Trends and Challenges in Additive Manufacturing for Circular Manufacturing – A Survey in Japan, Norway, and India

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Abstract

Achieving circular manufacturing is one of the critical factors in pursuing circular economy. RRRDR (remanufacturing, refurbishment, repair, and direct reuse) are critical elements in circular manufacturing. The material surface restoration process in RRRDR is one of the critical factors that determine the effects of RRRDR in increasing resource efficiencies. This study investigates the trends and challenges in material surface restoration technologies used in RRRDR. This study focuses, in particular, on the technologies of additive manufacturing or metal 3D printing that can potentially be used in RRRDR. The study is based on the observations in three countries, namely, Japan, Norway, and India. The implications of the advancement of these technologies on product eco-designs are also discussed in the study.

The restoration of damaged components is not a new conduct in RRRDR. Welding, for example, has been traditionally used to restore the shape and functionality of damaged engineering components. This study, first, reviews the existing technologies, processes, and applications of material surface restorations in RRRDR. While the traditional welding processes can be used to restore the shapes of damaged components, they cannot rebuild three-dimensional (3D) structures of damaged components. The recent advancement of additive manufacturing has made 3D feature rebuilding of damaged components possible. This study, second, reviews the technologies and applications of recent additive manufacturing technologies or metal 3D printing technologies in RRRDR. Directed Energy Deposition (DED) is one of the promising 3D printing technologies for the use in RRRDR. The situations of R&D and potential applications of the technologies are investigated based on literature review and surveys in the three countries. The potential applications include the intelligent and customized tooling systems developed by combining additive manufacturing technology and surface embedded sensors. A R&D case of such tooling systems is shown in the article.

While there are huge potentials in applications of metal 3D printing technologies in RRRDR, there are also big challenges. The R&D challenges are summarized in the study. One of the challenges is post-processes after 3D printing. Post-processes are required to achieve desirable dimensional tolerances, hardness and surface roughness, and to ensure like-new performance. However, the microstructure evolution during the 3D printing process is complicated, and the solidified microstructure can be nonuniform within different layers, which prevents the use of the restored components in high-strength applications. The R&D challenges are summarized and the implications of these technologies on product eco-designs are discussed.