CHAPTER 39

INDUSTRIAL APPLICATIONS OF OPTICAL MEASUREMENT SYSTEMS IN MOLD MANUFACTURING

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Introduction

In many circumstances, optical 3D measurement may replace tactile measurements made with mechanical gauges or coordinate measuring devices. It is used to verify that the geometric dimensions (size, form, and position) of components are correct. A light source (transmitter) that provides a unique, predetermined light signal to the test item and a receiving device (receiver) that captures the light signal are the typical components of optical sensor systems for 3D measurement operations. The item modifies the optical signal's amplitude, phase, polarization, or direction in a known way, which is then utilized as a measured variable. Depending on the measurement technique, the object's surface structure or 3D information can be inferred by analyzing this change.

In the field of mechanical engineering, 3D measuring technology facilitates and expedites every stage of the injection molding, blow molding, and thermoforming processes: from the design and manufacture of prototypes and tools to the first item inspection reports, assembly analysis, and load testing. optical 3D coordinate measuring device that, regardless of the object size, enables non-contact measurements of the whole surface of tools, electrodes, prototypes, and injection-molded components. This technology even swiftly and thoroughly catches complicated freeform features, unlike tactile measurement procedures. Full-field surface measurements provide targeted tool correction and a quicker first item inspection, which cut down on production lead times. The whole assessment procedure as well as the measurements may be automated for quality control that goes hand in hand with production.

Mold dimensions and tolerances are measured during the production process using optical measuring devices. Since they are a non-contact measurement technique, the mold is not physically touched, potentially reducing the risk of mold damage. Many characteristics on molds may be measured with optical measuring equipment. Coordinate measuring machines (CMMs), optical profilers, and three-dimensional scanners are some of the most popular kinds of optical measurement systems utilized in the mold-making industry. In general, mold makers can benefit greatly from the use of optical measuring equipment. They can aid in lowering expenses, shortening inspection times, enhancing quality control, and improving accuracy.

Methods

Optical measuring instruments are used during production to determine the dimensions and tolerances of the mold. Since they use a non-contact measurement method, there is no physical contact with the mold, which may

lower the possibility of mold damage. Optical measuring tools may be used to measure a wide range of mold properties, including the size, surface quality, conformal precision, positions of the gate and ejector, and draft angles.

Optical measuring instruments are becoming more and more important in mold manufacture. Several advantages may be seen when contrasting these technologies with traditional measurement methods.

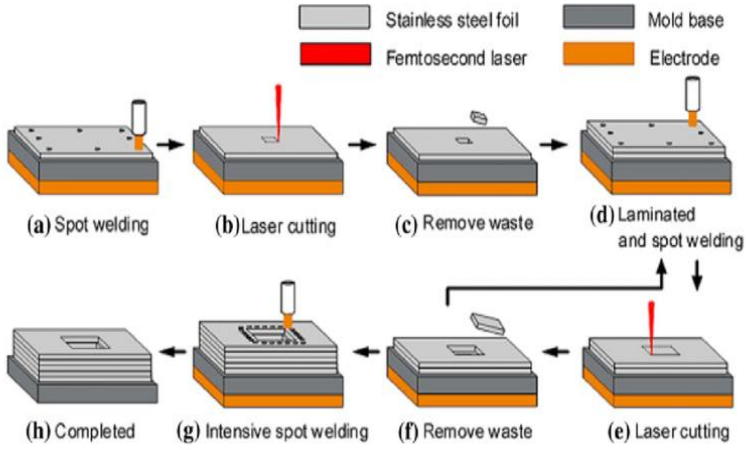


Figure 1. Schematic diagram of micro-mold manufacturing process (Shiquan L., et al., 2013).

For example, accuracy: optical measurement instruments may attain tolerances of up to 0.0001 inches, which makes them incredibly accurate. Speed: Optical measurements may be completed quickly and easily since they don't involve making direct physical contact with the mold. Non-destructive: Optical measurements are non-destructive since they do not cause any damage to the mold. Versatility: Optical measurement tools may be used to assess a mold's dimensions, surface polish, profile, and other characteristics.

