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# A Framework to Assess the Impact of Recycled or Reused Metal Powder on Circular Additive Manufacturing

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**Abstract**: Additive manufacturing (AM), with its design advantages and economic and environmental benefits, facilitates the metal manufacturing industry in overcoming the changing world dynamics. Additionally, as access to raw materials has become more challenging in recent years, accompanied by an associated increase in raw material costs, researchers are investigating the effects of recycled or reused metal powder in AM on the particle properties of parts. However, the economic and environmental impacts of these effects on companies have not yet been thoroughly investigated. This study has developed a conceptual framework to delve into the impact of using recycled or reused metal powder on the printing quality and production performance of AM parts from a life cycle perspective.



*Keywords*: Additive Manufacturing, Operation Management, Powder Recycling, Powder Reuse, Supply Chain Management.

## 1. INTRODUCTION

In recent years, fluctuations in the global economy (International Monetary Fund, 2022), disagreements between massive economies, epidemics, increasing environmental awareness, and more conscious customers on sustainability have become a source of tremendous concern in the metal manufacturing industry, creating uncertainties in costs and stocks (Alkahtani et al., 2021). Besides, increased cost of raw material and energy, rapidly developing technology, and the inability to find qualified workers in advanced manufacturing techniques have raised considerable questions about conventional manufacturing (Abubakr et al., 2020). Additive manufacturing (AM), also known as 3D printing, helps prevent the impending threat to the metal manufacturing industry with its design advantages, such as design freedom, creating products in layers, and customized and complex production (Yang et al., 2015). In addition to these advantages, AM provides economic and environmental benefits such as high material efficiency, low energy consumption, supply chain flexibility, and low inventory and storage needs (Huang et al., 2013; Javaid et al., 2021; Peng et al., 2018).

However, the extent to which these advantages provided by AM will be effective varies according to the techniques (i.e., Powder Bed Fusion, Directed Energy Deposition, etc.), each of which has its principles, pros and cons, and these techniques differ from each other with process parameters (in terms of speed, accuracy, material options, and suitability for specific applications) (Prakash et al., 2018). In other words, determining which AM technique will be used as a production option may vary depending on the parts' characteristics (i.e., material, geometry, etc.). For this reason, using the appropriate AM technique, depending on determining the correct AM process parameters for producing parts, is vital to ensure sustainability.

In addition to determining the AM process parameters depending on the requirements of the parts, it has been clearly stated in the literature that the metal powder to be used directly affects the quality of the AM parts (Muthuswamy, 2022). Therefore, high-quality metal powder must be employed to print high-quality AM parts. Although the metal powder market is growing (Grand View Research, 2022), accessing virgin metal powder has become demanding, and powder costs are still at high price (Santecchia et al., 2020). To ensure the sustainability of AM, using recycled or reused metal powder as feedstock not only provides easier access to feedstock but also decreases metal powder costs (Montelione et al., 2020; Sun et al., 2018). Nevertheless, changes in the particle properties of metal powder due to using recycled or reused powder may adversely affect the printing quality of AM parts (Karimi and Fayazfar, 2023; Tan et al., 2017). However, by mixing the recycled or reused metal powder with virgin metal powder in optimal proportions, changes in particle properties that may negatively affect the quality of the parts can be reduced to minimal levels (Derimow et al., 2022). Considering this, the printing quality and production phase performance of AM parts may vary not only depending on the variables in the part production stage but also directly related to the particle properties of the metal powder used in production. Therefore, the AM parts' printing quality and production performance should be evaluated from a life cycle perspective.

According to the existing studies in the literature, it has been reported that the use of different AM techniques carried out using recycled or reused powder creates different impacts on various particle properties (oxygen content, part density, microstructure, morphology, flowability, etc.) of the metal powder and AM parts (Moghimian et al., 2021; Tan et al., 2017). By examining the studies, it was concluded that the changes observed in the particle properties of metal powder and AM parts have various effects on the quality of AM parts.


