Lasermeister LM300A＋SB100で実現する自動補修ソリューションの紹介

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Introduction to Automated Repair Solution Enabled by Lasermeister LM300A + SB100

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ニコンは2019年に金属3D プリンター Lasermeister 100A を発売し，2024年には LM300A と SB100を発売し，これら装置を用いた自動補修ソリューションを提案した．LM300A は大出力レーザーと造形空間の拡大により，タービンブレードなどの大型部品補修に対応する．SB100は内蔵3D スキャナーによる高精度な形状計測や補修部位の自動抽出，さらに LM300A 用の加工パス自動生成を行う．両機をセットで使用することで，計測から積層造形まで一連の自動補修プロセスを高精度かつ安定して繰り返し実行できる点が大きな強みである．タービンブレード補修では現品の歪みといった予測困難な課題にも対応し，±0.25 mm 以内の高精度補修を実現した．設計モデルがなくとも現物計測データのみで補修形状を生成でき，幅広い実務ニーズに応える．今後は金型など薄肉補修にも展開し，顧客ニーズに応じた自動補修ソリューションの拡充を目指す．

Nikon launched the metal three-dimensional (3D) printer Lasermeister 100A in 2019 and introduced LM300A and SB100 in 2024, based on which an automated repair solution was proposed. LM300A is equipped with a high-power laser and features a large build volume, thus enabling the repair of large components such as turbine blades. SB100 features a built-in 3D scanner for the precise measurement and automatic extraction of damaged areas, as well as for the automatic generation of tool paths for use with LM300A. This solution is advantageous as it uses both devices simultaneously, thus enabling a highly accurate and stable automated repair process from measurement to additive manufacturing. In repairing turbine blades, the system used can accommodate unpredict issues such as the deformation of actual components and affords a repair accuracy of ± 0.25 mm. Moreover, in cases where the original design model is unavailable, the system can generate repair shapes solely from measurement data, thus satisfying a wide range of practical requirements. In the future, Nikon plans to expand this solution to thin-walled components such as molds, thereby enhancing automated repair solutions in response to diverse customer requirements.

Key words 金属積層造形，3D 計測，欠損部位特定，タービンブレード補修，金型補修
additive manufacturing, 3D measurement, defect-area identification, turbine-blade repair, mold repair

1 Introduction

In 2019, Nikon launched the Lasermeister 100A (hereinafter referred to as the LM100A) optical processing machine (Fig. 1) as a new business initiative.

The LM100A is a metal additive manufacturing system, commonly referred to as a 3D printer, developed by applying one of Nikon's core competencies—laser control technology.

The LM101A, incorporating a five-axis mechanism, and the LM102A, equipped with advanced melt-control functions, have also been launched. Figure 2 shows the inspection of the build volume in the LM102A.

The LM100A series employs the Directed Energy Deposi-

Fig. 1　Lasermeister 100A

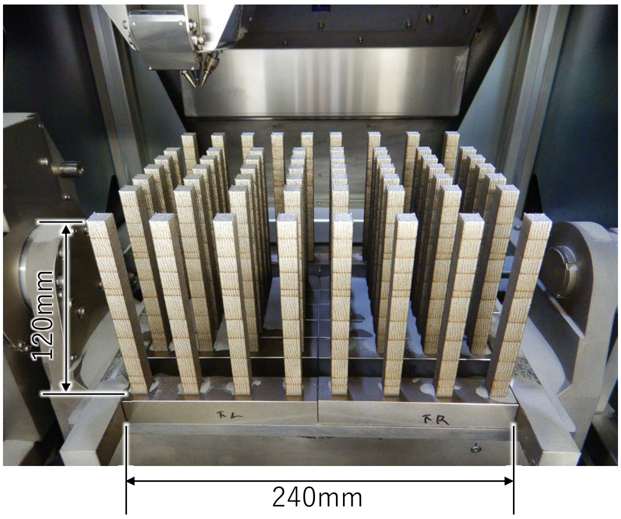

Fig. 2 Build scene using the Lasermeister 102A

Fig. 3
Lasermeister LM300A (right)
Lasermeister SR100 (left)

tion (DED) method, which involves the use of metal powder and a laser. Hereinafter, this “DED method using metal powder and a laser” is referred to simply as DED.

