

# Fabrication and Property Comparison Aluminium TiB<sub>2</sub> Composites Manufactured Through Additive Manufacturing and Conventional Manufacturing: a Comparative Review

Rajaneesh N. Marigoudar<sup>1</sup> - ORCID <https://orcid.org/0000-0001-7786-5692>

Received: 11 November 2025 / Revised: 29 January 2026 / Accepted: 18 February 2026

**Abstract:** Additive manufacturing is most emerging techniques of fabricating components with desired dimensions to the near net shape. Metal additive manufacturing is the challenging area and lot of research under progress. In the present review paper, an attempt is made to compare the properties of aluminium reinforced TiB<sub>2</sub> metal matrix composites fabricated through conventional manufacturing technique and also LASER assisted additive manufacturing technique. Bulk composite materials casting (stir casting) is followed for conventional method and layer wise material printing is done in additive manufacturing. Upon fabrication, the specimens are checked for particle distribution using SEM images. It is observed from micrographs that, distribution of reinforcing particles i.e. TiB<sub>2</sub> is fair enough in the composite fabricated through additive manufacturing technique. This influences possessing the uniform properties for further testing. The microhardness of the two different specimens are checked and it is found that, composites manufactured through conventional manufacturing showed higher hardness than composites manufactured through additive manufacturing. Higher composite ductility is observed in additive manufactured specimen.

**Keywords:** aluminium matrix composites, TiB<sub>2</sub>, additive manufacturing, characterization, fabrication, microhardness.

## 1. Introduction

Development of new materials these days to cope up human needs has become common trend. Every day, every hour there are new materials being developed for varieties of applications. The fabrication of newly developed materials as per the required shape, conventional shaping techniques are being used. Casting, machining and forming processes are commonly employed to get the shape for the developed material. The problems faced by these processes directly or indirectly are numerous which leads to increase in the manufacturing cost, reduction in the performance, deviation in the utilizability etc. Many prominent problems associated with shaping and fabrication of alloys and composite materials. With the development in the technology, the applications of aluminium alloys [1]–[2] and aluminium matrix composite reinforced by the particles of SiC [3]–[8], Al<sub>2</sub>O<sub>3</sub> [9], [10], B<sub>4</sub>C [11]–[13], Si<sub>3</sub>N<sub>4</sub> [14], [15],

and carbon nanotubes [16], [17] has significantly increased. Metal based composites are widely used in the aerospace sector [5], [18], electronics industries [15], [20], automotive industry [14], [18], military organizations [21], and any others manufacturing sector. When such wide applications are identified, then there is a scope for research in the area of development and fabrication. To minimize the problems associated with conventional process of fabrication and also shaping, new technology being developed called Additive manufacturing.

Additive manufacturing method is a most advanced fabrication technique to develop the product to the actual shape and size without much losses in the process. Any material, may be monolithic material, alloys, polymer based composites, metal based composites and also concrete products can be shaped as per the requirements and dimensions. The process is well optimized compared to conventional fabrication process. The process is game changer which helps in manufacturing components near net shape with superior quality along with reformed process parameters. Still there are challenges faced by the additive manufacturing process for the fabrication of complex material parts which actually need further research [22], [23].

The processes mentioned in the figure 1 are suitable for manufacturing both polymer based materials and metal

<sup>1</sup> Jain Institute of Technology, Davanagere, Karnataka, India

✉ Rajaneesh N. Marigoudar  
rajaneeshmarigoudar@gmail.com



based materials as well. Specifically the commercially available processes with different trade names such as Selective Laser Melting (SLM), Laser Cusing and Direct Metal Laser Sintering (DMLS). The process which is exceptional in metal additive manufacturing is Electron Beam melting (EBM) process where the process is carried out under vacuum. All the processes mentioned are very much suitable for metal based manufacturing of products. The rest of the processes shown in the fig. 1 are for polymer based and other categories of materials.

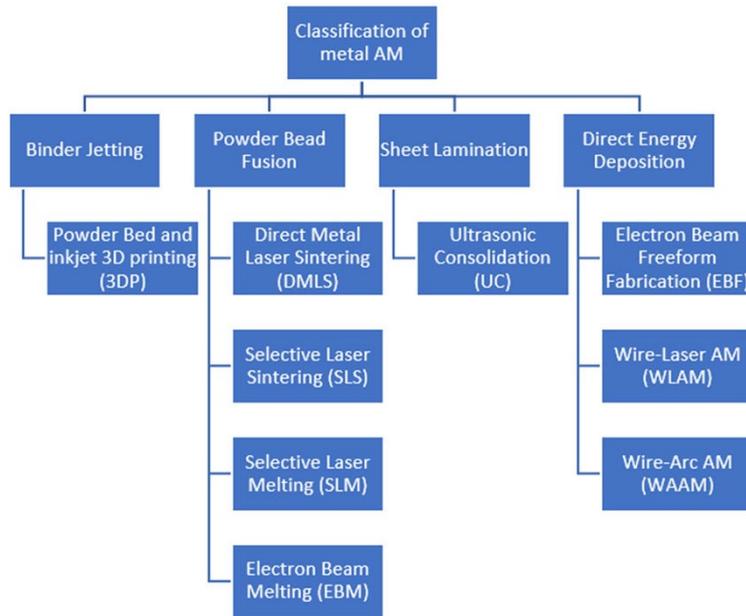


Fig. 1. Classification of Metal additive manufacturing [14]

Metal matrix composites show extremely superior properties compared to monolithic materials. By reinforcing hard reinforcement in to the matrix make is strong and available for varieties of applications. Aluminium based composites are the special category of composites which show light weight and high strength and finds wide applications. Metal based composites are fabricated by conventional methods and also by adopting advanced technology i.e. Additive manufacturing method. The present paper emphasize property comparison of aluminium based composites manufactured by additive manufacturing and conventional manufacturing [24]–[29].