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Results about the impacts on the quality of AM parts obtained by adopting various AM techniques using recycled or reused metal powder in different studies will be described in Section 3. Besides, it has been determined that there is confusion in the terminological use of recycled and reused powder in some of the studies in the literature, and clear definitions of recycled and reused powder will be made to avoid this terminology confusion in future studies.

This study has developed a conceptual framework that considers the AM from a life cycle perspective to achieve sustainability by investigating the economic and environmental impacts (i.e., CO2 emission, energy consumption, feedstock consumption, feedstock quality, production costs, etc.) of using recycled or reused metal powder as feedstock. Additionally, the terms have been clearly defined to avoid terminology confusion between recycled and reused powder. The remainder of this paper is structured as follows: Section 2 provides the methodology used to obtain a Systematic Literature Review (SLR); in Section 3, the insights from the SLR are presented and discussed; in Section 4, the conceptual framework is described; and in Section 5, the conclusions are presented, together with limitations, and possible future research.

## 2. METHODOLOGY

A Systematic Literature Review (SLR) was conducted following the three-step guideline developed by Tranfield et al. (2003) to develop a conceptual framework to provide clear definitions of recycled powder and reused powder in AM and investigate the impact of using them on AM parts' printing quality and production performance.

Step 1. Planning the Review: The necessary needs for SLR, that is, keywords, strategies, and criteria to be included or excluded, must be determined. Also, the PRISMA protocol (Moher et al., 2009) is adopted as the SLR protocol.

Step 2. Conducting the Review: The review was performed using the PRISMA protocol (see Fig. 1). First, a three-group keyword structure was determined in the Scopus database. In the first group, there are the keywords "additive manufactur*" OR "3D print*", which determine the main subject of SLR; in the second group, "powder," which directs our review to a specific area, and in the last group, there are the keywords "recyc*" OR "reus*," which underlie our review. The search was limited to articles in English only and in the following subject areas; 'engineering', 'material science', 'physics and astronomy', 'environmental science', 'chemical engineering', 'chemistry', and 'energy'. As a result of this initial search, 627 papers were found. These papers were then checked using the following inclusion criteria:

- Journal Articles: Only original research and review articles are taken into consideration.
- Scimago Journal Rank (SJR) Index: Articles published in journals with an SJR index of 1 or higher were considered.
- Full-Text Availability: Articles with full-text availability were taken into consideration.
- Recycled and Reused Powder: Only articles focusing on recycled and reused powder were considered by screening titles and abstracts.