Coordinate measuring machines (CMMs)

CMMs are computer-controlled devices that measure the geometry of real-world objects using touch probes. These probes are able to reach different locations on the surface of a mold, gathering information on its dimensions, angles, and other important characteristics. After the data is gathered, the CMM's software processes it to produce a 3D digital model of the mold, enabling precise analysis and comparison with the design requirements. (Artkin, F., 2022; 2023).

They are employed to precisely measure a variety of mold component dimensions, including inserts, cores, and cavities. After that, this information is utilized to confirm that the mold satisfies all necessary requirements and to spot any possible flaws that may have an impact on the finished product.

The use of CMMs in mold technology Inspection of Dimensions: Critical mold dimensions, such as cavities, cores, inserts, and parting lines, may be precisely measured with CMMs.

Coordinate measurement machines (CMMs) are essential for guaranteeing accuracy and excellence in the production of molds. They are extremely useful instruments that have several benefits over conventional inspection techniques, which makes them essential in the cutthroat mold-making market of today.

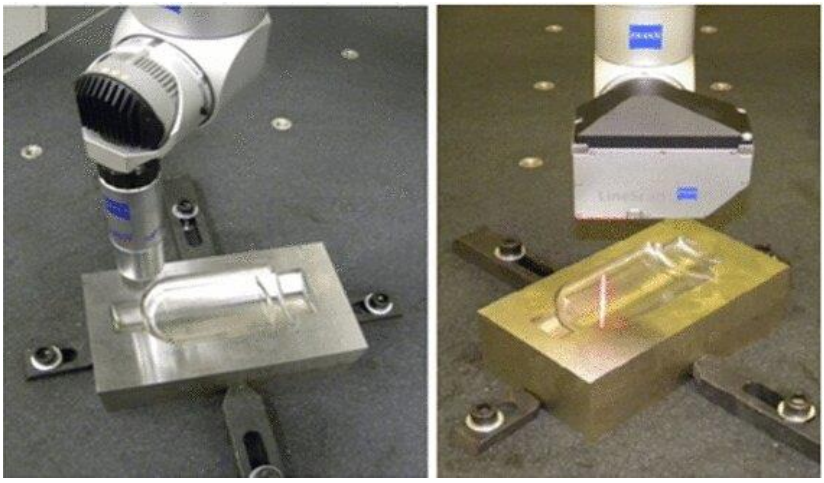


Figure 2. Scanning of the mold cavity using the probes on the stationary CMM, (Syed Hammad Mian et al., 2019).

By doing this, molds are guaranteed to fulfill design requirements and yield components with the required tolerances. Geometry Verification: CMMs check the intricate mold geometries, including radii, angles, and profiles. By doing this, problems during component manufacture are avoided and any design deviations are easier to find.

Surface Finish Analysis: CMMs are able to evaluate the molds' surface roughness and texture. This is important for applications such as plastic injection molding, where low errors and high-quality components are achieved with a smooth mold surface. Tool Wear Monitoring: Using CMMs to measure variations in mold dimensions, one may monitor tool wear over time. By doing so, production downtime caused by worn-out tools is avoided and preventative

maintenance may be scheduled. Reverse Engineering: By using CMMs, digital models of pre-existing molds may be produced. This is helpful for mold replication, production problems, and mold design optimization. Advantages of Mold Manufacturing using CMMs: High precision: When compared to manual measurement techniques, CMMs provide greater precision, reducing mistakes and guaranteeing constant part quality. Decreased Inspection Time: By automating the inspection process, CMMs boost productivity and efficiency by drastically cutting inspection time when compared to manual techniques. Better Quality Control: By offering extensive information on mold dimensions and surface properties, CMMs help to improve quality control and identify any problems early on. Decreased Scrap and Rework: Precise measurements and prompt fault identification result in fewer components being trashed and a decrease in rework, which lowers material waste and manufacturing expenses. Improved Development and Design: Improved Design and Development: By utilizing CMM data, mold designs can be improved, manufacturing procedures can be optimized, and new molds with higher performance and efficiency may be created.

