

# Assessing the nanomechanical, wear and thermal stability of Ti-Al-Si-V alloys produced via laser engineered net shaping (LENS) in-situ alloying

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**Abstract.** Titanium aluminide (TiAl) intermetallic alloys are highly recognized because of their lightweight qualities and are particularly useful for replacing heavier Nickel-based (Ni-based) superalloys in high-temperature components. This study focused on the investigation of the nanomechanical, wear, and thermal stability of intermetallic Ti-Al-Si-V alloys fabricated by in situ alloying with elemental metal powders using the laser engineered net shaping (LENS) technology. The impact of Vanadium (V) feed rate was examined both before and during the annealing heat treatment, which involved 60mins at temperatures of 1200 and 1400°C, and furnace cooling (FC) conditions. After heat treatment (1200°C and 1400°C), it was discovered that V addition enhances the Ti-Al-Si-V alloy's nanomechanical properties. According to the nanoindentation results, the mechanical characteristics of the heat-treated samples were typically better than those of the as-deposited alloy and were equivalent to the qualities of commercially available TiAl alloys. The alloy that was heat-treated at a temperature of 1200°C exhibited better tribological and thermal stability. Lastly, the as-deposited sample performed better in terms of tribological and thermal stability aspects than the sample that was heat-treated at 1400°C.

## 1 Introduction

Intermetallics are a class of metallic alloy consisting of two or more metallic elements forming an ordered solid-state combination. They often have outstanding mechanical qualities at high temperatures, but they are also hard and brittle. This group of compounds consists of fixed ratios of two or more elemental metals, as opposed to constantly fluctuating ratios (as in solid solutions). Intermetallic compounds frequently have distinct crystal

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structures and characteristics from those of their constituent parts. Titanium aluminide (TiAl)-based intermetallic compounds are regarded as great options for high-temperature applications, like aero engines, because of their low density (3.9–4.2 g/cm<sup>3</sup>), high specific strength, high elastic modulus, and high creep resistance (upwards of 750°C) [1-4]. Due to these exceptional physical characteristics, TiAl-based intermetallic are regarded as one of the most promising alternatives to Ni-based superalloys [3, 5]. TiAl alloys have been judged to exhibit extensive potential utilisation in the aerospace and automotive areas due to their features and performance. As a result, TiAl-based alloys have garnered a lot of interest for use as elevated temperature structural components in the field of aerospace, including turbine wheels, pistons and compressor blades for structural and aeronautical applications [1-2, 6]. Consequently, TiAl-based metals have emerged as the frontier hotspot for aerospace materials and is a type of elevated temperature structural material with potential applications below 750°C.

However, the main drawback of TiAl alloys, is their poor ductility at ambient temperatures, which prevents them from being widely used in application [6] such turbo-charger wheel, turbine blades and compressors. It is also challenging to process using these alloys using traditional production techniques like welding and forging [2, 4, 6] because of their poor fracture toughness. TiAl-based alloys have shown to be difficult to build better engineering structures because of their inherently brittle nature, despite the fact that various alloys have been employed to do so. Due to their infamously complex processing, these alloys can have production costs up to 65 times higher than those of nickel (Ni) superalloys [3-6]. Currently, traditional fabrication techniques including casting, forging, and powder metallurgy processing are generally used for fabricating TiAl alloys. Nonetheless, insufficient heat workability remains a major problem with TiAl alloys, prompting researchers to focus their efforts on mitigating the accompanying disadvantages that face a wider use of this kind of material [7]. As a result, novel production processes for TiAl alloys have been devised.

Additive Manufacturing (AM) techniques, like the direct energy deposition (DED) technique, enable design freedoms and capabilities to be included into a part as it is produced layer by layers [3]. The materials that are produced using this technology have different initial microstructures than those created via other methods of production. As a result, it is feasible that components manufactured using conventional manufacturing techniques will have different mechanical qualities than ones produced using DED [8]. Compared to a conventional technique (like casting and forging), DED laser deposition produces metal pieces of exceptional feature and strength with little to no waste of materials as the molten pool solidifies and cools quickly. This method greatly shortens the whole process, from design to manufacture, which can save time and money in component production process [9]. The parts produced by laser engineered net shaping (LENS) devices, a kind of DED technology, are made of metallic powder that is fed straight into an area where a powerful laser beam is concentrated while being shielded by an argon (Ar) gas environment [2,7]. Near-net shaped components are made with great dimensional precision layer by layer using a CAD model as a basis.