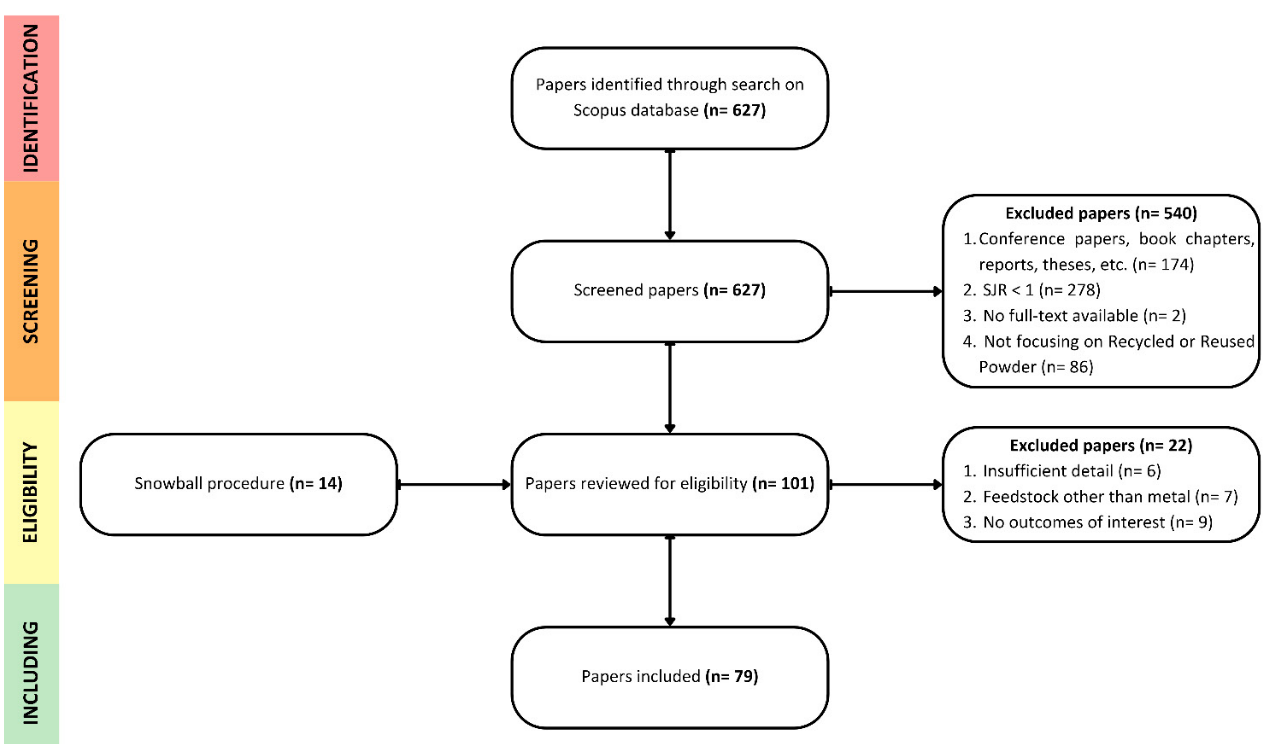


Figure 1. PRISMA protocol diagram

Finally, the snowball procedure was applied by examining the references of the selected articles.

Step 3. Reporting and Dissemination: The distribution of the selected articles by years and the results obtained by examining these articles are presented in Section 3.

## 3. INSIGHTS FROM SYSTEMATIC LITERATURE REVIEW

As a result of the initial search, 627 papers were found. After the identification step, these papers were screened according to inclusion criteria, and the paper set was reduced to 87 journal articles. The full texts of the articles were read to confirm eligibility, and the irrelevant ones (i.e., insufficient detail, feedstock other than metal, or no outcomes of interest) were discarded. With the eligibility step, there are 65 articles left. Lastly, by applying the snowball approach, 14 more articles were considered for review. These new articles were read to check eligibility, leading to 79 articles being included in the SLR.

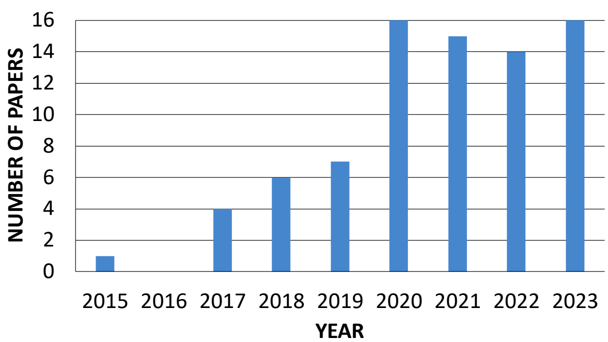


Figure 2. Number of articles per publication year

Recycled and reused metal powder can provide significant advantages for the metal manufacturing industry in ensuring sustainability in AM. Fig. 2 reports the researchers' interest in using recycled or reused metal powder as feedstock in AM has increased over the years. However, it is still seen that the terms recycled and reused metal powder are misused in some studies in the literature. For this reason, clearly defining these two terms below is aimed to avoid terminology confusion that may be encountered in the future.

*Recycled Powder*: It is a metal powder produced by recycling waste from different supply chains, faulty parts produced, and end-of-life parts.

*Reused Powder*: It is the excess metal powder during the AM process and is ready to be reused by passing through the necessary procedures.

Moreover, as presented in Table 1, most of the articles in the literature have been published in journals in the field of material sciences. The detailed review of the articles concluded that the studies focused on the changes in the particle properties of powders when using recycled or reused metal powder in AM. However, to the best of the authors' knowledge, it has been observed that the impacts of these changes in the particle properties of powders on companies from the perspective of operations and supply chain management have never been investigated.