## 2. Materials and Manufacturing

Aluminium based composite fabrication is done using conventional stir casting method. The process in which weighed amount of aluminium ingots are taken in the graphite crucible and heated till melt is formed. The molten mass is stirred using stainless steel stirrer coated with refractory material which prevent diffusion of stirrer material in to the molten metal. The stirring is continued till molten metal whirl is formed inside the crucible. The pre heated TiB<sub>2</sub> particles size between 5 μm to 10 μm up to 600 °C is

introduced in to the molten metal whirl for proper distribution. Pre heating is done to break the protective coating around the ceramic particles which will improve the wettability between molten metal and reinforcing particles.

Once it is assured that particles are distributed evenly in the molten metal, immediately the molten mixture is transferred in to the metallic dies of suitable dimensions. The poured mass is allowed to attain the room temperature with proper solidification. Six different specimen with 0 %, 1 %, 2 %, 3 %, 4 % and 5 % were fabricated by mentioned process. The solidified specimen is taken out from the die and subjected to further testing methods [30], [31].

The micrographs of the fabricated specimen shows uniform distribution of reinforcing particles. At certain portions of the specimen reinforcing particles get clustered up due to variations in the density level of the materials. In some cases, formation of voids or blow holes in the specimen which is a common type of defect noticed in the conventional fabrication processes. To get precise testing results, the fabricated specimen is subjected to extrusion process or equal channel angular processing process. By these processes, the extent of voids or blow holes can be minimized [22], [23].

Aluminium matrix composites fabricated through additive manufacturing route shows different path for the manufacturing of critical components to near shape. For comparison of fabrication processes, laser metal deposition process is considered. In this process, high power laser beam is used for the melting of powders. The following fig. 2 shows the coaxial laser deposition additive manufacturing process in which laser and metal powder and also reinforcement are deposited on a strong base.

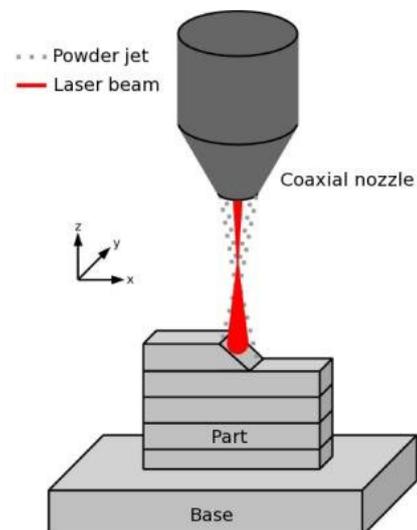


Fig. 2. Working principle of coaxial laser metal deposition process

Aluminium powder of average particle size of  $60\ \mu\text{m}$  to  $80\ \mu\text{m}$  was used and average particle size of  $\text{TiB}_2$  between  $5\ \mu\text{m}$  to  $10\ \mu\text{m}$  was used for the fabrication process. The powdered material when come in contact with high energy containing laser, it melts and get deposited on the substrate. During the process of molten metal deposition, the reinforcement particles are sprayed through same nozzle on the deposited metal layer. Layer by layer deposition of metal powder and reinforcement powder is executed till desired thickness of the product is achieved. The fabrication process is carried out under argon atmosphere using laser 150 device. The variables set for the fabrication process are laser power of 450 W, hatch spacing  $50\ \mu\text{m}$ , laser beam spot size of  $70\ \mu\text{m}$ , layer thickness of  $50\ \mu\text{m}$ , scans peed range between 1600 to 2600 mm/s with a constant step of 200 mm/s [24].

Relative movement of the cladding head is made with machine table as per the composite specimen configuration. Almost near to final shape of the specimen can be fabricated by the process and no need of any further machining process. The process of laser metal deposition starts with formation of line later developed as surface and finally a 3 dimensional product can be achieved. The process of laser metal deposition is carried out under argon environment to prevent product from oxidation process [25]–[29].

Aluminium –  $\text{TiB}_2$  composites with 0 %, 1 %, 2 %, 3 %, 4 % and 5 % reinforcement were fabricated by LASER additive manufacturing process. Specimens from both the manufacturing techniques are prepared for the microstructure analysis following the standard metallographic procedure. The polished specimen is etched with Keller's reagent for clear visibility of reinforcing particles. The micrographs are taken from both the composite specimen and further examined. Microhardness measurements are performed using HXS-1000AY Vickers indenter with a load of 200 g with indentation time of 15 seconds. The average value of microhardness is considered by testing at 15 points on the specimen.

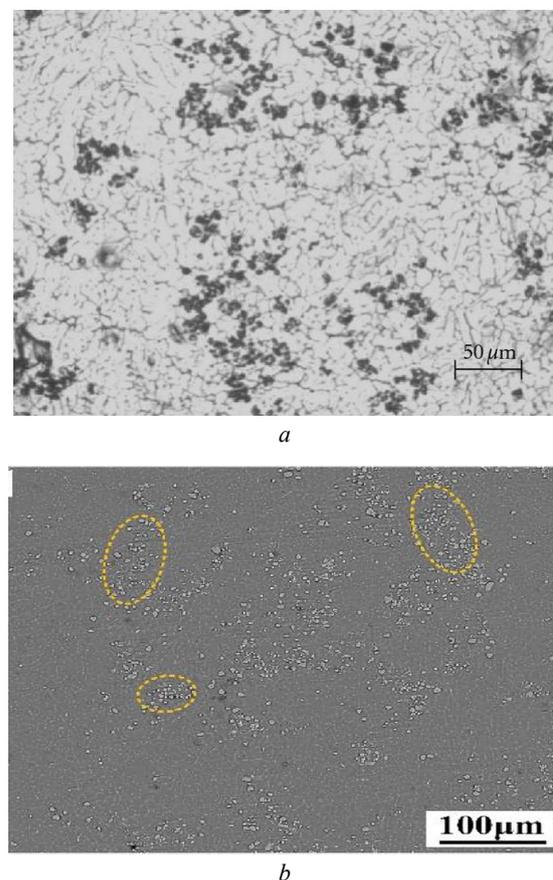
### 3. Microstructure evaluation

The fabricated specimen is observed under metallurgical microscope for the distribution of reinforcing particles. For all  $\text{TiB}_2$  reinforcing concentrations in to the aluminium matrix, observations are made. For better visibility and detailed information SEM micrographs of the composite specimen are taken and analysed. The following fig. 3 shows the SEM micrographs of aluminium  $\text{TiB}_2$  composites fabricated through conventional stir casting method and also additive manufacturing process.