The LENS technology has recently been effectively utilised for processing a variety of materials, including functionally graded materials (FGM), ceramics, composites and metals, such as alloys made of the Ti-Al system [1, 7, 10–12]. Additionally, it has been observed that alloying and heat treatment optimisation of the microstructure may greatly increase the room- and high-temperature characteristics of TiAl alloys. Solid solution strengthening may be used to increase the strength and plasticity of TiAl alloys with the addition of V, Cr, W, Nb and other alloying material. This is especially useful for high-temperature service performance [1, 13]. Given the challenges associated with manufacturing TiAl parts using traditional methods, efforts have been undertaken to create net-shaped components of  $\gamma$ -TiAl through

the use of LENS technology. Furthermore, this technique is very flexible, which makes it perfect for fabricating customised structural parts [5]. One postprocessing method that is thought to be able to relieve internal tension in manufactured components and homogenise their microstructure is heat treatment. The Ti-Al binary phase diagram demonstrates that various heat treatment temperatures and techniques may be applied to create distinct microstructures. This is dependent upon both the amount of aluminium included and the method of cooling the alloy or composition.

Considerable research has been conducted on the TiAl alloy in the last several decades in an attempt to improve its mechanical characteristics. Xu et al. [13] studied the effect of V additive on microstructure and elevated temperature mechanical properties of Ti<sub>46</sub>Al<sub>7</sub>Nb<sub>0.4</sub>W<sub>0.6</sub>Cr alloy, which was manufactured by the cold crucible directed solidification process. The findings demonstrated that the ultimate tensile strength (UTS) and elongation increased at 973–1173K following the addition of 2 at.% V. The TiAl alloy's behaviour at the brittle-to-ductile transition (BDT) at 1073K is the outcome of the change from dislocation-dominated to twin-dominated deformation. Wang et al. [6] investigated how the Al content affected the microstructure features, phase composition, tensile properties and microhardness of the as-deposited TiAl alloy. The findings indicate that there is a trend for the microhardness to rise when the Al level decreases. The optimal  $\alpha_2/\gamma$  ratio, *c/a* value, and lamellar spacing of the as-deposited Ti-48Al alloy provide superior tensile qualities when juxtaposed with other TiAl alloys. Tlotleng et al. [14] used a laser melt pool to study the effects of micro-alloying  $\gamma$ -TiAl with Nb. The study aimed to understand how Nb affects the structure of  $\gamma$ -Ti-48Al alloys. It was shown that Nb directly affected the Ti-48Al alloy's microstructural change. It has been reported that for Ti-48Al alloy, twinning in the  $\alpha_2$  phase is promoted by Nb of 6 at.%, but annealing twinning in the  $\gamma$ -phase was accomplished at 8 at.% Nb content when heat-treated at 1400°C and then cooled in a furnace (FC). Kanyane et al. [2] produced laser-in-situ Ti-Al-2Cr, TiAl-3Cr, and Ti-Al-4Cr alloys and examined the composition influence on structural development and nanomechanical characteristics. After heat treatment at 1350°C and air cooling (AC), TiAl-3Cr reached a maximum microhardness of 493.98Hv, whereas TiAl-2Cr reached a minimum value of 435.89Hv. As-built samples had a higher nanoindentation stiffness than heat-treated samples.