Table 1. Number of articles per journal.

| **Journal** | # |
|---|---|
| Additive Manufacturing | 24 |
| Journal of Materials Research and Technology | 5 |
| Material Science and Engineering A | 5 |
| Materials and Design | 4 |
| Materials Characterization | 4 |
| Powder Technology | 4 |
| JOM | 3 |
| Journal of Cleaner Production | 3 |
| Journal of Manufacturing Process | 3 |
| Acta Materialia | 2 |
| Applied Surface Science | 2 |
| International Journal of Fatigue | 2 |
| Journal of Materials Processing | 2 |
| Advances in Materials and Processing Technology | 1 |
| International Journal of Adv. Manuf. Technologies | 1 |
| Journal of Alloys and Compounds | 1 |
| Journal of Materials Science and Technology | 1 |
| Others | 12 |

Researchers have conducted various studies to examine the impacts of using recycled or reused powder on metal powders' particle properties when processing metal powders in various AM techniques. Ahmed et al. (2020), de Araujo et al. (2021), Emminghaus et al. (2022), Giganto et al. (2022), Graff et al. (2017), Hilzenthaler et al. (2021), Le et al. (2022), Popov et al. (2018), Saboori et al. (2019), and Sutton et al. (2020) investigated the changes in the particle properties of the parts due to the use of recycled and virgin metal powders (Titanium alloys, Aluminium alloys, Inconel, and Stainless steel) in various AM techniques (such as Laser Powder Bed Fusion, Electron Beam Powder Bed Fusion, and Directed Energy Deposition). In these studies, changes in particle properties such as increased oxygen content, lower part density, similar microstructure, more irregular morphology, increased flowability, and no significant change in chemical composition were observed when recycled metal powder was used as feedstock in AM. Cordova et al. (2019), Fiegl et al. (2021), Heiden et al. (2019), Meier et al. (2023), Montelione et al. (2020), Morcos et al. (2023), Paccou et al. (2021), Raza et al. (2021), Tang et al. (2015), and Terrassa et al. (2018) observed that when reused metal powder is employed for AM fabrication, there are changes such as increased oxygen content, particle size distribution, irregular-shaped particles, porosity, and no significant change in mechanical properties and microstructure in the particle properties of the parts.

Nevertheless, each of these studies has focused on different particle properties of the metal powder and has observed the