Taking into Account CMM Utilization in Mold Manufacturing Cost: Since CMMs are an expensive investment, it's critical to assess how cost-effective they are in relation to production volume and necessary precision. Operator Training: To correctly program, operate, and analyze data, CMMs need operators with a high level of ability. Optimal usage requires proper training. Mold Complexity and Size: The size and complexity of a mold can affect the CMM that is selected as well as its capabilities. Make sure the CMM you've selected can manage the unique requirements of your mold manufacture.

Laser Scanners

Traditional mold measuring methods are generally done manually using contact measuring tools such as vernier measuring tools or micrometers. Only a few attributes such as mold width, height, and depth can be measured, while the curvature of the surfaces and sunken surfaces are difficult to measure.

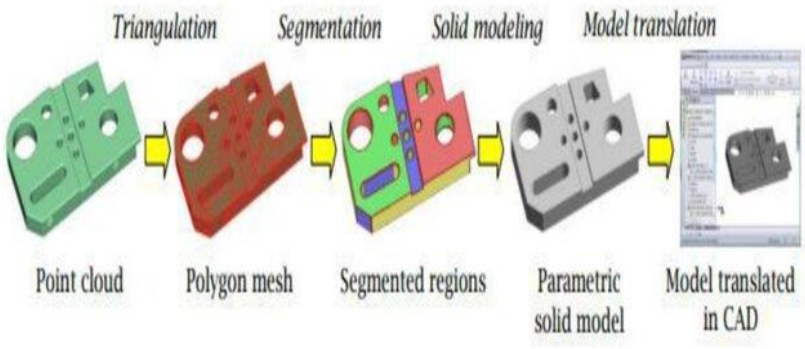


Figure 3. General process of 3D model generation (Y.P.Jadhav et al., 2015).

These measuring methods are not only complicated and time consuming, but it is also difficult to ensure measuring quality and accuracy of large-size molds, making mold measuring a very time-consuming and laborious part of industrial manufacturing. For this reason, non-contact 3D scanner measurement is gradually becoming one of the main methods of industrial mold measuring due to its abilities of overcoming the deficits of traditional measuring methods and achieving high-quality inspection which is vital to guarantee a long term fluent production of high quality identical molded products.

Laser scanners use a laser beam to scan the mold surface. The data from the laser scanner is then used to create a 3D model of the mold. The fast access to the 3D scanning data and the immediate capacity of full size measurement of the data is a huge advantage of the whole process. The high measurement accuracy, up to 0.01mm and the fast and efficient data capturing and software processing helped to complete.

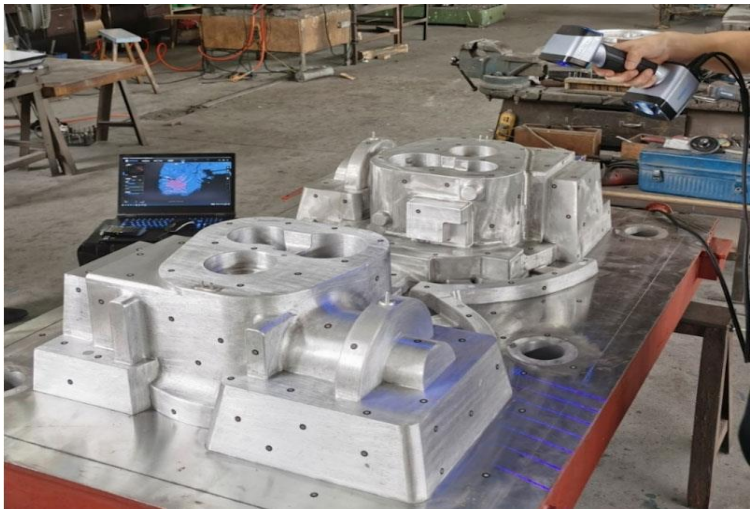


Figure 4. 3D Scanning Applications in Mold Industry (shining3d.com, 2023).

The 3D laser scanning mode has a scanning speed of approximately 480,000 dots/sec. The technician spent only about 10 minutes to obtain the complete high-precision 3D model data of the aluminum mold directly.

