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ISS-ELF の高速度カメラによる Ti-6Al-4V の結晶成長速度解析と誤差の検討

Precision analysis of crystal growth rate of Ti-6Al-4V using the onboard high-speed camera of the ISS-ELF

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1. Introduction

Understanding the crystal growth of metal plays an important role in simulating materials processes, such as casting or additive manufacturing. However, the crystal growth process is hard to observe because it is covered by the crucible. In addition, the process is too fast to observe. Therefore, the levitation techniques with high-speed cameras are effective because those are containerless process and high in the time resolution. By using the electrostatic levitation furnaces on the ground (ESL) and in the ISS (ISS-ELF), the methods to obtain the recalescence time[1)] and the crystal growth rate[2)] using the high-speed camera are established in the previous studies, respectively. However, certain errors originated from the methodologies have not been discussed well. Therefore, the aim of this study was to evaluate those errors quantitatively.

2. Experimental and analytical procedures

The samples were produced for *Hetero-3D* mission. Ti-6Al-4V powder was uniformly mixed with 2 mass% TiC particles. Then, the mixed powder was sintered into a bulk. Subsequently, the bulk was cut and sphered. The sample weighing around 25 mg was levitated to stabilize. The sample was levitated, melted, and solidified in the ISS-ELF under the Ar atmosphere. The high-speed camera was employed to capture the solidification process during recalescence with a resolution of 240 x 224 and a frame rate, f, of 10000 frames per second. The crystal growth rate, v, was calculated by the captured images under the assumption that the sample was a sphere because the molten droplet is sphered by the surface tension. The crystal growth rate was calculated for every vertex of the solid phase in every frame and summarized in the time[2)].

3. Results

The representative series of recalescence images captured by the high-speed camera is shown in **Fig. 1**. Nine images were obtained during recalescence. The brighter and darker region of the sample were identified as a solid and liquid phase, respectively, because the solid phase illuminate during the recalescence. A square solid phase grew on the spherical surface of the sample. The brightness and contrast were adjusted to clarify the solid-liquid interface. The crystal growth rate is also shown in **Fig. 1**.

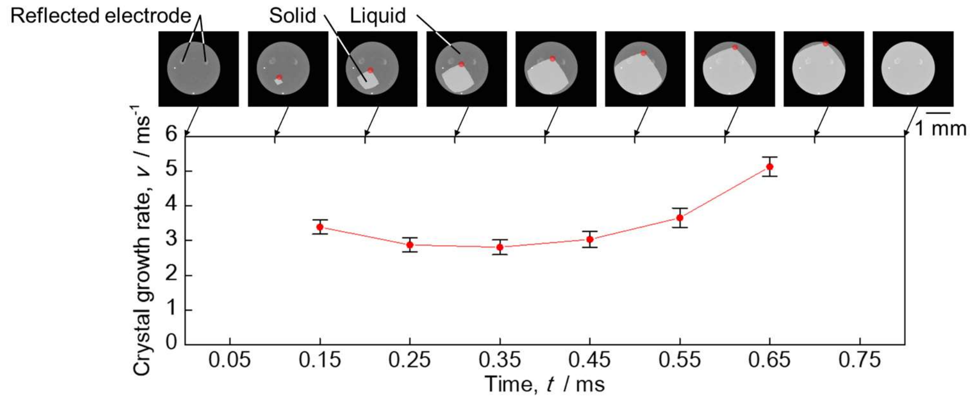

Figure 1. Representative series of images obtained by the high-speed camera and crystal growth rate with error. Only the upper vertexes indicated by red circles are shown as representatives.

4. Discussion

The error was categorized into three factors. The rotation of the sample during the levitation is the first, which comes from the movement of the sample. The error was calculated from the rotating interval and it was less than 0.03% compared to the obtained crystal growth rate at every vertex of every timestep. The distortion of the high-speed camera is originated from the equipment, which is the unique value of the geometry depending on the installed lens. The value is 0.18%. The quantification error is the last, which is generated when the visible light is converted into the digits at the sensor array of the high-speed camera. The errors were less than 10%. The schematic illustration is shown in **Fig. 2**. Those errors are summed and indicated in **Fig. 1.** The error is smaller than the change in the crystal growth rate because the error bars were not overwrapped between 0.15 ms and 0.25 ms, or 0.45 ms and 0.65 ms. Therefore, the solidification rate can be said to have the tendency to decelerate first and then to accelerate.

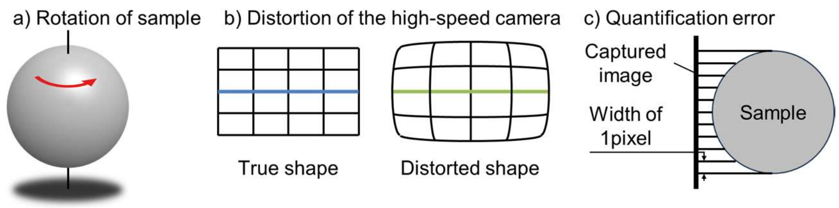

Figure 2. Schematic illustration of three factors of error.

5. Conclusions

The error was summarized in the three factors; rotation of the sample of 0.03%, distortion of the high-speed camera of 0.18%, and quantification error of up to 10% compared to the calculated crystal growth rate. Although every factor originating from the levitation method or experimental setup was quantitatively evaluated, the amount was smaller enough to recognize that the crystal growth rate of this sample in *Hetero-3D* first decelerated and then accelerated.

References

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