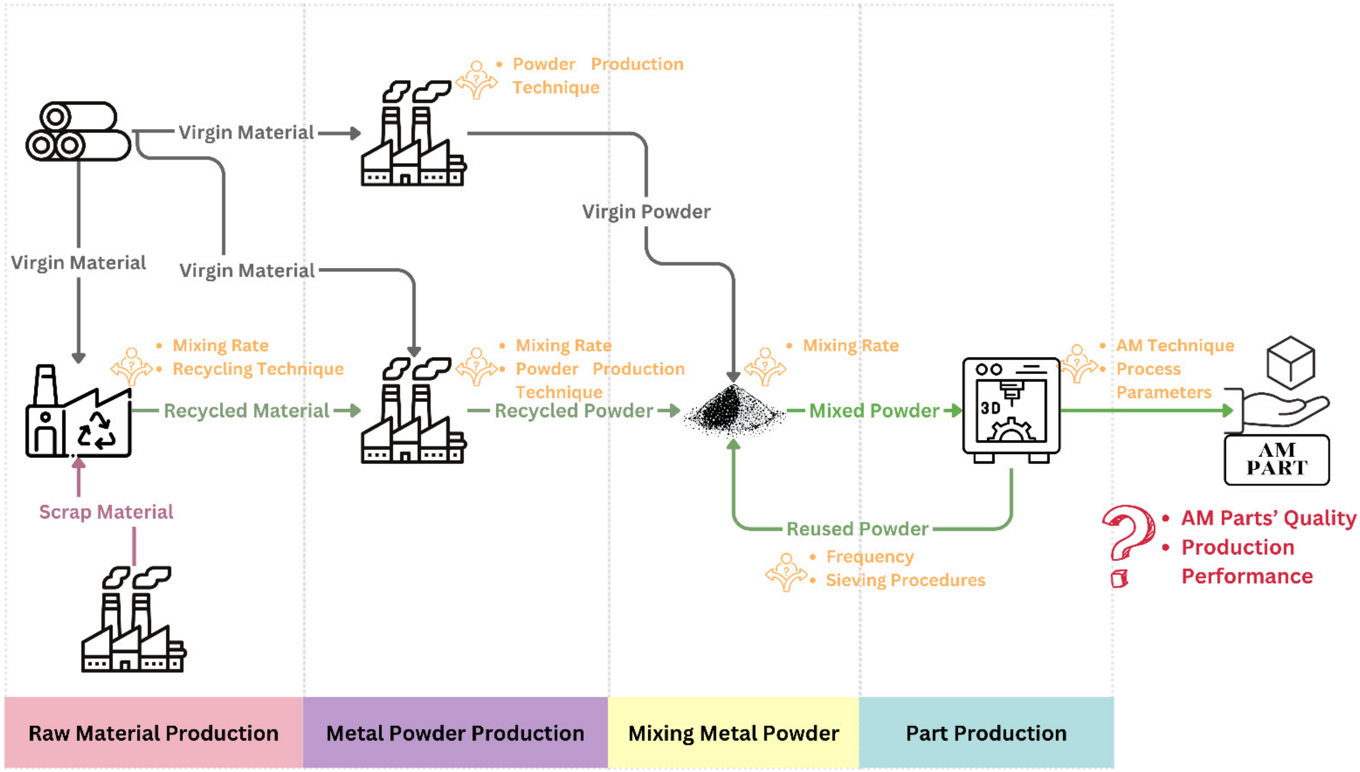


Figure 3. Conceptual framework for circular AM production

changes in particle properties. However, no study in the literature considers the AM parts' printing quality and production performance depending on the changes in the particle properties of metal powders. This study aims to address this gap by developing a conceptual framework to ensure the sustainability of AM with AM parts' high-quality and high production performance (low energy consumption, low raw material consumption, and low $CO_2$e emissions, etc.) printing by using recycled or reused powder from a life-cycle perspective.

## 4. FRAMEWORK

Existing studies indicate that using recycled or reused metal powder in AM provides economic and environmental benefits (Lodha et al., 2023). Although true, drawing a general conclusion without thoroughly examining many important variables for AM, such as production techniques, process parameters and feedstock material, is inaccurate. Besides, using recycled or reused metal powder in AM requires a life cycle perspective to evaluate whether parts meet the necessary printing quality standards.

The life cycle of AM consists of production and transportation phases. This study focused on the production phase to fill the literature gap and encourage practitioners and managers to use recycled or reused metal powder in the AM. To investigate the impact of production decisions at the stages of the production phase on AM parts' printing quality and production performance, a conceptual framework consisting of the following four stages (decision areas) shown in Fig. 3 has been developed:

1. Raw Material Production: This is the stage where it is decided whether the raw material used in metal powder production will be produced from virgin or waste material. In line with this decision, if the production of raw materials with waste materials is adopted, it is necessary to determine which technique will be used to recycle the waste materials and to what extent the waste materials will be mixed with virgin material.
2. Metal Powder Production: This is the stage where it is decided whether the metal powder used in AM will be produced from virgin raw materials or recycled raw materials. Regardless, this decision should determine which technique or process condition will be used for metal powder production. However, supposing producing metal powder with recycled raw materials is adopted, it is necessary to determine in what proportion the recycled raw materials and virgin raw materials will be mixed.
3. Mixing Metal Powder: In this stage a decision is made on which of the virgin metal powder, recycled metal powder, or a mixture of virgin and recycled metal powders will be used for AM. In line with the decision, if the mixture of metal powders will be used in AM, it is necessary to determine in what proportion the recycled metal powder will be mixed with virgin metal powder.
4. Part Production: Part is produced with AM in this stage. First, deciding which AM technique will be adopted in part production is necessary. In addition, it is essential to determine how often and in what

proportion the used powder will be mixed with unused powder for reuse after production.

