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Balancing Strength and Ductility in AA7075 through Controlled Heat Treatment Parameters

(Mengimbangi Kekuatan dan Kemuluran dalam AA7075 melalui Parameter Rawatan Haba Terkawal)

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ABSTRACT

AA7075-T6 aluminium alloy, known for its high strength-to-weight ratio, is an ideal material for many industries, such as aerospace and structural engineering. However, its mechanical performance is highly sensitive to heat exposure, and inconsistent heat treatment practices across industries have resulted in varying performance outcomes. Despite the alloy's importance, there is limited empirical data that systematically correlates specific heat treatment parameters with resulting mechanical properties. This study addresses this gap by investigating the effects of post-treatment heat exposure at 425 °C, 450 °C, and 475 °C for durations of 30 min and 60 min. Mechanical testing showed that tensile strength decreased from 600 MPa in the T6 condition to as low as 377 MPa after treatment at 425 °C for 60 min. Similarly, yield strength dropped from 540 MPa to 199 MPa under the same conditions. Hardness declined from approximately 91 HRB in the untreated state to 55 HRB after extended exposure. In contrast, elongation improved from 13.2% in the original condition to a maximum of 22.5%, indicating increased ductility. Young's modulus remained stable at approximately 16.3-17.3 GPa across all heat-treatment conditions. These results show the importance of controlled heat treatment to maintain strength while improving ductility, providing useful understanding for optimizing AA7075 in demanding applications.

Keywords: Aluminium alloy AA7075; heat treatment; mechanical characteristics

ABSTRAK

Aloi aluminium AA7075-T6 yang dikenali dengan nisbah kekuatan-ke-berat yang tinggi, merupakan bahan yang ideal untuk banyak industri seperti aeroangkasa dan kejuruteraan struktur. Walau bagaimanapun, prestasi mekanikalnya sangat sensitif terhadap pendedahan haba dan amalan rawatan haba yang tidak tekal merentasi industri telah menghasilkan hasil prestasi yang berbeza-beza. Walaupun berkepentingan, terdapat data empirik yang terhad yang secara sistematik menghubungkan parameter rawatan haba tertentu dengan sifat mekanikal yang terhasil. Penyelidikan ini menangani jurang ini dengan mengkaji kesan pendedahan haba selepas rawatan pada 425 °C, 450 °C dan 475 °C untuk tempoh 30 minit dan 60 minit. Ujian mekanikal menunjukkan bahawa kekuatan tegangan menurun daripada 600 MPa dalam keadaan T6 kepada serendah 377 MPa selepas rawatan pada 425 °C selama 60 minit. Begitu juga, kekuatan hasil menurun daripada 540 MPa kepada 199 MPa di bawah keadaan yang sama. Kekerasan menurun daripada kira-kira 91 HRB dalam keadaan tidak dirawat kepada 55 HRB selepas pendedahan yang berpanjangan. Sebaliknya, pemanjangan bertambah baik daripada 13.2% dalam keadaan asal kepada maksimum 22.5%, menunjukkan peningkatan kemuluran. Modulus Young kekal stabil pada kira-kira 16.3-17.3 GPa merentasi semua keadaan rawatan haba. Keputusan ini menunjukkan kepentingan rawatan haba terkawal untuk mengekalkan kekuatan sambil meningkatkan kemuluran, memberikan pemahaman yang berguna untuk mengoptimumkan AA7075 dalam aplikasi yang mencabar.

Kata kunci: Aloi aluminium AA7075; ciri mekanikal; rawatan haba

INTRODUCTION

Aluminum alloys have become increasingly vital in modern engineering due to their favorable strength-to-weight ratio, excellent corrosion resistance, and adaptability. These attributes make them well-suited for applications in aerospace, automotive, marine, and construction sectors, where minimizing weight without compromising strength is a key consideration (Sunar et al. 2020). The demand for aluminum alloys continues to rise as industries shift towards energy-efficient solutions through the use of lightweight materials (Feizi & Ashjari 2018).

Aluminum alloys are classified into different series based on their primary alloying elements, which in turn influence their mechanical behavior and suitability for various applications. The classification ranges from the 1XXX to 8XXX series, each defined by its main alloying constituent. The 1XXX series consists mostly of pure aluminum (>99% Al), offering high electrical conductivity and corrosion resistance, but with limited strength. The 2XXX series, primarily alloyed with copper, delivers enhanced strength and fatigue resistance, but it compromises corrosion resistance (Abd El-Hameed & Abdel-Aziz 2021). Alloys in the 6XXX series, such as AA6061, incorporate magnesium and silicon, yielding moderate strength, good weldability, and excellent resistance to corrosion (Georgantzia, Gkantou & Kamaris 2021). Meanwhile, the 7XXX series, including AA7075, is mainly zinc-based and offers exceptional strength, but it is less weldable than other series (Rometsch et al. 2014).

