temperature	0 to 40 degrees Celsius

WFD TECHNOLOGY

WFD technology combines the short measurement time of the Time of Flight (ToF) method and the high accuracy of the Phase Shift method to enable quick and highly accurate 3D measurements. The ToF method measures three-dimensional information from the time taken for a light pulse emitted by the measuring machine to return after being reflected by the product. The phase-shift method measures distance from the phase shift between the emitted and reflected light and from the wavenumber, or frequency, of the light. The combination of these two techniques enables quick and highly accurate measurement of even large products.

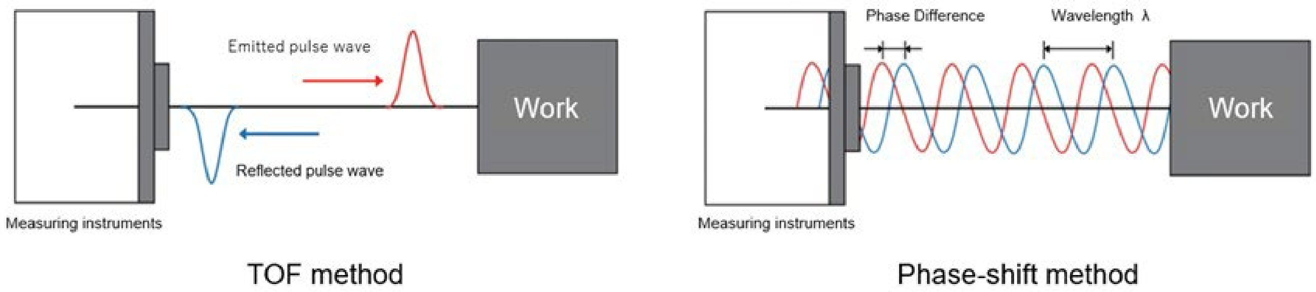

Fig.3 - Illustration of ToF and phase shift methods.

MEASUREMENT METHOD IN ACTUAL OPERATION

As shown in Figure 4, a target is mounted and reflectors are read before the 3D measurement. The target can be mounted on a location other than the product as long as the positional relationship with the product is aligned. In this case, it is desirable to install many targets because it is necessary to read the coordinates of the reflectors on at least three locations. By overlaying the data measured at multiple locations, data for the entire product shape can be obtained as shown in Figure 5.

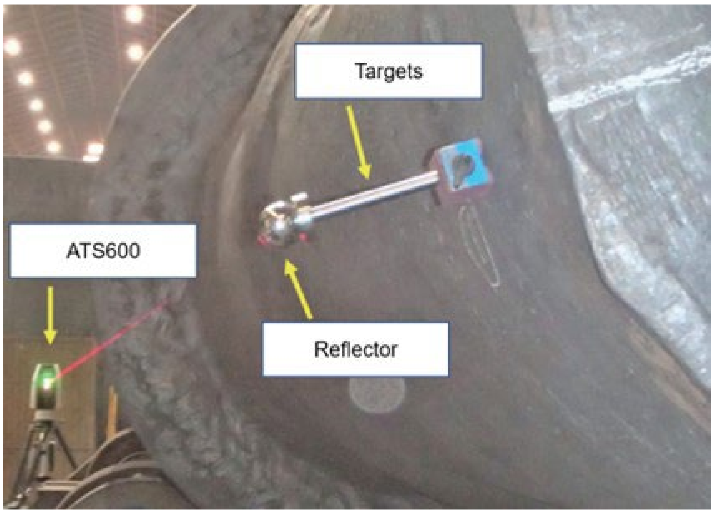

Fig.4 - Work to read reflector position.

Fig.5 - Overlaying scanned data.

Next, the measured data is compared with the CAD model of the product shape to determine the amount of excess wall thickness. The measured data can be processed using PolyWorks|Inspector™ software. By converting the measurement data into polygons and comparing it with the CAD model, the surface deviation is automatically calculated and output as a color map as shown in Figure 6. The alignment of the measurement data and the CAD model can be adjusted manually. The alignment can be adjusted by translating or changing the angle. This allows the user to set the optimum center in consideration of machining and quality in the next process during the product centering operation.

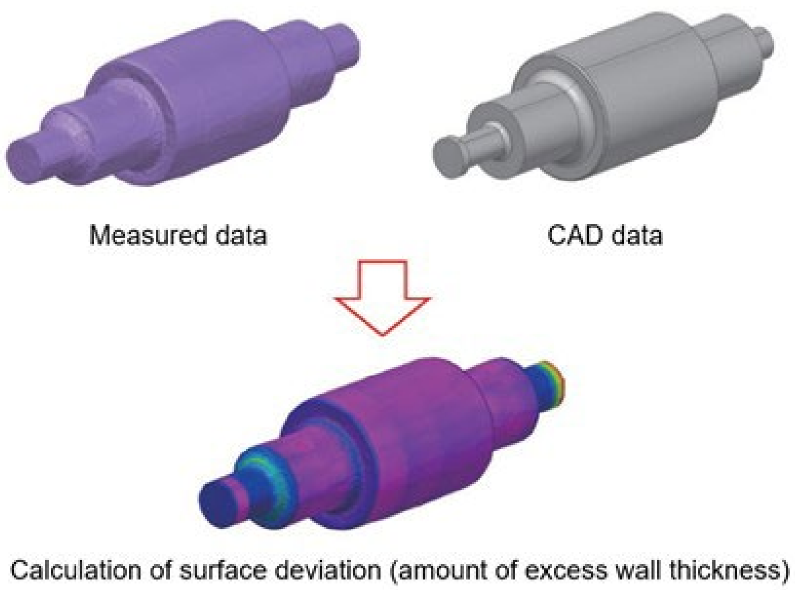

Fig.6 - Matching of measurement data with CAD data.