Fig. 3 *a* shows SEM micrograph of aluminium  $\text{TiB}_2$  composite specimen fabricated through stir casting process. It is observed from the micrograph that, composite specimen fabricated by stir casting shows fair distribution of reinforcing material. Dark black colored entities indicates  $\text{TiB}_2$  particles and grey colored portion indicates aluminium matrix. At some portions clustering of the particles is noticed along with some blow holes in the specimen. Even

after taking at-most care, blow hole formation and clustering of the particles in the composite specimen do happen in the stir casting process. Such variations in the metal based composites may leads to variations in the properties either during testing or in the product in the final assembly.

Fig. 3 *b* shows SEM micrograph of a aluminium  $\text{TiB}_2$  composite specimen fabricated through Additive manufacturing technique. It can be observed from from SEM micrograph that relatively fair distribution of  $\text{TiB}_2$  particles in the aluminium matrix. Here also clustering of the  $\text{TiB}_2$  particles are noticed. Comparatively minimum clustering of the reinforcing particles is noticed and also moderately less blow holes formation is observed in the fabricated specimen. Due to this condition, the fabricated composite can be considered practically isotropic. By subjecting this specimen to any testing method, consistent and accurate results can be obtained.



**Fig. 3.** Micrographs of aluminium  $\text{SiC}$  specimen fabricated through: *a* – stir casting [22]; *b* – additive manufacturing [23]

By overall observations of SEM micrographs obtained from both the fabricated composites that, both conventional fabrication and additive manufacturing methods results in composites with good particle distribution. Good bonding between matrix and reinforcement material is also observed in both cases. Compared to conventional stir casting method, a slight better particle distribution is noticed in additive manufacturing technique. Extent of blow hole formation in the fabricated specimen is more in the case of

conventional fabrication process. In stir casting, while stirring the molten metal using mechanical stirrer, air get trapped inside the molten metal leading to blow hole formation. There may be another reason that while pouring the particles in to the molten metal, air get trapped in the matrix results in blow hole formation. But in additively manufactured composites, the extent of blow hole formation is very less. By comparing both SEM micrographs, it is observed that Additively manufactured aluminium based composite has more positive points than conventionally manufactured composites [22], [23].

The specimen from both fabricating techniques are subjected to microhardness testing method to check the performance level of the material. In this review microhardness values of both the materials are compared. The comparative results are presented in the following section [32]–[38].

#### 4. Microhardness testing

Fig. 4 depicts the microhardness values of aluminium TiB<sub>2</sub> composites with reinforcement variation from 0 % to 4 % in the step of 1 %. Both conventional manufactured and additive manufactured composite specimen are subjected to microhardness testing process and results are compared.

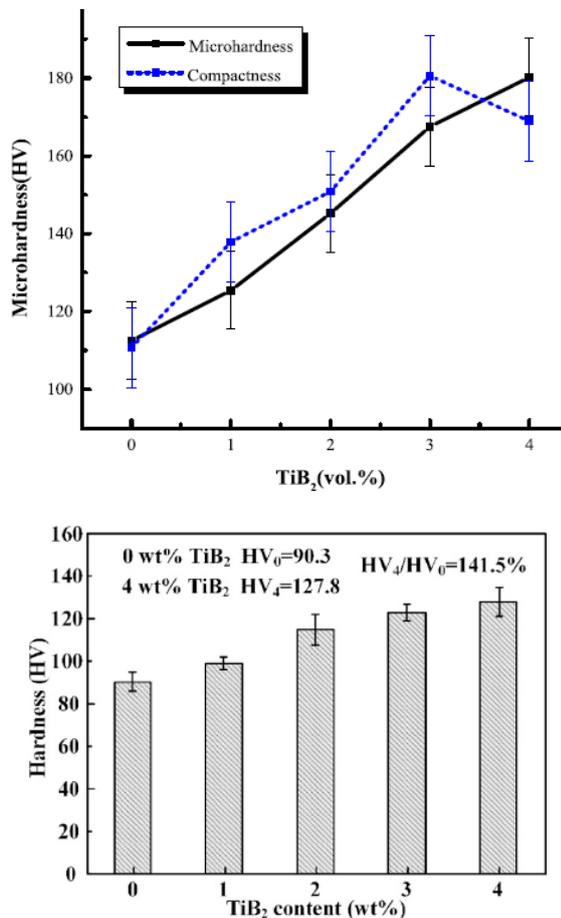


Fig. 4. Microhardness of Aluminium TiB<sub>2</sub> composite fabricated by (1) Conventional manufacturing process [37] (2). Laser Additive manufacturing process [38]