AA6061, an aluminum-magnesium-silicon alloy, is widely used in structural applications thanks to its balanced combination of strength, weldability, and corrosion resistance (Gandhi et al. 2019). It is commonly applied in sectors such as construction, automotive, and pipelines, where durability and corrosion resistance are equally critical.

AA7075 is an aluminum alloy primarily composed of zinc, magnesium, and copper, known for its exceptional strength and hardness. It has a slightly higher density than other aluminum alloys, approximately 2.81 g/cm^3, and its melting temperature ranges between 477 and 635 °C (Rathinasuriyan et al. 2024). After undergoing heat treatment, especially in the T6 temper, AA7075 can achieve ultimate tensile strength values ranging from 540 to 600 MPa and yield strength between 480 and 540 MPa (Silva et al. 2004). The presence of zinc and copper significantly improves its mechanical performance but results in lower weldability and reduced corrosion resistance when compared to AA6061 (Mehdi & Mishra 2020). Owing to its excellent strength-to-weight ratio, AA7075 is widely utilized in aerospace structures, automotive components, and high-performance sports equipment (Andersen et al. 2018).

Aluminum alloys are further categorized into heat-treatable and non-heat-treatable types. Heat-treatable alloys, such as AA6061 and AA7075, undergo processes like solution heat treatment, quenching, and aging to significantly enhance mechanical properties by altering their microstructure (Georgantzia, Gkantou & Kamaris 2021). These treatments improve strength, hardness, and ductility, making the alloys suitable for demanding engineering applications. In contrast, non-heat-treatable alloys, like those in the 3XXX and 5XXX series, derive mechanical improvements through cold working. These alloys are often used where formability and corrosion resistance are prioritized over high strength (Abd El-Hameed & Abdel-Aziz 2021), such as in cookware, roofing, and heat exchangers, where heat treatment is unnecessary.

Despite AA7075's popularity in strength-critical applications, its performance is highly sensitive to heat treatment conditions. Improper selection of parameters such as temperature and duration can negatively affect its mechanical properties, resulting in reduced strength, hardness, or ductility. As a result, industries often face challenges in achieving consistent mechanical performance from AA7075 components due to the lack of precise control and understanding of optimal heat treatment conditions. Many studies have explored the general effects of heat treatment on aluminum alloys. However, there is limited focused research that systematically investigates the optimization of specific parameters such as heating temperature and duration for AA7075 with direct evaluation of mechanical performance outcomes. Inconsistencies in processing practices and heat treatment standards across industries further highlight the need for an evidence-based framework tailored specifically to AA7075. Addressing this gap is essential in improving its performance reliability and expanding its application in high-performance and safety-critical environments.

This study aims to address the gap by optimizing heat treatment parameters to enhance the mechanical performance of AA7075, providing an understanding for its optimal use in demanding engineering applications.

METHODOLOGY

This section is structured to systematically investigate the effects of varying heat treatment parameters on the mechanical properties of AA7075 aluminum alloy. The experimental approach involves subjecting the alloy to heat treatments at different temperatures and durations, followed by detailed mechanical testing. This enables a focused evaluation of AA7075's performance under various heat conditions.

The procedure begins with the preparation of AA7075 specimens, which are then heat-treated under controlled conditions. After the heat treatment process, the samples undergo tensile testing to determine ultimate tensile strength, yield strength, and elongation, as well as hardness testing to assess surface resistance. The collected data is analyzed to understand the influence of different heat treatment parameters on the mechanical behavior of the alloy. The results are plotted to identify performance trends and support the optimization of heat treatment conditions for improved mechanical performance.

A total of six tensile test specimens is heat treated for AA7075 aluminum alloy, covering a range of temperature and duration combinations. The detailed dimensions and geometry of the tensile test specimens are presented in Figure 1. For each heat-treatment condition, at least three specimens were tested. Reported values in the Table 2 represent the mean ± standard deviation (SD) for tensile strength, yield strength, elongation, and hardness. This ensures statistical reliability of the results. The heat treatment process is carried out using a programmable electric furnace to ensure accurate control of both temperature and time. The specimens are treated at three target temperatures: 425 °C, 450 °C, and 475 °C, with each temperature applied for two different durations, 30 min and 60 min, as shown in Table 1. An additional specimen is left untreated to serve as a control for comparison purposes. After heat treatment, all specimens are immediately quenched in water to preserve the mechanical characteristics developed during the process.