According to the existing literature, studies on the wear, thermal stability and nanomechanical characteristics of TiAl-based alloys produced by AM processing are not easily found. In this work, we concentrate on using LENS in-situ powder deposition to synthesise the TiAl-based (Ti-Al-Si-V) alloy. This study presents the nanomechanical, wear and thermal stability of a LENS fabricated alloy to examine the impact of V on the processability of Ti-Al-Si-V intermetallic ( $\gamma$ -TiAl) components. To comprehend the impact of V addition on the ternary Ti-Al-Si alloy, the nanomechanical characteristics, tribological and thermal stability of these alloys following heat treatments are investigated. The findings of this study would provide a useful point of reference for the creation of suitable alloy compositions based on TiAl that are manufactured with AM technology.

## 2 Methodology

The experimental configuration and parameters employed in this investigation have a resemblance to those of Raji et al. [7], Raji et al. [12], and Raji and Popoola [15], but with a minor alteration concerning the V feed rate. Table 1 highlights the development parameters for the alloys. Using the elemental powders of Ti, Al, Si, and V, the Ti-Al-Si-V sample was created, yielding cube coupons of 10mm by 10mm by 15mm. To build samples on Ti-6Al-4V alloy base-plate, the Optomec 850R LENS machine (Optomec, Albuquerque, NM, USA) equipped with a 1kW IPG fibre laser was utilised. The powders ranged in particle size from 45-90 $\mu$ m. Ti and Al were supplied via the LENS machine's two powder feeders, while Si and

V were fed from two externally attached GTV powder feeders. With this design, we have a modified LENS four-way powder feeder delivery system for our experimental setup.

The sample as-deposited was examined both before and after heat treatment, with the findings shown in the next section. In a tube furnace with an Ar-rich atmosphere, heat treatment was done at 1200°C and 1400°C at a heating rate of 100°C/hour kept for 60mins and FC. Using an Anton-Paar TTX-NHT3 apparatus, the nanomechanical properties of the LENS- produced sample were examined in order to learn more about its mechanical characteristics. The highest force used in the nanoindentation experiments is 200mN, and each indentation takes a total of 60 seconds to complete, including loading, holding, and unloading (20 seconds each). The mechanical parameters (modulus of elasticity {E}, stiffness, yield stress {YS}, and UTS) were represented by the indentation findings. In order to analyse the load displacement curve and create the true stress-true strain curves that were utilised to ascertain these mechanical parameters, the Oliver and Pharr [16] approach was applied.

**Table 1.** Metal powders deposition parameters for the quaternary Ti-Al-Si-V alloys.

Parameters	Values			
Scan speed (mm/s)	10.58			
Centre purge (l/min)	25			
Hatching spacing (mm)	2.5			
Layer thickness (mm)	5			
Laser Power (W)	450			
	Ti	Al	Si	V
Powder feed rate (g/min)	2.21	0.48	0.025	0.50
Carrier gas (l/min)	4.2	2.4	2.0	2.0

In compliance with the ASTM G99-95 standard, the Anton-Paar tribological tester (Anton Paar, TRB3) was used to examine the tribological reaction of the manufactured Ti-Al-Si-V alloy. For the test, a pin-on-disk made of stainless steel was used. A 3000mm sliding distance was employed with a 15N load force. For 900 seconds, the dry tribological test was performed. Thermal gravimetric analyser (TGA 4000; PerkinElmer Inc., USA) manufactured by PerkinElmer was used to measure the samples' resistance to oxidation. This was utilised for determining the samples' weight change in relation to the temperature-controlled time unit. The test environment consists of an intake gas that is heated at a rate of 50°C/min to 900°C, containing 20ml/min of O<sub>2</sub> and N<sub>2</sub> with a 21% and 79% composition, respectively. The sample's weight changes during the heating process up to the maximum temperature, and this is tracked by an integrated weigh scale that has a pan within the chamber. Plotting the TGA curves is done using the acquired data and the oxidation resistance evaluation. The findings and comments section contains the results that have been evaluated and presented.