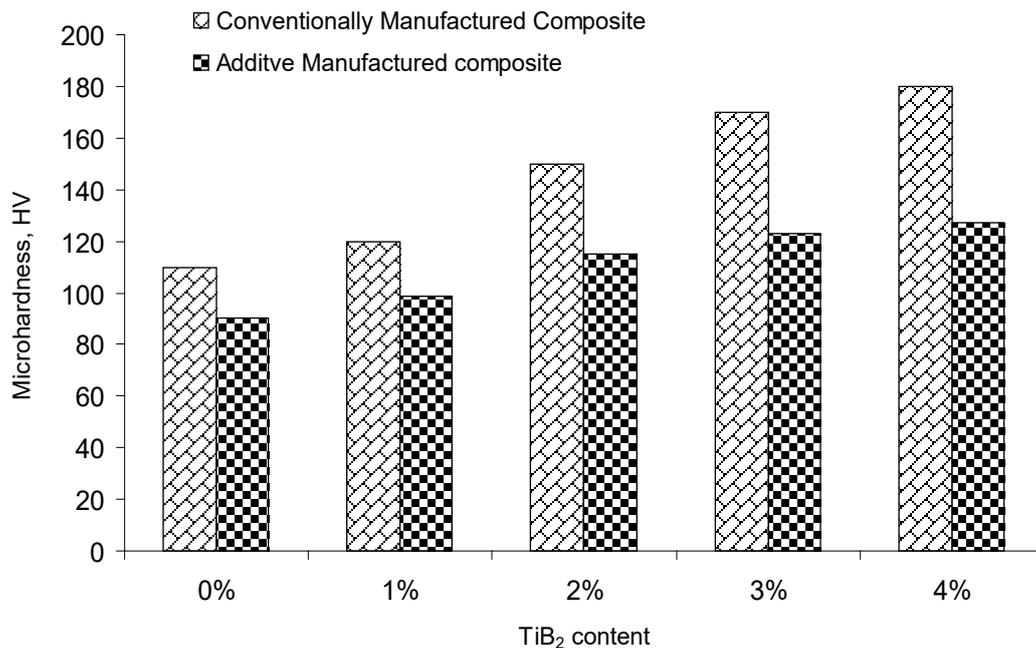
H. M. Wand et. al. [37] fabricated TiB<sub>2</sub> (average particle size of 10  $\mu$ m) reinforced aluminium composite material and tested the material for different properties. The conventionally fabricated specimen is subjected to microhardness testing procedure and results are presented in fig. 4 (1). The fabrication of composite specimen is done varying TiB<sub>2</sub> percentage in the steps of 1 %. The alloy without reinforcement shows hardness value of 110 HV and with addition of 1 % TiB<sub>2</sub>, increased hardness of 120 HV is noticed. For specimen with 2 % reinforcement, 150 HV, for 3 %, 170 HV and for 4 % reinforcement maximum of 180 HV is noticed. As reinforcement concentration is increased in the alloy, hardness of the specimen increases correspondingly.

B. Jiang [38] et. al. fabricated aluminium reinforced with TiB<sub>2</sub> particulate metal matrix composites by additively manufacturing technique i.e. LASER melt deposition. The influence of particle content on the variation of micro-hardness is shown in fig. 4 (2). Specimen without containing TiB<sub>2</sub> reinforcement shows hardness of 90.3 HV. 1 % TiB<sub>2</sub> is introduced and the hardness measured to be 98.9 HV. Reinforcement is increased to 2 % which resulted in hardness of 115.3 HV. Further increasing the TiB<sub>2</sub> to 3 % and 4 % shows the hardness values of 122.7 HV and 127.8 HV respectively. Nearly 41 % increase in the hardness is noticed between unreinforced and 4 % reinforced specimen.

Fig. 5 clearly compares the microhardness values between conventional and additive manufactured composites. By observing the results of the both the experimental values, it is clear that the hardness values are higher for conventionally fabricated composites than additively manufactured composites. The trend for both the categories shows increasing with increased reinforcement content.

In conventional fabrication process of aluminium composites, the introduction of ceramic particles stops the growth of dislocations. This leads to increased microhardness in the respective composite specimen. The other reasons for increased microhardness may be due to introduction of dislocations in composites during cooling process which causes difference in thermal expansion coefficient of matrix and reinforcement material [39]–[51].

In additively manufactured aluminium composites, as reinforcement come in contact with the molten matrix, grain refinement process takes place leading to fine grain structure. Many recrystallized grains formed during the process which indicate the increase in hardness value because of grain refinement. Sub grain formation and fraction of low angle grain boundaries are formed as reinforcement percentage in the composite increases. This fine-grained material exhibit less occurrence of twins and increases the dynamic recovery through enhancing the activity of prismatic slip leading to high ductility. Hence lower hardness and improved ductility is noticed for the additive manufactured aluminium composite than conventional manufactured composite material. Compared to conventionally fabricated composites, additive manufactured composites possess good ductile property [52]–[65]. Remelting of aluminium in the process leads to further increase in the ductility of the matrix where composite material gains several advantages [21].



**Fig. 5.** Comparison of microhardness of conventionally manufactured and additively manufactured composites [37], [38]

## Conclusions

In the present review process, comparison is made between aluminium based composites fabricated by conventional stir casting technique and also by Laser melt deposition process. It is observed that there is a lot of scope for the material characterization of additively manufactured composites. Not much experimental evaluation of material fabricated through additive manufacturing technique is being done and very minimum data is available for comparison. With available resources, systematically some of the parameters are compared between aluminium based composite material. Overall, this review establishes a direct comparison between the structural and mechanical properties of a aluminium-TiB<sub>2</sub> composites fabricated through conventional stir casting and those produced via laser-based additive manufacturing. The analysis shows that conventional fabrication generally yields higher hardness, whereas additive manufacturing offers improved ductility and more uniform particle distribution, highlighting the distinct performance trends associated with each fabrication route. Further observations of the review process are as follows

1. The fabrication of aluminium TiB<sub>2</sub> composites with different percentages ranging from 0 % to 4 % of reinforcement is carried out using two different techniques. Conventional method of fabrication and also Laser Metal deposition techniques are followed for obtaining the test specimen

2. As per ASTM standards test specimen were fabricated containing reinforcement weight percentages 0 %,

1 %, 2 %, 3 %, and 4 %. All fabricated specimen were subjected to microhardness testing procedure

3. The SEM micrographs of both the specimen were examined for the distribution of reinforcement distribution. It is very clear from the micrographs that, composite fabricated through Laser metal deposition technique shows better distribution of reinforcing particles than conventional fabrication technique. In conventional fabricated composite, clustering of particles is noticed along with blow hole formation. That is not observed in the case of additive manufactured composite.