A method that is in contrast to DED is Laser Powder Bed Fusion (L-PBF), a method employed in Nikon SLM Solutions' systems. While both DED and L-PBF fabricate parts by irradiating metal powder with a laser to melt the metal, they differ significantly in how the metal powder is supplied. DED fabricates parts by irradiating the target object with a laser and concentrically supplying metal powder to the region of the target that has been melted. In contrast, L-PBF fabricates parts by irradiating a flat surface called a powder bed to melt the metal powder that is uniformly spread over the powder bed. Because of this difference in the metal powder supply principle, the fabrication approaches in which each method excels also differ.

One of the advantages DED has over L-PBF is that it facilitates additive manufacturing onto existing components. Given its metal powder supply principle, L-PBF inevitably covers the part fabricated up to that point with the metal powder it supplies. However, in additive manufacturing onto existing components, the process results in the existing parts being completely covered, making it difficult to determine the laser irradiation position. In contrast, with DED, the object to be irradiated by the laser is always visible, making it easier to align with the position where additive manufacturing is to be performed.

Leveraging this advantage and addressing customer needs, the Lasermeister LM300A and Lasermeister SB100 (Fig. 3) were newly developed, targeting “repair” applications, and launched in 2024. Hereinafter, they are referred to as LM300A and SB100, respectively.

2 Features of LM300A + SB100

The LM300A inherits the design lineage of the LM100A series. However, compared with the LM100A (maximum laser power: 200 W; build volume in vertical direction: 200 mm), the LM300A is designed with an increased maximum laser power of 300 W, providing greater melting capability, and a build volume of 400 mm in the vertical direction, making it easier to accommodate existing components. The expanded size in the vertical direction results from small gas turbine blades adopted as a concrete model for repair fabrication.

The primary role of the SB100 is to automate the repair process. The main hardware function it incorporates is a non-contact 3D measurement device, commonly referred to as a 3D scanner. Using this measuring instrument, the system performs shape measurement of the repair target, identification of the repair location, and generation of the geometry of the repair area. Furthermore, it has the capability of interfacing with the LM300A to generate machining paths executable by the LM300A.

By appropriately setting up the LM300A and SB100, it is possible to repeatedly perform repairs under identical conditions for repair targets of the same shape.

3 Concept of Repair Fabrication

The repair process is illustrated in Fig. 4.

(1) Initial setup

Set various parameters related to the repair, including the measurement conditions, laser power, powder feed rate, and model of the final shape serving as the repair

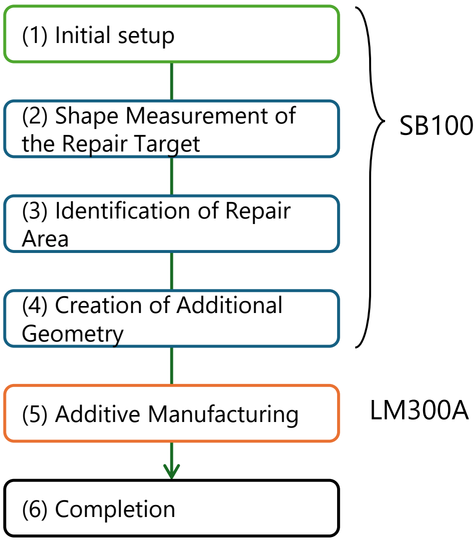

Fig. 4 Repair process

goal. It was determined that these settings need not be changed as long as both the final shape and the type of damage or wear remain unchanged.

(2) Shape Measurement of the Repair Target
The built-in 3D scanner is used to measure the shape of the repair target.

(3) Identification of Repair Area
The difference between the finished-shape model set in (1) and the 3D measurement results obtained with the 3D scanner is calculated. This difference corresponds to the defect area, which is the repair area itself.

(4) Creation of Additional Geometry
The shape of the repair area can be directly used for additive manufacturing. Based on the repair area identified in (3), a set of machining path data is generated for operating the LM300A, including all control commands for managing laser irradiation positions and power.

(5) Additive Manufacturing
The LM300A performs additive manufacturing based on the above machining path.

Based on the additive manufacturing capabilities developed with the LM100A, automation functions to facilitate “repair” were added and offered as the SB100. By adopting this concept, it became possible to make full use of the proven existing functions on the manufacturing unit side almost as they are, while focusing efforts on developing measurement functions for highly accurate detection of repair areas and on execution-control functions for implementing the repair strategy.