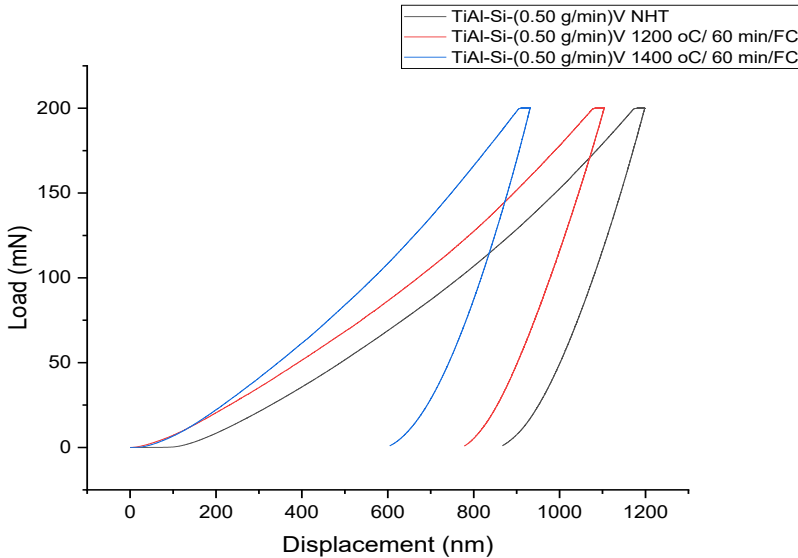
### 3 Results and discussions

#### 3.1 Nanoindentation (mechanical properties)

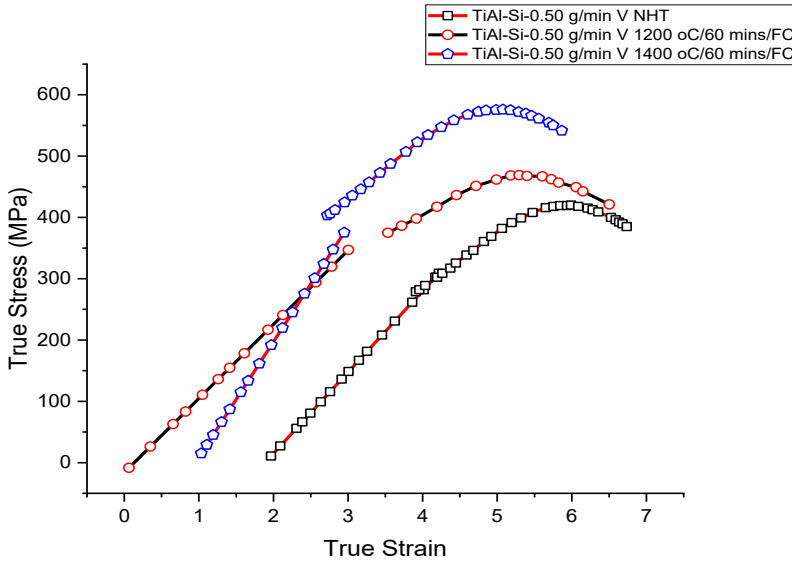
The elastic modulus and stiffness of the produced sample were measured using a load-displacement curve derived using equipment with a maximum set applied load of 200mN. One benefit of nanoindentation is its ability to measure material characteristics at incredibly tiny scales [2]. Fig. 1 displays the load-displacement curves for the as-deposited and heat-treated Ti-Al-Si-0.50g/min V alloy, and Fig. 2 displays the real stress-true strain curves under the same conditions. The mechanical performance of the alloy is determined using the load-displacement curve and analysis based on the Oliver and Pharr [16] technique. According to

Oyen and Cook [17], all of the materials given in this investigation displayed elastic-plastic characteristics. However, compared to the other samples, the as-deposited sample should show higher plastic deformation. The unloading section discusses the material's stiffness and shows that it was quite close to the stiffness of the as-deposited and 1200°C/60 mins/FC.