4. Microhardness test is done on both composites, conventional stir casted composite showed higher hardness than additively manufactured composites. Good ductility is observed in additively manufactured composites. Increasing hardness trend is noticed in both materials, but conventionally fabricated composite shows higher microhardness value.

5. Additive manufactured metal matrix composites retain softness which is advantageous in many applications where sudden failure of the part can be avoided.

## Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship, or any other nature that could affect the research and its results presented in this article.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

## References

- [1] A. K. Pandey, S. Chatterjee and S. S. Mahapatra, “Analysis and characterisation of weld quality during butt welding through friction stir welding,” *Indian Journal of Engineering and Material Sciences*, Vol. 26, pp. 298–310, 2019.
- [2] A. T. Kermanidis, “Aircraft aluminum alloys: applications and future trends. In: Revolutionizing aircraft materials and processes,” *Springer International Publishing*, pp. 21–55, 2020, doi: [https://doi.org/10.1007/978-3-030-35346-9\\_2](https://doi.org/10.1007/978-3-030-35346-9_2).
- [3] A. K. Bodukuri, K. Eswaraiiah, K. Rajendar and V. Sampath, “Fabrication of Al–SiC–B<sub>4</sub>C metal matrix composite by powder metallurgy technique and evaluating mechanical properties,” *Perspectives in Science*, Vol. 8, pp. 428–431, 2016, doi: <https://doi.org/10.1016/j.pisc.2016.04.096>.
- [4] S. Pradhan, S. Ghosh, T. K. Barman and P. Sahoo, “Tribological behavior of Al–SiC metal matrix composite under dry, aqueous and alkaline medium,” *Silicon*, Vol. 9, pp. 923–931, 2017, doi: <https://doi.org/10.1007/s12633-016-9504-y>.
- [5] P. K. Jain, P. Baredar and S. C. Soni, “Development of silicon carbide particle reinforced aluminium 6101 metal matrix composite using two-step stir casting,” *Materials Today Proceedings*, Vol. 18, pp. 3521–3525, 2019, doi: <https://doi.org/10.1016/j.matpr.2019.07.281>.
- [6] Essam A. M. Shalaby et al., “A comparative study of thermal conductivity and tribological behavior of squeeze cast A359/AlN and A359/SiC composites,” *Journal of Materials Engineering and Performance*, Vol. 26, pp. 3079–3089, 2017, doi: <https://doi.org/10.1007/s11665-017-2734-3>.
- [7] E. A. Mohamed and A. Y. Churyumov, “Investigation of the microstructure and properties of Al–Si–Mg/SiC composite materials produced by solidification under pressure,” *The Physics of Metals and Metallography*, Vol. 117, pp. 1054–1060, 2016, doi: <https://doi.org/10.1134/S0031918X16100070>.
- [8] A. Zulfia, K. Raga, W. Narottama and S. Yunus, “Al 6061 reinforced Al<sub>2</sub>O<sub>3</sub> metal matrix composite produced by double blade stir casting,” *International Journal on Advanced Science Engineering and Information Technology*, Vol. 9, pp. 1544–1549, 2019, doi: <https://doi.org/10.18517/ijaseit.9.5.8611>.
- [9] B. Behera, R. Dalai, D. K. Mishra and S. K. Badjena, “Development and characterisation of Al<sub>2</sub>O<sub>3</sub> and SiC reinforced Al–Cu metal matrix hybrid composites,” *Materials Science Forum*, Vol. 978, pp. 202–208, 2020, doi: <https://doi.org/10.4028/www.scientific.net/MSF.978.202>.
- [10] A. V. Pozdniakov, A. Lotfy, A. Qadir and V. S. Zolotarevskiy, “Effect of the B<sub>4</sub>C content on the structure and thermal expansion coefficient of the Al–5% Cu alloy-based metal-matrix composite material,” *The Physics Metals and Metallography*, Vol. 117, pp. 783–788, 2016, doi: <https://doi.org/10.1134/S0031918X16060107>.
- [11] A. V. Pozdniakov et al., “Development of Al–5Cu/B<sub>4</sub>C composites with low coefficient of thermal expansion for automotive application,” *Material Science and Engineering A*, Vol. 688, pp. 1–8, 2017, doi: <https://doi.org/10.1016/j.msea.2017.01.075>.
- [12] A. V. Pozdniakov et al., “Microstructure and material characterisation of 6063/ B<sub>4</sub>C and 1545K/B<sub>4</sub>C composites produced by two stir casting techniques for nuclear applications,” *Journal of Alloys and Compounds*, Vol. 664, pp. 317–320, 2016, doi: <https://doi.org/10.1016/j.jallcom.2015.12.228>.
- [13] A. Lotfy et al., “Novel preparation of Al–5%Cu / BN and Si<sub>3</sub>N<sub>4</sub> composites with analysing microstructure, thermal and mechanical properties,” *Materials Characterization*, Vol. 136, pp. 144–151, 2018, doi: <https://doi.org/10.1016/j.matchar.2017.12.015>.
- [14] Essam A. M. Shalaby, A. Churyumov, D. Besisa, A. N. Solonin and A. Lotfy, “Preparation and characterisation of hybrid A359/(SiC+Si<sub>3</sub>N<sub>4</sub>) composites synthesised by stir/squeeze casting techniques”, *Materials Science and Engineering A*, Vol. 674, pp. 18–24, 2016, doi: <https://doi.org/10.1016/j.msea.2016.07.058>.
- [15] J. L. Z. Li et al., “Review of Wire Arc Additive Manufacturing for 3D Metal Printing”, *International Journal of Automation Technology*, Vol. 13, pp. 346–353, 2019, doi: <https://doi.org/10.20965/ijat.2019.p0346>.
- [16] Aniruddha S. Patil, Vijay D. Hiwarkar, Pankaj K. Verma and Rajesh K. Khatirkar, “Effect of TiB<sub>2</sub> addition on the microstructure and wear resistance of Ti–6Al–4V alloy fabricated through direct metal laser sintering (DMLS),” *Journal of Alloys and Compounds*, Vol. 777, pp. 165–173, 2019, doi: <https://doi.org/10.1016/j.jallcom.2018.10.308>.
- [17] S. Poria, G. Sutradhar and P. Sahoo, “High Temperature Tribological behaviour of Stir cast Al–TiB<sub>2</sub> Metal Matrix Composites”, *Surface Review and Letters*, Vol. 25, No. 08, 1850122, pp. 1–18, 2018, doi: <https://doi.org/10.1142/S0218625X18501226>.
- [18] S. Pan et al., “Metal matrix nanocomposites in tribology: Manufacturing, performance, and mechanisms,” *Friction*, Vol. 10, pp. 1596–1634, 2022, doi: <https://doi.org/10.1007/s40544-021-0572-7>.
- [19] J. Jue, D. Gu, K. Chang and D. Dai, “Microstructure evolution and mechanical properties of Al–Al<sub>2</sub>O<sub>3</sub> composites fabricated by selective laser melting,” *Powder Technology*, Vol. 310, pp. 80–91, 2017, doi: <https://doi.org/10.1016/j.powtec.2016.12.079>.
- [20] Q. Han et al., “Macro and nanoscale wear behaviour of Al–Al<sub>2</sub>O<sub>3</sub> nanocomposites fabricated by selective laser melting,” *Composites Part B: Engineering*, Vol. 127, pp. 26–35, 2017, doi: <https://doi.org/10.1016/j.compositesb.2017.06.026>.
- [21] Y. Zhoua, L. Duan, S. Wen, Q. Wei and Y. Shi, “Enhanced micro-hardness and wear resistance of Al–15Si/TiC fabricated by selective laser melting,” *Composites Communications*, Vol. 10, pp. 64–67, 2018, doi: <https://doi.org/10.1016/j.coco.2018.06.009>.
- [22] Rajesh Kumar Bhushan, “Effect of SiC particle size and weight % on mechanical properties of AA7075 SiC composite”, *Advanced Composites and Hybrid Materials*, Vol. 4, pp. 74–85, 2021, doi: <https://doi.org/10.1007/s42114-020-00175-z>.