Tensile tests are performed using the Zwick/Roell Z100 universal testing machine (Figure 1). The procedure adheres to ASTM E8 standard as shown in Figure 2, ensuring consistency and reliability across all test results.

During the tensile testing process, each specimen is subjected to a uniaxial load until fracture to assess its mechanical performance. Key parameters measured include the Ultimate Tensile Strength (UTS), which represents the maximum stress the material can endure before failure; the Yield Strength, which marks the onset of permanent plastic deformation; and Elongation, defined as the percentage increase in the specimen's length at the point of rupture, reflecting the material's ductility.

The AA7075 plate was precisely cut, as shown in Figure 3, in accordance with the dimensional requirements specified by the ASTM E8 standard. These dimensions were specifically prepared for tensile testing using the Zwick Roell Universal Testing Machine and for microhardness testing using the Zwick Roell Universal Hardness Tester, following the ASTM E18-22 standard.

RESULTS

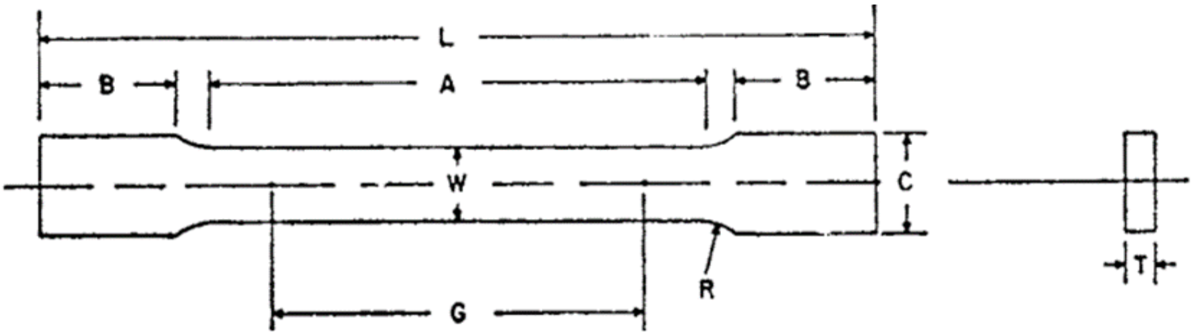
MECHANICAL PROPERTIES

This section outlines the effects of heat treatment temperature and duration on the mechanical properties of AA7075 aluminium alloy. The discussion is structured around key parameters: ultimate tensile strength, yield strength, elongation, and microhardness. Each property is analysed to identify trends across different heat treatment

TABLE 1. The temperature and duration of heating applied to the samples

Samples	1	2	3	4	5	6	7
Temperature (°C)	-	425	425	450	450	475	475
Duration (min)	-	30	60	30	60	30	60

FIGURE 1. Zwick/Roell Z100 universal testing machine



Dimension of tensile test specimens	
Dimension in mm	
G-Gauge Length	50
W-Width	12.5
T-Thickness	3
R-Radius of fillet	12.5
L-Overall Length	200
A-Length of reduced section	57
B-Length of grip section	50
C-Width of grip section	20

FIGURE 2. Specimens following ASTM E8 standards

FIGURE 3. Samples post-cutting for tensile testing

conditions, with comparisons made to the as-received T6 condition. The sequence begins with tensile strength, followed by yield strength and elongation to assess strength and ductility, and concludes with microhardness to evaluate surface resistance changes.

TENSILE STRENGTH

Figure 4 and Table 2 present the UTS of AA7075 under the various heat treatments, compared to the T6 condition. The T6 baseline in this study recorded the highest UTS of 600 MPa, consistent with expectations for a peak-aged alloy. In comparison, Bertolini et al. (2021) reported a lower UTS of approximately 530 MPa for a similar condition. In all heat-treated samples, UTS declined relative to T6, with the degree of reduction depending on temperature and time. The 425 °C treatments led to the most severe strength loss: after 30 min at 425 °C, UTS had already dropped well below the T6 value, and by 60 min it reached 377 MPa, the lowest UTS among all conditions. This indicates that 425 °C (even for short duration) overaged the alloy considerably, drastically reducing its tensile strength (Jiang et al. 2021).