The 1400°C/60 mins/FC sample had the maximum stiffness, followed by the as-deposited sample, while the 1200°C/60 mins/FC sample had the least stiffness, according to the unloading part, which defines the material's stiffness. The stiffness of the as-deposited sample is  $0.95416 \times 10^6$  N/m, that of the 1200°C/60 mins/FC sample is  $0.77367 \times 10^6$  N/m, and that of the 1400°C/60 mins/FC sample is  $1.0379 \times 10^6$  N/m. As stated by Kanyane et al. [2], this indicates that the created TiAl alloy showed a drop in stiffness value following heat treatment at 1200°C; however, the rise in stiffness observed at 1400°C in this work tends to differ from findings made by other researchers. Fig. 2 shows that, in comparison to the as-deposited sample, the heat-treated samples showed increased YS and UTS. However, in correlation to the 1200°C/60 mins/FC sample, the 1400°C/60 mins/FC sample had a greater UTS. This can be clarified by the Ti-Al binary phase diagram, which predicts a fully lamellae (FL) microstructure of the alloy sample at 1400°C for 60 mins.



**Fig. 1:** Nanoindentation load-displacement curves of Ti-Al-Si-0.50 g/min V alloy.



**Fig. 2:** True stress-true strain curves of Ti-Al-Si-0.50 g/min V alloy.

According to Fig. 2, the as-deposited alloy's UTS and YS values are 420MPa and 308MPa, respectively, and its modulus of elasticity (E) is 132GPa. The value of E for the as-deposited sample is 21.4% lower than that of the commercially available Ti48Al2Nb2Cr alloy, also known as the GE alloy, which has an E of  $168\pm 2$ GPa at room temperature (RT) according to Lerch et al. [18]. Comparing the as-deposited sample to the GE alloy, the YS is 5.5% lower at 326MPa; however, the UTS at 422MPa for GE and the as-deposited sample were almost equal ( $0.5\% < GE$ ). This suggests that the as-deposited sample may not be able to tolerate greater stress at RT. As a result, mechanical characteristics are not as good as the GE alloy. The bulk value indicates that the values are within similar TiAl-based alloys, even though E may not show a noticeable change [2, 18]. The sample heat-treated at 1200°C/60 mins/FC has an E of 121GPa and UTS and YS values of 469MPa and 350MPa, respectively. The heat-treated 1200°C/60 mins/FC sample would sustain more stress than GE prior to suffering plastic deformation, as evidenced by the 1200°C/60 mins/FC sample E's RT value being roughly 26.2% lower than that of the GE alloy but a 7.4% greater YS. In a similar vein, the UTS is 11% higher than the GE alloy UTS. As a result of its superior mechanical qualities over GE, the sample heat-treated at 1200°C for 60mins and FC would experience greater plastic deformation and be able to sustain higher stress at RT before breaking. According to a previous study by Raji et al. [7], this was attributed to the strengthening mechanism of  $\zeta$ -Ti<sub>5</sub>Si<sub>3</sub> owing to the presence of Si.

The sample that was heat-treated at 1400°C for 60mins and FC had UTS and YS values of 575MPa and 380MPa, respectively; the E value was 188GPa. At RT, the 1400°C/60 mins/FC sample E is approximately 12% higher than the GE alloy. In a similar vein, the heat-treated 1400°C/60 mins/FC sample's YS was around 16.6% lower than that of GE, indicating that it would require more stress than GE to undergo plastic deformation. Moreover, the 1400°C/60 mins/FC sample's UTS is around 36.3% higher than the GE alloys. As a result, compared to the GE alloy at RT, the 1400°C/60 mins/FC sample stress limit is much greater. Because of this, the 1400°C/60 mins/FC alloy has superior mechanical characteristics than the GE alloy at RT.

The 1400°C/60 mins/FC sample is expected to exhibit plastic deformation at higher stress than the 1200°C/60 mins/FC sample, demonstrating that it has greater fracture toughness than the GE alloy. Its superior toughness over the as-deposited and 1200°C/60 mins/FC samples,

including the GE alloy, is suggested by its high UTS value of 575MPa. Therefore, for structural applications, the mechanical characteristics of the 1400°C/60 mins/FC sample would be preferred. This implies that the TiAl alloys that were created have a higher resistance to plastic deformation. As a result, these alloys should exhibit superior deformation under stress performance compared to the existing GE alloy. Additionally, it is anticipated to exhibit superior elevated temperature capabilities and creep due to the  $\zeta$ -Ti<sub>5</sub>Si<sub>3</sub> phase's strengthening process. It has been found that Si can impact the strength enhancement as  $\zeta$ -Ti<sub>5</sub>Si<sub>3</sub> by solution strengthening or precipitation hardening [19].