In order to check whether the aluminum mold meets the accuracy requirements, the scanned aluminum mold data and a digital model of the original design were imported into the measuring software. After the coordinates were aligned, the deviation comparison analysis was performed using the chromatogram to obtain the annotated deviation diagram. Finally the measuring report could be exported.Laser scanners use a laser beam to scan the mold surface. The data from the laser scanner is then used to create a 3D model of the mold. 3D Scanning Improves Efficiency on Mold Building.

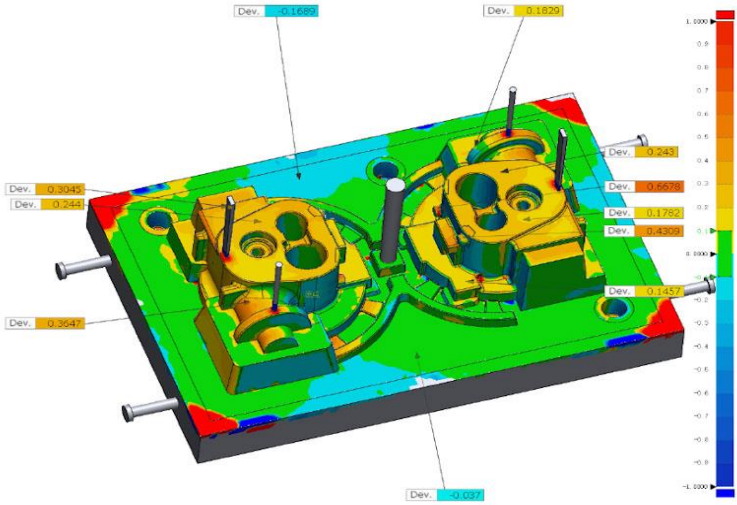


Figure 5. The Scanned Aluminum Mold Data and Orginal Design and Digital Data (shining3d.com, 2023).

The scanning process took less than 30 minutes from applying reference points to 3D scanning to obtaining the final comparison analysis report. This method saved a lot of time in relation to traditional measuring methods and solved many parametrical problems, which cannot be detected by traditional measuring tools.

Optical Profilers

With an optical profilometer, the surface topography is examined using a light source as a kind of microscope. Through the use of a beam splitter, the beam of light from the profiling lamp is divided into two paths: one route heads towards the surface, while another pathway is focused into the reference mirror. Optical profilometry is a technique used for the topographical study of the materials surface which works on the principle of light instead of the physical probe in determining the data. The main feature of this technique is directing the light source to detect the three-dimensional data of the surface. There are different ways of optical techniques used such as optical interference, focus and phase detection, confocal aperture detection, pattern projection, and optical imaging technique.

The working principle of optical profilometry is a non-destructive, non-contact surface analysis technique. With an optical profilometer, the surface topography is examined using a light source as a kind of microscope. Through the use of a beam splitter, the ray of light from the profiler lamp is divided into

two paths: one route goes towards the surface, while another path is sent towards the referencing mirror.

The reflections from these two paths are recombined and are projected onto an array detector, the difference in the path of recombined beams is on the order of a few wavelengths which leads to less interference. The vertical resolution can be obtained in the order of several angstroms and the lateral resolution depends on the objective and ranges from 0.3-8 microns (mri.psu.edu, 2023). The working principle of the optical profilometer is shown in the Fig-6.

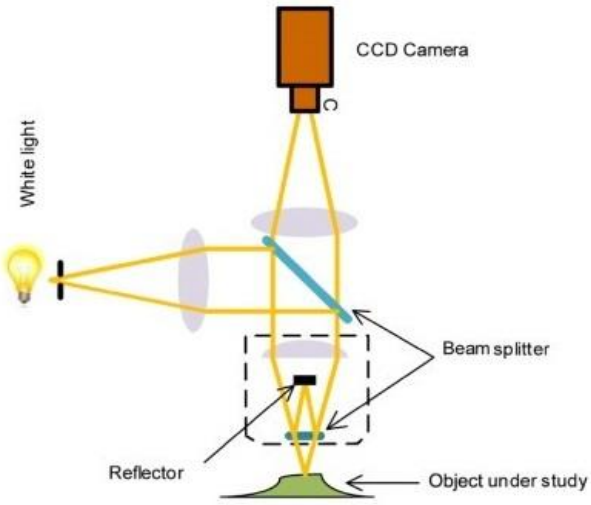


Figure 6. The working principle of optical profilometer, (Bakhtazad, A., et al., 2019).