The intermediate 450 °C treatments showed a non-monotonic trend. UTS initially fell to 469 MPa at 30 min, then increased to 495 MPa after 60 min. In other words, a longer hold at 450 °C partially recovered the tensile strength, yielding a ‘valley-then-peak’ behavior (mirrored in the hardness results as well). This unexpected uptick suggests some re-strengthening mechanism at the longer 450 °C duration. In AA7075 aluminium alloy, the high strength observed in the T6 condition is primarily attributed to the presence of fine, metastable η′ (eta prime) precipitates, composed mainly of magnesium and zinc ($MgZn_2$). These precipitates play a critical role in strengthening the alloy. It is well established that the mechanical properties of Al-Zn-Mg-Cu alloys, particularly hardness, tensile strength, and elongation, are highly sensitive to precipitate size and distribution (Hsiao et al. 2022). These precipitates form during artificial aging and are highly effective at strengthening the alloy by hindering dislocation movement. However, when exposed to elevated temperatures or extended heat treatment durations, η′ precipitates tend to coarsen or dissolve, reducing their ability to reinforce the matrix. This leads to a noticeable drop in mechanical properties such as tensile strength and hardness, a phenomenon known as overaging (Jiang et al. 2021). At the highest temperature of 475 °C, the short 30 min treatment retained the greatest UTS (527 MPa) among the heat-treated specimens. Despite a slight loss from the 600 MPa control, this strength is comparable to the typical T6 range and indicates that a 475 °C/30 min exposure nearly solution-treated the alloy. The subsequent quench and natural aging (T4-type condition) could form Guinier–Preston zones or fine η′ precipitates, which help maintain a high UTS (Liu et al. 2024). However, when the 475 °C exposure was extended to 60 min, UTS dropped sharply to 443 MPa as shown in Table 2. Prolonged heating near the solvus likely dissolved most strengthening precipitates and even allowed some grain growth, resulting in a much softer (overaged) material.

YIELD STRENGTH (YS)

The yield strength trends (Figure 5, Table 2) closely paralleled the UTS behavior, with even more pronounced drops. The T6 sample had a YS of about 540 MPa, which is very high and only 10% lower than its UTS (600 MPa). Such a small UTS–YS gap in T6 indicates a limited ductility reserve before plastic yield, characteristic of a peak-aged alloy. After heat treatment, YS decreased in all cases, reflecting the alloy’s lower resistance to the onset of plastic deformation. The most drastic reduction was observed for the 425 °C/60 min condition: YS plummeted to 199 MPa, barely 37% of the original value (a 63% drop). In fact, this lowest YS approaches the typical yield strength of fully annealed 7075-(140 MPa), highlighting how severely the T6 strengthening precipitates were degraded. Even the highest YS among the treated samples, 352 MPa at 475 °C/30 min, was still significantly below the T6 baseline. Clearly, brief high-temperature exposure retained more yield strength than longer or lower-temperature treatments, but no condition matched the original 540 MPa.

The variation of YS with heat treatment mirrors the UTS pattern. At 425 °C, extensive overaging led to the lowest YS values; increasing the hold from 30 to 60 min further depressed YS (exact 425 °C/30 min YS was higher than 199 MPa but still far below T6). The 450 °C treatments showed a dip then slight recovery: YS fell to 291 MPa at 30 min, then rose to 317 MPa at 60 min. This 450 °C/60 min yield strength (317 MPa) was higher than the 30 min value, consistent with the partial re-hardening observed in UTS. At 475 °C, YS was relatively high after 30 min (352 MPa) but dropped to 248 MPa after 60 min, once again indicating that prolonged exposure negates the strengthening retained in the short soak. The sensitivity of YS to precipitate state is evident: YS tends to decrease even more steeply than UTS under overaging, since the yield point (start of plastic flow) benefits greatly from fine, coherent precipitates that pin dislocations. As thermal exposure time or temperature increases, the strengthening effect of the precipitates diminishes. This allows dislocations to move more easily under lower applied stresses, resulting in a significant reduction in yield strength (Li et al. 2022). Moreover, any grain growth during the 60 min treatments would further reduce YS via the Hall–Petch effect. Consequently, the 425 °C/60 min sample, likely having the fewest remaining fine precipitates and largest grains, showed an extremely low YS, whereas the 475 °C/30 min sample, almost re-solutionized and then naturally aged, maintained the highest YS of the group. Overall, the yield strength ranking of the conditions followed the same order as UTS (best retained in 475 °C/30 min, worst in 425 °C/60 min), highlighting the trade-off between thermal exposure and strength.