- [23] M. Khomutov et al., "Structure and properties of AA7075-SiC composite parts produced by cold spray additive manufacturing," *The International Journal of Advanced Manufacturing Technology*, Vol. 116, pp. 847–861, 2021, doi: <https://doi.org/10.1007/s00170-021-07457-w>.
- [24] L. Xi, et al., "Microstructure development, tribological property and underlying mechanism of laser additive manufactured submicro-TiB2 reinforced Al-based composites," *Journal of Alloys and Compounds*, Vol. 819, article number 152980, 2020, doi: <https://doi.org/10.1016/j.jallcom.2019.152980>.
- [25] S. Lathabai, "Additive Manufacturing of Aluminium-Based Alloys and Composites," *Fundamentals of Aluminium Metallurgy*, pp. 47–92, 2018, doi: <https://doi.org/10.1016/B978-0-08-102063-0.00002-3>.
- [26] H. Xie et al., "Selective laser melting of SiCp/Al composites: Densification, microstructure, and mechanical and tribological properties," *Ceramics International*, Vol. 47, pp. 30826–30837, 2021, doi: <https://doi.org/10.1016/j.ceramint.2021.07.263>.
- [27] L. Xi et al., "Grain refinement in laser manufactured Al-based composites with TiB2 ceramic," *Journal of Materials Research and Technology*, Vol. 9, pp. 2611–2622, 2020, doi: <https://doi.org/10.1016/j.jmrt.2020.04.059>.
- [28] S. Pfeiffer et al., "Direct laser additive manufacturing of high performance oxide ceramics: A state-of-the-art review," *Journal of the European Ceramic Society*, Vol. 41, pp. 6087–6114, 2021, doi: <https://doi.org/10.1016/j.jeurceramsoc.2021.05.035>.
- [29] M. B. Abrami et al., "High Temperature Wear Behavior of AlMgScZr Alloy Produced By Laser Powder Bed Fusion," *Procedia Structural Integrity*, Vol. 33, pp. 878–886, 2021, doi: <https://doi.org/10.1016/j.prostr.2021.10.098>.
- [30] H. Tan et al., "Direct metal deposition of TiB2/AlSi10Mg composites using satellited powders," *Materials Letters*, Vol. 214, pp. 123–126, 2018, doi: <https://doi.org/10.1016/j.matlet.2017.11.121>.
- [31] X. Xi et al., "Microstructure and mechanical properties of SiC reinforced AlSi10Mg composites fabricated by laser metal deposition," *Journal of Manufacturing Processes*, Vol. 58, pp. 763–774, 2020, doi: <https://doi.org/10.1016/j.jmapro.2020.08.073>.
- [32] X. Wen et al., "Laser solid forming additive manufacturing TiB2 reinforced 2024Al composite: microstructure and mechanical properties," *Materials Science and Engineering: A*, Vol. 745, pp. 319–325, 2019, doi: <https://doi.org/10.1016/j.msea.2018.12.072>.
- [33] P. He et al., "Elevated temperature mechanical properties of TiCN reinforced AlSi10Mg fabricated by laser powder bed fusion additive manufacturing," *Materials Science & Engineering A*, Vol. 811, pp. 141025, 2021, doi: <https://doi.org/10.1016/j.msea.2021.141025>.
- [34] B. Jiang et al., "Microstructure and mechanical properties of TiB2- reinforced 7075 aluminum matrix composites fabricated by laser melting deposition," *Ceramics International*, Vol. 45, pp. 5680–5692, 2019, doi: <https://doi.org/10.1016/j.ceramint.2018.12.033>.
- [35] A. Kumar et al., "An investigation on wear characteristics of additive manufacturing materials," *Materials Today: Proceedings*, Vol. 47, pp. 3654–3660, 2021, doi: <https://doi.org/10.1016/j.matpr.2021.01.263>.
- [36] A. Coyal, N. Yuvaraj, R. Butola and L. Tyagi, "An experimental analysis of tensile, hardness and wear properties of aluminium metal matrix composite through stir casting process," *SN Applied Sciences*, Vol. 2, article number 892, 2020, doi: <https://doi.org/10.1007/s42452-020-2657-8>.
- [37] B. Q. Shi, R. S. Chen and W. Ke, "Influence of grain size on the tensile ductility and deformation modes of rolled Mg–1.02 wt.% Zn alloy," *Journal of Magnesium and Alloys*, Vol. 1, pp. 210–216, 2013, doi: <https://doi.org/10.1016/j.jma.2013.09.001>.
- [38] L. Zhenglong et al., "Effect of TiB2 content on microstructural features and hardness of TiB2/AA7075 composites manufactured by LMD," *Journal of Manufacturing Processes*, Vol. 53, pp. 283–292, 2020, doi: <https://doi.org/10.1016/j.jmapro.2020.02.036>.
- [39] H. M. Wang et al., "Effect of TiB2 content on microstructure and mechanical properties of (TiB2p + B4Cp)/Al composites fabricated by microwave sintering," *Journal of Materials Research and Technology*, Vol. 13, pp. 1509–1520, 2021, doi: <https://doi.org/10.1016/j.jmrt.2021.05.084>.
- [40] A. A. Annaz, S. S. Irhayyim, M. L. Hamada and H. Sh. Hammood, "Comparative study of mechanical performance between Al–Graphite and Cu–Graphite self-lubricating composites reinforced by nano-Ag particles," *AIMS Materials Science*, Vol. 7, pp. 534–551, 2020, doi: <https://doi.org/10.3934/mat.2020.5.534>.
- [41] D. K. Das, P. C. Mishra, S. Singh and R. K. Thakur, "Properties of ceramic-reinforced aluminium matrix composites - a review," *International Journal of Mechanical and Materials Engineering*, Vol. 9, pp. 1–12, 2014, doi: <https://doi.org/10.1186/s40712-014-0012-9>.
- [42] G. Mahajan et al., "Analysis of Microstructure, Hardness and Wear of Al-SiC-TiB2 Hybrid Metal Matrix Composite," *Indian Journal of Science and Technology*, Vol 8, pp. 101–105, 2015, doi: <https://doi.org/10.17485/ijst/2015/v8iS2/59081>.
- [43] T. Zhaoa et al., "Laser metal deposition for additive manufacturing of AA5024 and nanoparticulate TiC modified AA5024 alloy composites prepared with balling milling process," *Optics and Laser Technology*, Vol. 131, article number 106438, 2020, doi: <https://doi.org/10.1016/j.optlastec.2020.106438>.
- [44] I. A. Pelevin et al., "Selective Laser Melting of Al-Based Matrix Composites with Al2O3 Reinforcement: Features and Advantages," *Materials*, Vol. 14, pp. 1–17, 2021, doi: <https://doi.org/10.3390/ma14102648>.
- [45] J. Shi and Y. Wang, "Development of metal matrix composites by laser assisted additive manufacturing technologies: a review," *Journal of Materials Science*, Vol. 55, pp. 9883–9917, 2020, doi: <https://doi.org/10.1007/s10853-020-04730-3>.