Performance factors of Optical Profilers

The profilometer performance is very important in order to analyze the surface topography properly hence the essential factors to be considered are Spatial resolution: The spatial resolution varies for different profilometers, it mainly varies in the longitudinal and lateral directions. The range of this spatial resolution depends on the objectives of the users which in turn depends on the different accuracy levels.

Field of view: The whole surface area of the material that the profilometer is capable of measuring is called the field of view. The kind and size of the profiler determine this, and it is crucial to comprehend the characteristics of the broader region. Picture acquisition time: Depending on the desired picture type, frame rates, precision, and measurement technique, this is another

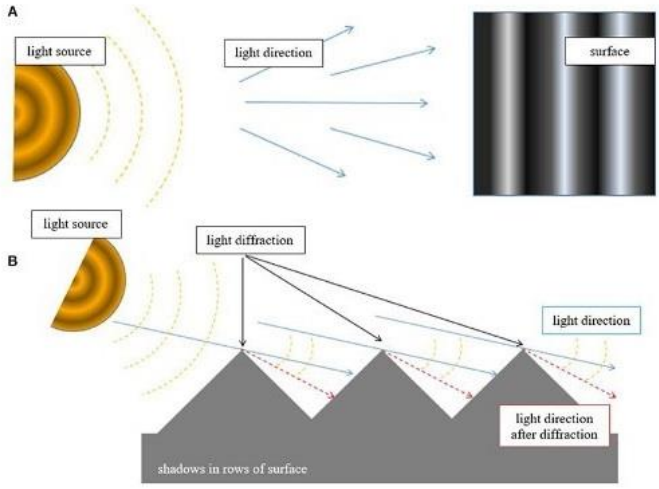


Figure 7. The scattered light diagram that appears on the surface under test (Grochalski, K., et al., 2020).

crucial aspect of the profilometer (rp-photonics.com, 2023). The maximum height difference that the profiler can accurately measure. Important for surfaces with significant variations in height. Measurement Accuracy: The degree to which the profiler's measurements match the actual surface profile. Affected by factors like calibration, noise, and environmental conditions. Measurement Speed: Faster measurement times are beneficial for high-throughput applications or large samples. Cost and Maintenance: Depending on their capabilities, optical profilers can cost anywhere from a few thousand to hundreds of thousands of dollars.

Through the use of a light source to examine the material's surface, the optical profilometer operates on a non-contact mode that allows for true imaging and the measuring of an area. In comparison to contact mode data capture, this approach offers faster data acquisition speeds and greater area coverage. Because the sample is not harmed by this non-destructive procedure, it can be utilized for additional analysis.

In order to collect the three-dimensional surface data, this approach allows for the measurement of the x, y, and z coordinates the crucial dimensional measurements.

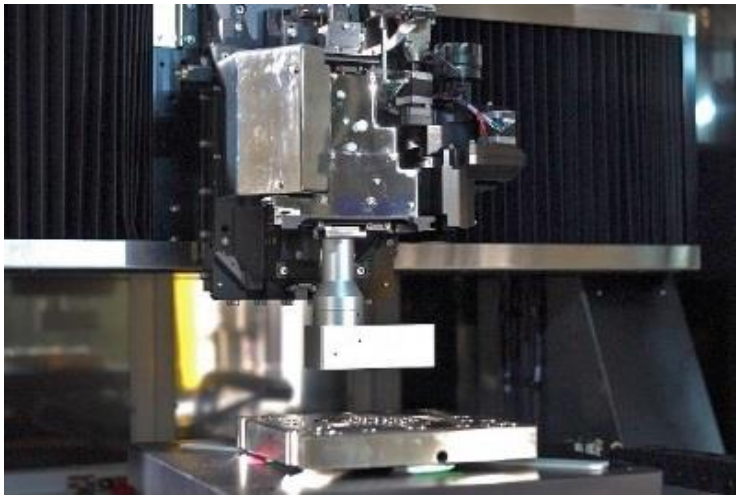


Figure 8. The optical profilometer use mold technology (zygo.com, 2023).