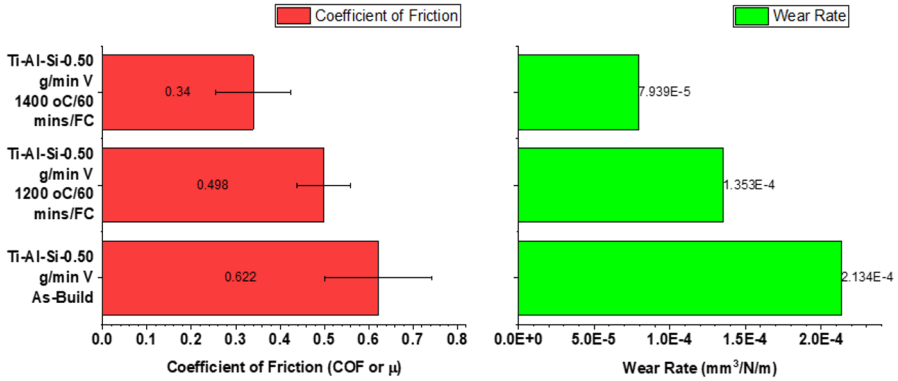
The findings indicate that the mechanical characteristics of TiAl alloy were significantly induced by V addition during heat treatment. After heat treatment, the  $\alpha_2$  phase concentration increases progressively while the lamellar spacing tends to decrease, as mentioned by Raji et al. [7]. These microstructure features help to upgrade the mechanical properties of the Ti-Al-Si-V alloy. Additionally, residual stress has the ability to prevent dislocation movement, which enhances the mechanical qualities [6]. Xu et al. [13] have indicated that the inclusion of V could increase the elongation and strength of TiAl-based alloys. For example, the Ti46Al7Nb0.4W0.6Cr2V alloy has been reported to have an elongation of 5.76% and a UTS of 542MPa. It was stated that the lamellar spacing and strength followed the Hall-Petch relationship.

The indentations at the targeted location may also indicate creep behaviour, according to this nano-indentation test. With respect to the possibility of instability, this phenomenon has an impact on values [20]. The dislocation of slip is thought to be responsible for plastic deformation in crystalline metals, according to published research. It is noteworthy that the created alloy's phase combination reduced the sliding plane, hence preventing interlunar dislocations. As a result, their nanomechanical characteristics improved, demonstrating that the alloys were experiencing greater deformation.

### 3.2 Tribological and thermogravimetric analyzer (TGA)

Assessing the tribological performance and thermal stability is essential to determining how long-lasting TiAl-based alloy parts are in applications. An important aspect of high-temperature usage for the engines and gas turbines of advanced supersonic aircraft is the oxidation behaviour of TiAl alloys [21]. This is a serious problem for applications involving aero engines because the working temperature range of a turbocharger is 700–950 degrees Celsius. Long-term stability in the presence of air, where the microstructure and mechanical properties should be preserved all through the components' lifecycle, is a vital attribute of high-temperature TiAl alloys.

Tribological study is used to evaluate the TiAl alloy resistance to the sliding motion. The coefficient of friction (CoF or  $\mu$ ) and wear rate of the as-deposited and heat-treated Ti-Al-Si-0.50g/min V alloy are displayed in Fig. 3. The CoF usually decreases from the as-deposited sample (0.622) to the samples at 1200°C and 60 mins and FC (0.498) and 1400°C and 60 mins and FC (0.34), which have the lowest CoF values. There is a direct proportionality relationship between the CoF and the wear rate because the wear rate similarly exhibits the same trend as the CoF. As a result, the sample that was as-deposited sample had the highest wear rate value,  $2.134 \times 10^{-4}$  mm<sup>3</sup>/N/m, followed by the sample that was heat-treated at 1200°C for 60 mins/FC, wear rate of  $1.353 \times 10^{-4}$  mm<sup>3</sup>/N/m, while the sample heat-treated at 1400°C demonstrated the least wear rate value of  $7.939 \times 10^{-5}$  mm<sup>3</sup>/N/m.