APPLICATION TO PRE-MACHINING RULED WORK

The ATS600 can direct the laser to any location on the product. This makes it possible to apply the ATS600 to pre-machining creasing work. Figure 7 shows the flow of creasing work using the ATS600. By selecting a face of the CAD model on the PC, the laser can be directed to the end face position of the CAD model on the product. By repeating this process and connecting three or more targeted points with a line, it is possible to create a ruled line. In the creation of the center position, the laser can be directed to the center position by creating a line passing through the axis center of the CAD model. The above operations have greatly improved the efficiency of ruled line work, which was conventionally performed on a surface plate.

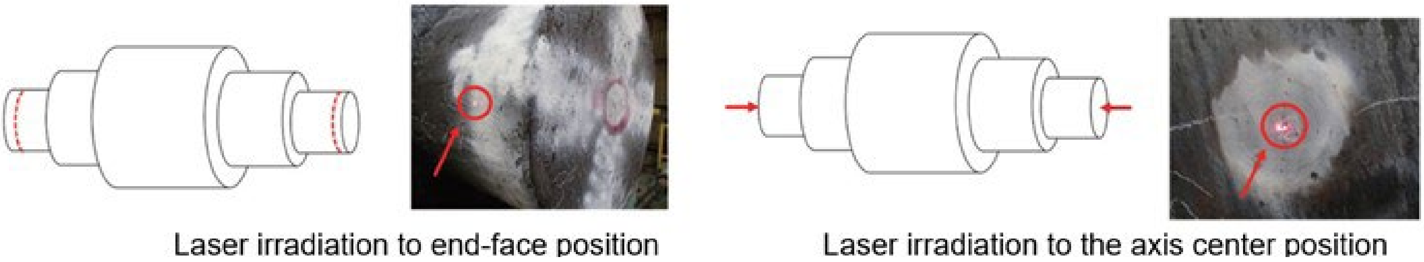

Fig.7 - Ruled writing work using ATS600.

EFFECTS OF ATS600 APPLICATION

At present, 3D measurement is applied to almost all products for large forgings such as shaft shapes and cylindrical shapes, and dimensional measurement and ruled line work are being performed. Therefore, we calculated the work time for each product to investigate the improvement effect of ATS600. Figure 8 shows the average time required for dimensional measurement and creasing work per product (products of all shapes, including shaft-shaped products and cylindrical products).

If the time required for conventional thread tensioning in the heat treatment shop and surface plate ruled lines in the machine shop is considered to be 100%, the application of the ATS600 eliminates double work and reduces work time by about 65%. In addition, while at least three people were required for each measurement in the conventional yarn tensioning operation, the ATS600 enables measurement and creasing by one person, thus saving manpower in the measurement process.

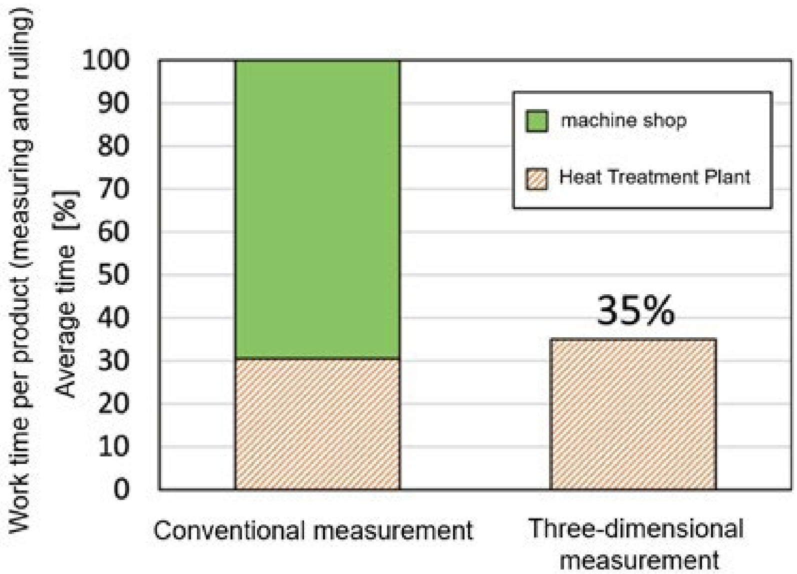

Fig.8 - Change in dimensional measurement and ruled work time.

SUMMARY

The application of the ATS600 to forging eliminated the duplication of conventional work. The results are summarized below.

The accuracy of the ATS600 was verified, and it was confirmed that there were no problems in its operation.

The application of 3D measurement to dimensional measurement and ruled line work eliminated the conventional duplication of work, resulting in a 65% reduction in work time.

The company plans to improve the processing capacity of 3D measurement for further expansion to applicable products in the future. The introduction of the ATS600 has also made it possible to see parts that were previously invisible, such as the amount of deformation caused by the heat treatment process. The company plans to use the ATS600 in a wide range of applications to further reduce costs and shorten working times.

REFERENCES

[1] Hannes Maar and Hans-Martin Zogg: "WFD Wave Form Digitizer Technology", White Paper, Leica Geosystems AG, Heinrich-Wild-Strasse CH-9435 Heerbrugg, (2014).

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