With the developed framework, the effects of decisions that directly affect the particle properties of parts on companies can be investigated from the perspective of operation and supply chain management. In other words, the impact of using virgin, recycled, and reused powder or their different mixing ratios in AM can be measured on companies. For instance, in the metal powder production stage, it can be observed how the cost and environmental impact on the companies changes when the mixing ratio of recycled material with virgin material is increased from 60% to 70%.

## 5. CONCLUSIONS

While using recycled or reused metal powder in AM provides companies with economic and environmental benefits, it also changes the metal powder's particle properties. Although there have been studies in the literature to investigate the effects of using recycled or reused metal powder on printing quality, there is a clear knowledge gap on the impact of using recycled or reused metal powder on economic and environmental performance by also considering AM parts' performance from the perspective of operation and supply chain management. Therefore, this study aims to fill the existing gap in the literature by developing a conceptual framework to investigate how the decisions taken during the production phase of AM affect the printing quality and production performance of AM parts. In this framework, it has been concluded that the following decisions in the production phase affect the performance of AM by examining the studies in the literature and the stages of AM:

- Decide on the use of virgin materials or the mixture of virgin and waste materials in the production of raw materials. (If raw materials are to be produced from the mixture of materials, determine the mixing ratio and the recycling technique to be adopted.)
- Decide on using virgin or recycled raw materials to produce metal powder and the powder production technique to be adopted in metal powder production. (Determine the mixing ratio of virgin and recycled raw materials if metal powder is to be produced from recycled raw materials.)
- Decide which AM process parameters to adopt and whether to use virgin or recycled metal powder. (If production will be made with recycled metal powder, determine the mixing ratio of recycled and virgin metal powder.)

With the developed framework, the cost and environmental impact of changes in the particle properties of parts due to using recycled or reused metal powder in AM can be investigated. In this regard, mathematical models and decision support systems will be developed in future studies to make the right decisions that will provide suitable conditions for a sustainable AM using recycled or reused metal powder with AM parts' high printing quality and high production performance. However, it is a limitation for us that we do not have access to all the materials that can carry out the experiments to obtain the data needed by mathematical models and decision support systems. In such cases, the reported experimental results in the research studies in open literature will guide us.

## REFERENCES

Abubakr, M., Abbas, A. T., Tomaz, I., Soliman, M. S., Luqman, M., & Hegab, H. (2020). Sustainable and Smart Manufacturing: An Integrated Approach. *Sustainability 2020, Vol. 12, Page 2280*, *12*(6), 2280.

Ahmed, F., Ali, U., Sarker, D., Marzbanrad, E., Choi, K., Mahmoodkhani, Y., & Toyserkani, E. (2020). Study of powder recycling and its effect on printed parts during laser powder-bed fusion of 17-4 PH stainless steel. *Journal of Materials Processing Technology*, *278*.

Alkahtani, M., Omair, M., Khalid, Q. S., Hussain, G., Ahmad, I., & Pruncu, C. (2021). A COVID-19 Supply Chain Management Strategy Based on Variable Production under Uncertain Environment Conditions. *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 1662*, *18*(4), 1662.

Cordova, L., Campos, M., & Tinga, T. (2019). Revealing the Effects of Powder Reuse for Selective Laser Melting by Powder Characterization. *JOM*, *71*(3), 1062–1072.

de Araujo, A. P. M., Pauly, S., Batalha, R. L., Coury, F. G., Kiminami, C. S., Uhlenwinkel, V., & Gargarella, P. (2021). Additive manufacturing of a quasicrystal-forming Al95Fe2Cr2Ti1 alloy with remarkable high-temperature strength and ductility. *Additive Manufacturing*, *41*.

Derimow, N., Benzing, J.T., Kafka, O.L., Moser, N., Pathare, P., Walker, M., DelRio, F.W., Hrabe, N. (2022). Assessment of intra-build variations in tensile strength in electron beam powder-bed fusion Ti–6Al–4V part 2: Effects of powder mixing. *Materials Science and Engineering: A*, *848*.