**Fig. 3:** Coefficient of friction and wear rate of Ti-Al-Si-0.50g/min V alloy.

Given that a high CoF measured by the as-deposited sample was not expected to translate into a correspondingly high wear rate, the tribological behavior found for these alloys was quite surprising. This was suspected to be due to high quantity of columnar grain of  $\alpha_2$ -phases present in the as-deposited alloy as reported in the work of Raji et al. [7]. Owing to these phases been susceptible high wear volume during contact loading. However, a high rate of wear indicates that more material was removed from the surface during the sliding test, and the material would wear out more quickly as the coefficient of friction increased. On the other hand, deep ploughing indicated the removal of material. The spatial depiction of the trails provided excellent clarity regarding this process. It was also discovered that the worn-out depth varied. These variations developed mostly as a result of microstructural defects and phase fusion [20].

Furthermore, it was shown that the hard  $\zeta$ - $\text{Ti}_5\text{Si}_3$  particles and the FL microstructure in the 1400°C/60 mins/FC sample had the lowest CoF and wear rate resulting in less material removal from the surface during the sliding test. However, due to the presence of unmelted Al and fewer particles of  $\zeta$ - $\text{Ti}_5\text{Si}_3$  phase, the as-deposited sample exhibited the greatest wear rate with the highest CoF. The CoF of the heat-treated 1200°C/60 mins/FC sample was greater than that of the 1400°C/60 mins/FC sample, which was nearly half that of the sample as deposited. However, the wear rate is over 50% of the sample as deposited. Therefore, the Ti-Al-Si-V alloy's tribological characteristics were substantially balanced at 1200°C/60 mins/FC. Table 2 highlights the properties of the Ti-Al-Si-V alloy. By comparing the three samples it obvious the 1200°C/60 mins/FC sample demonstrated the more balanced overall properties.

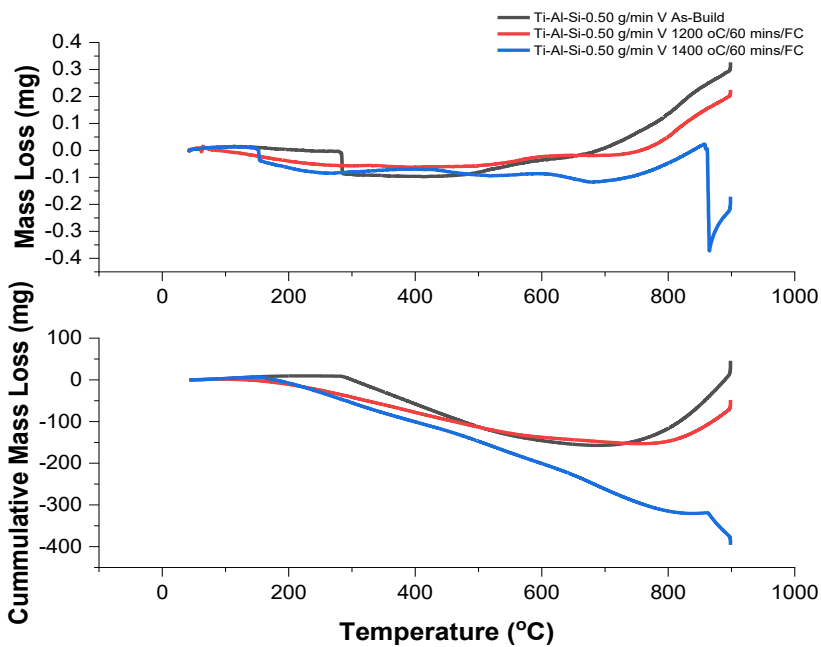
**Table 2.** The properties of the fabricated Ti-Al-Si-V alloy.