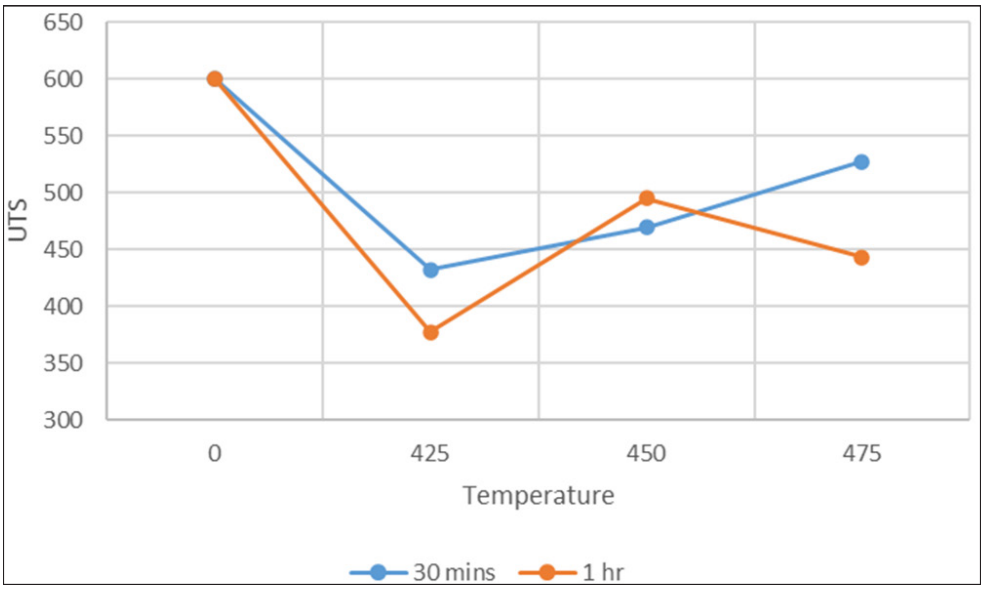


FIGURE 4. Tensile strength against heating temperature under different durations

TABLE 1. Mechanical properties of AA7075 specimens under various heat treatment conditions

Specimen	UTS (MPa)	Elongation (%)	Young's Modulus (GPa)	Yield Strength (MPa)
T6 (control)	600.2 ± 7.8	13.2 ± 0.4	17.3 ± 0.5	540.4 ± 6.9
425 °C / 30 min	432.1 ± 9.6	22.5 ± 0.6	16.8 ± 0.4	243.5 ± 5.3
425 °C / 60 min	377.0 ± 8.2	20.5 ± 0.5	16.3 ± 0.5	199.4 ± 4.7
450 °C / 30 min	469.2 ± 10.3	18.6 ± 0.5	16.7 ± 0.6	291.3 ± 6.1
450 °C / 60 min	495.5 ± 11.2	21.0 ± 0.6	16.9 ± 0.4	317.2 ± 7.0
475 °C / 30 min	527.4 ± 12.6	20.7 ± 0.6	17.1 ± 0.5	352.0 ± 8.2
475 °C / 60 min	443.3 ± 10.7	21.5 ± 0.5	16.4 ± 0.4	248.6 ± 5.9