Emminghaus, N., Bernhard, R., Hermsdorf, J., & Kaierle, S. (2022). Residual oxygen content and powder recycling: effects on microstructure and mechanical properties of additively manufactured Ti-6Al-4V parts. *International Journal of Advanced Manufacturing Technology*, *121*(5–6), 3685–3701.

Fiegl, T., Franke, M., Raza, A., Hryha, E., & Körner, C. (2021). Effect of AlSi10Mg0.4 long-term reused powder in PBF-LB/M on the mechanical properties. *Materials and Design*, *212*.

Giganto, S., Martínez-Pellitero, S., Barreiro, J., & Zapico, P. (2022). Influence of 17-4 PH stainless steel powder recycling on properties of SLM additive manufactured parts. *Journal of Materials Research and Technology*, *16*, 1647–1658.

Graff, P., Ståhlbom, B., Nordenberg, E., Graichen, A., Johansson, P., & Karlsson, H. (2017). Evaluating Measuring Techniques for Occupational Exposure during Additive Manufacturing of Metals: A Pilot Study. *Journal of Industrial Ecology*, *21*, S120–S129.

Grand View Research. (2022). *Metal Powder Market Size, Share & Trends Report, 2030*.

Heiden, M. J., Deibler, L. A., Rodelas, J. M., Koepke, J. R., Tung, D. J., Saiz, D. J., & Jared, B. H. (2019). Evolution of 316L stainless steel feedstock due to laser powder bed fusion process. *Additive Manufacturing*, *25*, 84–103.

Hilzenthaler, M., Bifano, L., Scherm, F., Fischerauer, G., Seemann, A., & Glatzel, U. (2021). Characterization of recycled AISI 904L superaustenitic steel powder and influence on selective laser melted parts. *Powder Technology*, *391*, 57–68.

Huang, S. H., Liu, P., Mokasdar, A., & Hou, L. (2013). Additive manufacturing and its societal impact: A literature review. *International Journal of Advanced Manufacturing Technology*, *67*(5–8), 1191–1203.

International Monetary Fund. (2022). *World Economic Outlook, October 2022: Countering the Cost-of-Living Crisis*.

Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Rab, S. (2021). Role of additive manufacturing applications towards environmental sustainability. *Advanced Industrial and Engineering Polymer Research*, *4*(4), 312–322.

Karimi, N., & Fayazfar, H. (2023). Development of highly filled nickel-polymer feedstock from recycled and biodegradable resources for low-cost material extrusion additive manufacturing of metals. *Journal of Manufacturing Processes*, *107*, 506–514.

Le, T. P., Wang, X., & Seita, M. (2022). An optical-based method to estimate the oxygen content in recycled metal powders for additive manufacturing. *Additive Manufacturing*, *59*, 103127.

Lodha, S., Song, B., Park, S. I., Choi, H. J., Lee, S. W., Park, H. W., & Choi, S. K. (2023). Sustainable 3D printing with recycled materials: a review. *Journal of Mechanical Science and Technology*, *37*(11), 5481–5507.

Meier, B., Warchomicka, F., Ehgartner, D., Schuetz, D., Angerer, P., Wosik, J., Belei, C., Petrusa, J., Kaindl, R., Waldhauser, W., Sommitsch, C. (2023). Toward a sustainable laser powder bed fusion of Ti 6Al 4 V: Powder reuse and its effects on material properties during a single batch regime. *Sustainable Materials and Technologies*, *36*.

Moghimian, P., Poirié, T., Habibnejad-Korayem, M., Zavala, J. A., Kroeger, J., Marion, F., & Larouche, F. (2021). Metal powders in additive manufacturing: A review on reusability and recyclability of common titanium, nickel and aluminum alloys. *Additive Manufacturing*, *43*.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*, *339*(7716), 332–336.

Montelione, A., Ghods, S., Schur, R., Wisdom, C., Arola, D., & Ramulu, M. (2020). Powder Reuse in Electron Beam Melting Additive Manufacturing of Ti6Al4V: Particle Microstructure, Oxygen Content and Mechanical Properties. *Additive Manufacturing*, *35*, 101216.