It should be noted that, when using the two devices based on the above concept, the challenge lies in position management. In this system, the measurement/manufacturing target is fixed to a designated table, which itself is transported between the devices. In other words, the table serves to link the two devices, and positional reproducibility among the two devices and the table is of critical importance. It is imperative to prevent any displacement of the measurement target (i.e., the additive manufacturing target) during this transfer and ensure high-precision positional reproducibility when installing the table itself.

To ensure positional reproducibility between the table and each device, a kinematic mount structure (Fig. 5) was adopted. The kinematic mount allows table installation to be performed with great ease and convenience while ensuring positional reproducibility, with an error of less than 0.01 mm.

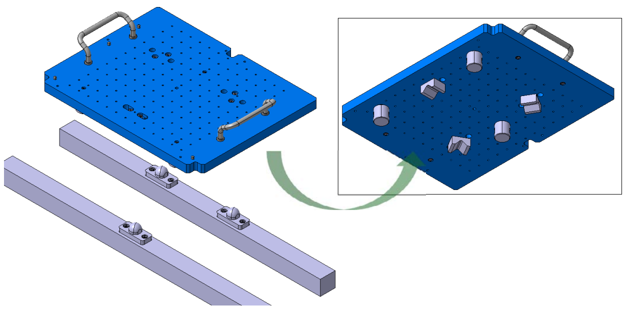

Fig. 5 Kinematic mount structure

In this way, position management between the LM300A and SB100 is made possible, with the table serving as the reference. For example, if a fixed point on the table that can be recognized by both the LM300A and SB100 is defined as the positional reference, then every location on the table can be uniquely correlated between the LM300A and SB100.

4 Turbine Blade Repair

In developing the LM300A, the initial repair target was set as turbine blades. Noting the fact that a viable repair business already exists, we collaborated with companies engaged in repair operations and set a practical goal of replacing the manual portions of existing business processes with the LM300A + SB100.

As a specific example, we focused on damage caused by wear at the blade tip (i.e., the blade’s top end), which accounts for a large proportion of turbine blade repairs, setting the maximum blade length at 400 mm or less and the allowable positional deviation for additive manufacturing within ± 0.25 mm.

The specific repair targets are shown in Fig. 6.

In practice, several issues arose, the most significant

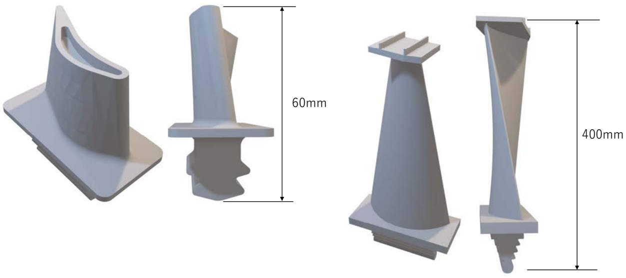

Fig. 6　Two types of turbine blade shapes targeted for repair

being deformation of the repair target itself. Compared with the turbine blade's design model, the actual component was significantly deformed, on the order of millimeters. It was found that simply calculating the difference between the design model and actual measurement results did not yield the intended additional geometry (Fig. 7).

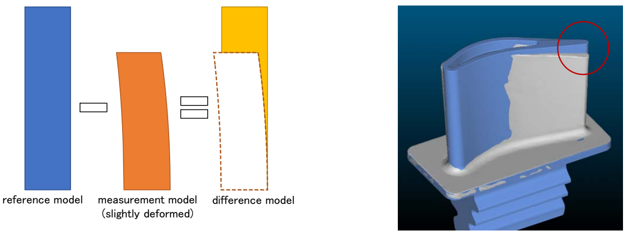

Fig. 7　Deformation of actual turbine blade

Ultimately, two methods were implemented.

The first method involves fitting the design model to the measurement results as closely as possible and then calculating the difference (Fig. 8). While this method is sufficiently versatile, there was concern about uncertainty arising from deforming the design model to match the actual component, which could cause the additional geometry to become unexpectedly distorted.

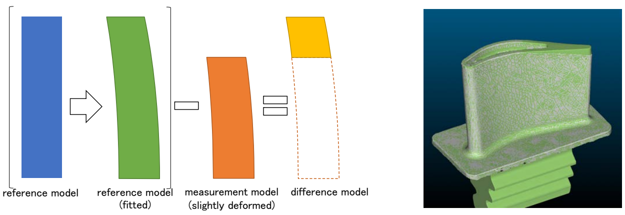

Fig. 8　Fitting the design model to the measurement results

The second method does not use the design model; instead, the measurement results are extended in the top-surface direction, and this increment is taken as the additional geometry (Fig. 9).