Conclusion

The application of optical measuring systems in mold manufacturing offers several benefits. Among the most significant benefits are the following: Enhanced precision and accuracy: Compared to conventional measuring tools like calipers and rulers, optical measurement devices have the capacity to be significantly more exact and accurate. This is because to their remarkable precision in measuring even the smallest traits and their immunity to human mistake. Compared to conventional methods, optical measuring devices can check molds significantly more quickly. This is due to their ability to measure every aspect of a mold automatically, eliminating the need for human involvement. Numerous pieces of information about a mold, such as its size and surface quality, may be obtained using optical measurement tools. This information may be utilized to detect potential issues and enhance the quality of molds. By guaranteeing that molds are made in accordance with specifications, optical measuring systems can contribute to a decrease in scrap rates. Manufacturers may save a substantial sum of money as a result. The molding process may be observed in real time with optical measuring equipment. To guarantee that molds are made to the right quality, this information may be utilized to modify the procedure as necessary.

References

Artkin, F., CMM Machines and Industrial Applications, 1. International Conference on Engineering, Natural and Social Sciences, Pages 1029-1033, December, 2022, Konya, Turkiye.

Artkin, F., CMM Measurements and Quality Control Applications, ASES International Kayseri Scientific Research Conference, Pages 248-253, September 01-03, 2023, Kayseri, Turkiye.

Bakhtazad, A., Chowdhury, S., 2019. An evaluation of optical profilometry techniques for CMUT characterization. Microsystem Technologies, 25(9), pp.3627-3642.

C. Veera ajay, B. A. Pradeep, C. Boopathi, R. K. Sanjeev, V. Meganathan, Comparison of geometrical accuracy and surface finish of cam profile generated by wire-EDM and CNC milling machine, IOP Conference Series: Materials Science and Engineering, Volume 764, International Conference on Advances in Materials Processing and Characterization 10-11 September 2019.

Grochalski, K., Wieczorowski, M., H'Roura, J. and Le Goic, G., 2020. The optical aspect of errors in measurements of surface asperities using the optical profilometry method. Frontiers in Mechanical Engineering, 6, p.12.

https://www.iqsdirectory.com/articles/machine-vision-system.html, Accessed 18 Dec., 2023.

https://www.mri.psu.edu/materials-characterization-lab/characterization-techniques/optical-profilometry-0, Accessed 16 Dec., 2023.

https://www.rp-photonics.com/optical_profilometers.html, Accessed 20 Dec., 2023.

https://www.shining3d.com/blog/3d-scanning-as-turnkey-solution-in-the-mold-industry/ Accessed 19 Dec., 2023.

https://www.zygo.com/products/metrology-systems/3d-optical-profilers/nexview-650, Accessed 17 Dec., 2023.

Laser Scanners. Hexagon Metrology. US. Retrieved 2023-09-01.

Shiquan L., Xiaoyu W., Bin X., Yunfeng H., Feng L., Feng G., Chenlin D., Shuangchen R., Laminated fabrication of micro-stepped gear mold based on femtosecond laser cutting of stainless steel foil, Microsyst Technol (2013) 19:1981–1990, DOI 10.1007/s00542-013-1760-9.

Syed Hammad Mian, Abdulrahman Al-Ahmari, Comparative Analysis of Different Digitization Systems And Selection of Best Alternative, June 2019, Journal of Intelligent Manufacturing 30(2):1-29, DOI: 10.1007/s10845-017-1371-x.

Y.P.Jadhav, V. N. Chougule, Cad Modeling Strategy For Complex Engineering Objects By Reverse Engineering Approach, International Engineering Research Journal (IERJ) Special Issue 2 Page 4632-4635, 2015, ISSN 2395-1621.