- [46] S. M. Storck et al., “Metal Matrix Composites synthesised with Laser based Additive Manufacturing,” *Johns Hopkins APL Technical Digest*, Vol. 35, pp. 409–413, 2021, <https://secwww.jhuapl.edu/techdigest/content/techdigest/pdf/V35-N04/35-04-Storck.pdf>.
- [47] T. Tarasova, G. Gvozdeva and R. Ableyeva, “Aluminium Matrix Composites Produced by Laser Based Additive Manufacturing”, *Materials Today: Proceedings*, Vol. 11, pp. 305–310, 2019, doi: <https://doi.org/10.1016/j.matpr.2018.12.149>.
- [48] B. Chen, X. Xi, C. Tan and X. Song, “Recent progress in laser additive manufacturing of aluminum matrix composites”, *Current Opinion in Chemical Engineering*, Vol. 28, pp. 28–35, 2020, doi: <https://doi.org/10.1016/j.coche.2020.01.005>.
- [49] M. Dadkhah, M. H. Mosallanejad, L. Iuliano and A. Saboori, “A Comprehensive Overview on the Latest Progress in the Additive Manufacturing of Metal Matrix Composites: Potential, Challenges, and Feasible Solutions”, *Acta Metallurgica Sinica*, Vol. 34, pp. 1173–1200, 2021, doi: <https://doi.org/10.1007/s40195-021-01249-7>.
- [50] M. Khomutov et al., “Structure and properties of AA7075-SiC composite parts produced by cold spray additive manufacturing,” *The International Journal of Advanced Manufacturing Technology*, Vol. 116, pp. 847–861, 2021, doi: <https://doi.org/10.1007/s00170-021-07457-w>.
- [51] E. Fereiduni and M. Elbestawi, “Process-Structure-Property Relationships in Additively Manufactured Metal Matrix Composites,” *Additive Manufacturing of Emerging Materials*, pp. 111–177, 2018, doi: [https://doi.org/10.1007/978-3-319-91713-9\\_4](https://doi.org/10.1007/978-3-319-91713-9_4).
- [52] J. K. Tiwari et al., “Novel approach for micrographical investigation of graphene in additively manufactured graphene/AlSi10Mg composite”, *Materials Letters*, Vol. 284, article number 128923, 2021, doi: <https://doi.org/10.1016/j.matlet.2020.128923>.
- [53] M. Prasad Behera, T. Dougherty, S. Singamneni and K. De Silva, “Selective laser melting of aluminium metal-matrix composites and the Challenges”, *Materials Today: Proceedings*, Vol. 33, pp. 5729–5733, 2020, doi: <https://doi.org/10.1016/j.matpr.2020.05.086>.
- [54] R. Rahmani, M. Brojan, M. Antonov and K. G. Prashanth, “Perspectives of metal-diamond composites additive manufacturing using SLM-SPS and other techniques for increased wear-impact resistance”, *International Journal of Refractory Metals and Hard Materials*, Vol. 88, article number 105192, 2020, doi: <https://doi.org/10.1016/j.ijrmhm.2020.105192>.
- [55] B. Blakey-Milner et al., “Metal additive manufacturing in aerospace: A review”, *Materials & Design*, Vol. 209, article number 110008, 2021, doi: <https://doi.org/10.1016/j.matdes.2021.110008>.
- [56] T. Tarasova, G. Gvozdeva and R. Ableyeva, “Aluminium Matrix Composites Produced by Laser Based Additive Manufacturing”, *Materials Today: Proceedings*, Vol. 11, pp. 305–310, 2019, doi: <https://doi.org/10.1016/j.matpr.2018.12.149>.
- [57] M. Srivastava and S. Rathee, “Microstructural and microhardness study on fabrication of Al 5059/SiC composite component via a novel route of friction stir additive Manufacturing”, *Materials Today: Proceedings*, Vol. 39, pp. 1775–1780, 2021, doi: <https://doi.org/10.1016/j.matpr.2020.07.137>.
- [58] P. Li et al., “Mechanically strong, stiff, and yet ductile AlSi7Mg/graphene composites by laser metal deposition additive manufacturing”, *Materials Science & Engineering A*, Vol. 823, article number 141749, 2021, doi: <https://doi.org/10.1016/j.msea.2021.141749>.
- [59] A. Mostafaei, A. Heidarzadeh and D. Brabazon, “Production of Metal Matrix Composites Via Additive Manufacturing”, *Encyclopedia of Materials: Composites*, Vol. 2, pp. 605–614, 2021, doi: <https://doi.org/10.1016/B978-0-12-803581-8.11884-3>.
- [60] A. Mandal et al., “Microstructural and thermal expansion behaviour of graphene reinforced 316L stainless steel matrix composite prepared via powder bed fusion additive manufacturing”, *Results in Materials*, Vol. 11, article number 100200, 2021, doi: <https://doi.org/10.1016/j.rinma.2021.100200>.
- [61] A. Riquelme, C. Sanchez de Rojas Candela, P. Rodrigo and J. Rams, “Influence of process parameters in additive manufacturing of highly reinforced 316L/ SiCp composites”, *Journal of Materials Processing Technology*, Vol. 299, article number 117325, 2022, doi: <https://doi.org/10.1016/j.jmatprotec.2021.117325>.
- [62] S. Yin, M. Hassani, Q. Xie and R. Lupoi, “Unravelling the deposition mechanism of brittle particles in metal matrix composites fabricated via cold spray additive manufacturing”, *Scripta Materialia*, Vol. 194, article number 113614, 2021, doi: <https://doi.org/10.1016/j.scriptamat.2020.10.055>.
- [63] S. Tang et al., “Additive Manufacturing of Aluminum-Based Metal Matrix Composites – A Review”, *Advanced Engineering Materials*, Vol. 23, article number 2100053, 2021, doi: <https://doi.org/10.1002/adem.202100053>.
- [64] N. Li et al., “Laser Additive Manufacturing on Metal Matrix Composites: A Review”, *Chinese Journal of Mechanical Engineering*, Vol. 34, article number 38, 2021, doi: <https://doi.org/10.1186/s10033-021-00554-7>.
- [65] M. Prasad Behera, T. Dougherty and S. Singamneni, “Conventional and Additive Manufacturing with Metal Matrix Composites: A perspective”, *Procedia Manufacturing*, Vol. 30, pp. 159–156, 2019, doi: <https://doi.org/10.1016/j.promfg.2019.02.023>.