As this method simply extends the shape in the specified direction without applying smoothing or other processing, there was concern about the effect of discontinuities in the side-surface geometry on the manufacturing results. Fortunately, because post-processing for finishing was anticipated after manufacturing, it was determined that any such effects could be sufficiently remedied during subsequent machining. Given this background, it was found that this method was, in fact, well-suited for blade tip repair, and it was therefore adopted. In addition, turbine blade repair is often performed by companies who do not manufacture the blades, and in many cases, the design models themselves are difficult to obtain. Therefore, the fact that this method does not require a design model for comparison was also well-received.

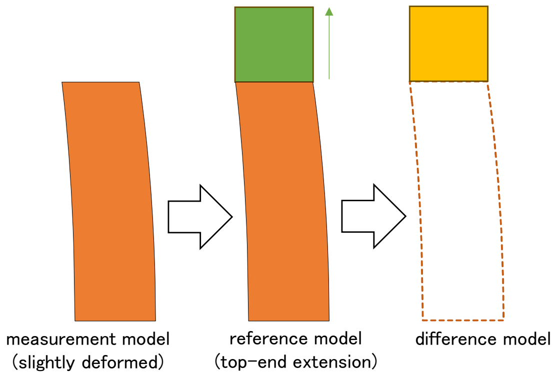

Fig. 9　Simple extension

These results are shown in Figs. 10 and 11.

Fig. 10　Turbine blade tip repair

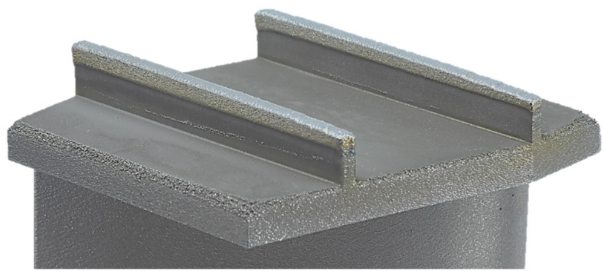

Fig. 11　Turbine blade shroud repair

The results of the shape measurement after repair manufacturing are shown in Fig. 12. This shows the difference between the repair result and repair target. As mentioned earlier, the allowable target positional deviation was ± 0.250 mm; however, these results show that it is generally in the range of 0 to 0.5 mm. It was also discovered during the collaboration that, in repair work, a negative deviation (i.e., smaller than the target) is an unacceptable outcome. For the purpose of finishing the shape through post-processing, it became a mandatory requirement that the result be positive (i.e., larger than the target). In consideration of this, the additional machining model was designed to be approximately 0.25 mm larger around the entire circumference. This ensures that, even when accounting for the ± 0.25 mm positional deviation, subtracting the repair target shape from the repair result will not yield a negative value.

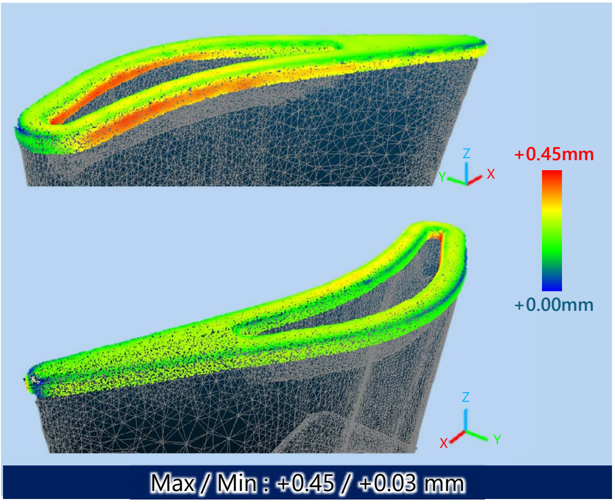

Fig. 12　Turbine blade tip repair measurement

5 Conclusion

Turbine blade repair, with its well-defined procedures and visually distinguishable defect areas, was an optimal first step for Nikon's proposed repair solution. In this way, we continue to demonstrate the value of the LM300A + SB100 through concrete applications. Having been able to present a clear example through turbine blade repair, we are fortunate to have also identified other repair needs. While turbine blade repairs involved several millimeters of build thickness, one such newly identified need is mold repair, which requires thin builds on the order of several hundred micrometers.

Going forward, we plan to further enhance repair applications using the Lasermeister, thereby leveraging Nikon's proprietary technologies to provide timely responses to specific requests.

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