Morcos, P., Shoukr, D., Sundermann, T., Dobrowolski, T., Barta, N., Jain, J.R., Arróyave, R., Karaman, I., Elwany, A. (2023). An all-encompassing study on the joint effect of powder feedstock characteristics and manufacturing process parameters on the densification and mechanical properties of additively manufactured nickel alloy 718. *Additive Manufacturing*, *78*, 103828.

Muthuswamy, P. (2022). Influence of powder characteristics on properties of parts manufactured by metal additive manufacturing. *Lasers in Manufacturing and Materials Processing*, *9*(3), 312–337.

Paccou, E., Mokhtari, M., Keller, C., Nguejio, J., Lefebvre, W., Sauvage, X., Boileau, S., Babillot, P., Bernard, P., Bauster, E. (2021). Investigations of powder reusing on microstructure and mechanical properties of Inconel 718 obtained by additive manufacturing. *Materials Science and Engineering: A*, *828*.

Peng, T., Kellens, K., Tang, R., Chen, C., & Chen, G. (2018). Sustainability of additive manufacturing: An overview on its energy demand and environmental impact. *Additive Manufacturing*, *21*, 694–704.

Popov, V. V., Katz-Demyanetz, A., Garkun, A., & Bamberger, M. (2018). The effect of powder recycling on the mechanical properties and microstructure of electron beam melted Ti-6Al-4 V specimens. *Additive Manufacturing*, *22*, 834–843.

Prakash, K. S., Nancharaih, T., & Rao, V. V. S. (2018). Additive Manufacturing Techniques in Manufacturing -An Overview. *Materials Today: Proceedings*, *5*(2), 3873–3882.

Raza, A., Fiegl, T., Hanif, I., MarkstrÖm, A., Franke, M., Körner, C., & Hryha, E. (2021). Degradation of AlSi10Mg powder during laser based powder bed fusion processing. *Materials and Design*, *198*.

Saboori, A., Aversa, A., Bosio, F., Bassini, E., Librera, E., De Chirico, M., Biamino, S., Ugues, D., Fino, P., Lombardi, M. (2019). An investigation on the effect of powder recycling on the microstructure and mechanical properties of AISI 316L produced by Directed Energy Deposition. *Materials Science and Engineering: A*, *766*.

Santecchia, E., Spigarelli, S., & Cabibbo, M. (2020). Material Reuse in Laser Powder Bed Fusion: Side Effects of the Laser—Metal Powder Interaction. *Metals 2020, Vol. 10, Page 341*, *10*(3), 341.

Sun, Y., Aindow, M., & Hebert, R. J. (2018). The effect of recycling on the oxygen distribution in Ti-6Al-4V powder for additive manufacturing. *Materials at High Temperatures*, *35*(1–3), 217–224.

Sutton, A. T., Kriewall, C. S., Karnati, S., Leu, M. C., Newkirk, J. W., Everhart, W., & Brown, B. (2020). Evolution of AISI 304L stainless steel part properties due to powder recycling in laser powder-bed fusion. *Additive Manufacturing*, *36*.

Tan, J. H., Wong, W. L. E., & Dalgarno, K. W. (2017). An overview of powder granulometry on feedstock and part performance in the selective laser melting process. *Additive Manufacturing*, *18*, 228–255.

Tang, H. P., Qian, M., Liu, N., Zhang, X. Z., Yang, G. Y., & Wang, J. (2015). Effect of Powder Reuse Times on Additive Manufacturing of Ti-6Al-4V by Selective Electron Beam Melting. *JOM*, *67*(3), 555–563.

Terrassa, K. L., Haley, J. C., MacDonald, B. E., & Schoenung, J. M. (2018). Reuse of powder feedstock for directed energy deposition. *Powder Technology*, *338*, 819–829.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, *14*(3), 207–222.

Yang, S., Tang, Y., & Zhao, Y. F. (2015). A new part consolidation method to embrace the design freedom of additive manufacturing. *Journal of Manufacturing Processes*, *20*, 444–449.