	As-deposited	1200°C/60 mins/FC	1400°C/60 mins/FC
<b>Stiffness (S, <math>10^6</math> N/m)</b>	0.95416	0.77367	1.0379
<b>Young modulus (E, GPa)</b>	132	121	188
<b>UTS (MPa)</b>	420	469	575
<b>YS (MPa)</b>	308	350	380
<b>CoF (<math>\mu</math>)</b>	0.622	0.498	0.34
<b>Wear rate (<math>\text{mm}^3/\text{N/m}</math>)</b>	$2.134 \times 10^{-4}$	$1.353 \times 10^{-4}$	$7.939 \times 10^{-5}$

Furthermore, the deposition of debris at the boundary of wear tracks demonstrated their resistance to plastic deformation. The wear tracks of the sample as deposited exhibited the highest pile-up, as evidenced by material build-up at the margins brought on by the high wear rate. The heat-treated samples, on the other hand, showed no appreciable material pile-up in their wear tracks, which was explained by their lower wear rates. There were also reports of surface smearing and fatigue-induced cracking in some places, which may have resulted from

heat produced during dry wear testing. These characteristics imply that adhesive and abrasive wear caused the samples to be worn [4]. This research demonstrated how much the phases formed during the LENS production process affected the wear outcomes. Therefore, neither an increased load nor a repeated cycle was required by the experiment.

The TGA curves for the as-deposited and heat-treated Ti-Al-Si-0.50g/min V alloy are displayed in Fig. 4. The TGA data show that, in relation to the sample's initial mass per unit area, mass loss increases with temperature. When mass increase is seen, it indicates that the products of corrosion are bound to the sample surface without spalling. The kind of chemical connection that occurs between the sample and air (nitrogen and oxygen) determines this. However, a negative mass change indicates that the corrosion products are volatile or that the alloy components are lost as a result of solid scale spalling. With an acute mass reduction at 284°C, it was found that the initial loss of mass for the as-deposited sample was reasonably near to zero value.



**Fig.4:** TGA curves of Ti-Al-Si-0.50g/min V alloy.

Up to 800°C, the cumulative mass loss persisted in decreasing for all samples, causing a little increase in the cumulative mass that indicates a mass gain. Nevertheless, the mass that was added after 800 degrees Celsius was insufficient to make up for the original material losses. With the exception of the 1400°C/60 mins/FC sample, which displayed an abrupt mass loss at 865°C, both the as-deposited and heat-treated samples demonstrated good high-temperature stability. This suggests that volatile materials would be produced at 865°C and alloy component loss would occur from the 1400°C/60 mins/FC sample. On the other hand, the mass added by the as-deposited sample and the 1200°C/60 mins/FC sample keeps on showing throughout the test, indicating that the oxide layers created are solid and adhered to the sample surfaces. This indicates that the alloy is stable. Overall, the alloys demonstrated better stability at high temperatures, although the mass loss observed was negative, indicating that alloy components were lost as a result of volatile corrosion products forming. At temperatures over 870°C, all of the samples showed positive mass changes overall, except for the heat-treated 1400°C/60 mins/FC showing a drastic drop in mass. This is indicative that the oxide scales adhered to the materials above this temperature for the as-deposited and

heat-treated 1200°C/60 mins/FC samples. Owing to the working temperature of a turbocharger wheel being between 850°C and 900°C, the as-deposited and heat-treated 1200°C/60 mins/FC Ti-Al-Si-V alloy would exhibit minimal spalling and it is suggested that the two alloys are appropriate for use for fabrication of turbocharger wheels.

## 4 Conclusion

The objective of this investigation is to study the nanomechanical, wear, and thermal stability of Ti-Al-Si-V alloy fabricated via LENS technology by utilizing elemental powders. According to the findings, the heat-treated samples outperformed the as-deposited sample in terms of mechanical characteristics and comparable to commercially available GE-TiAl alloys. Nonetheless, the alloy heat-treated at 1200°C exhibited improved tribological and thermal stability, whilst the as-deposited sample showed greater thermal stability than the 1400°C-treated sample. The investigation's findings showed that using laser-in-situ alloyed samples heat-treated to 1200°C would be beneficial for the creation of Ti-Al-Si-V samples, and fabrication of high-temperature components such as turbocharger wheels.

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