---

## Виготовлення та порівняння властивостей алюмінієвих композитів TiB<sub>2</sub>, виготовлених за допомогою адитивних технологій та традиційних методів виробництва. Оглядова стаття

Раджаніш Н. Марігудар<sup>1</sup>

<sup>1</sup> Інститут технологій Джайна, Даванагере, Карнатака, Індія

**Анотація.** Адитивне виробництво є однією з найновіших технологій виготовлення деталей з бажаними розмірами, що наближаються до кінцевої форми. Адитивне виробництво металів є складною галуззю, в якій проводиться багато досліджень. У даній оглядовій статті зроблено спробу порівняти властивості алюмінієвих армованих металевих матричних композитів TiB<sub>2</sub>, виготовлених за допомогою традиційної технології виробництва, а також за допомогою технології адитивного виробництва з використанням лазера. Традиційний метод передбачає лиття об'ємних композитних матеріалів (лиття з перемішуванням), а адитивне виробництво – друк матеріалів пошарово. Після виготовлення зразки перевіряють на розподіл частинок за допомогою зображень SEM. На мікрографіях спостерігається, що розподіл армуючих частинок, тобто TiB<sub>2</sub>, є достатньо рівномірним у композиті, виготовленому за допомогою адитивної технології. Це впливає на однорідність властивостей для подальших випробувань. Перевіряється мікротвердість двох різних зразків і встановлюється, що композити, виготовлені за допомогою традиційних технологій, мають вищу твердість, ніж композити, виготовлені за допомогою адитивних технологій. У зразках, виготовлених за допомогою адитивних технологій, спостерігається вища пластичність композиту.

**Ключові слова:** алюмінієві матричні композити, TiB<sub>2</sub>, адитивне виробництво, характеристика, виготовлення, мікротвердість.

---