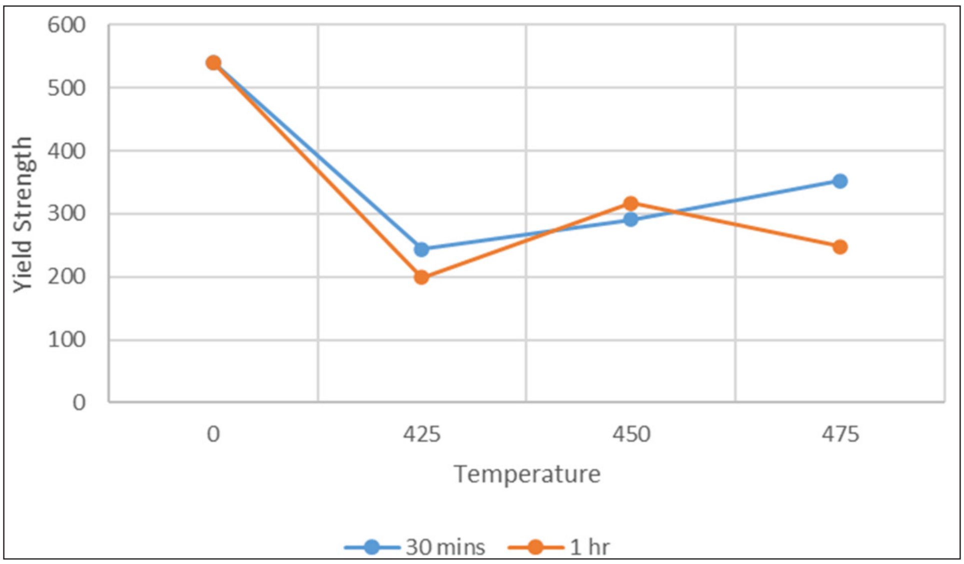


FIGURE 5. Yield Strength (YS) against heating temperature under different durations

ELONGATION

Tensile elongation (ductility) exhibited the opposite trend to strength, increasing substantially with heat treatment (Figure 6). The T6 condition had an elongation of about 13.2% (Table 2), which is typical for a peak-aged 7075 alloy (high strength but relatively low ductility, often around 11-15% in T6). All heat-treated specimens showed higher elongation than the T6 control, consistent with the expectation that overaging or partial annealing will make the alloy more ductile (Li et al. 2023). In fact, elongation roughly doubled in many cases, reaching values in the high-teens to low-twenties. The maximum recorded elongation was 22.5% at 425 °C for 30 min, nearly a 70% improvement over the baseline. Even the lowest ductility among the heat-treated conditions (18.6% at 450 °C/30 min) was significantly higher than 13.2%, demonstrating the classic trade-off between strength and ductility. Most conditions produced elongations around 18-21%, effectively doubling the material's ability to deform plastically before fracture. Notably, the 425 °C/60 min treatment resulted in an elongation of 20.5%, slightly lower than the 22.5% at 425 °C/30 min despite the longer time. This minor drop in ductility at the extremely overaged condition (425 °C/60 min) might be due to early onset of necking or micro-void formation once the alloy became very soft (Wciślik & Lipiec 2022). Nonetheless, both 425 °C treatments yielded far greater elongation than the T6 condition, as did all other heat-treated states.

The enhancement in ductility corresponds inversely to the loss of strength. Conditions that severely weakened the alloy (low UTS/YS) provided the largest elongation gains. The 425 °C/30 min sample, which had one of the lowest strengths, exhibited the highest ductility (22.51%); conversely, the 475 °C/30 min sample retained the highest strength and accordingly showed a more modest ductility increase. At 450 °C, extending the hold from 30 min to 60 min raised elongation from 18.6% to roughly 21%, as the additional softening improved the material's capacity for plastic strain. In practical terms, a heat treatment can be chosen to tailor the strength–ductility balance: if an application demands maximum ductility or formability (for example, to improve crash energy absorption or to facilitate cold working), a longer and/or lower-temperature treatment (425 °C for 30-60 min) yields an alloy that, while much lower in strength, can sustain roughly double the plastic deformation of the T6 condition. On the other hand, a short high-temperature exposure (475 °C for 30 min) offers a good compromise, slightly sacrificing ductility relative to the overaged conditions but retaining higher strength – beneficial when some structural load-bearing capability must be preserved, the elongation trends highlight the expected inverse relationship between strength and ductility in heat-treated alloys and demonstrate how thermal conditioning can be used to tune the mechanical performance of AA7075.

Although SEM analysis was not performed, the observed increase in elongation can be theoretically explained by ductile fracture mechanisms. In heat-treated AA7075, ductile fracture typically occurs through micro-void nucleation at second-phase particles (such as $MgZn_2$ precipitates), followed by void growth and coalescence. This process produces dimpled rupture surfaces in tensile specimens. Overaged conditions (425 °C/60 min) reduce precipitate strengthening, allowing easier dislocation motion and void growth, which enhances ductility. Conversely, shorter or higher-temperature treatments (475 °C/30 min) retain more strengthening precipitates, restricting dislocation mobility and limiting ductility. Hence, the ductility trends observed here are consistent with the expected transition in fracture morphology from relatively fine dimples in stronger states to coarser dimples in overaged states.

STRESS–ELONGATION OF HEAT-TREATED AA7075

Figure 7 displays the stress–elongation curves of AA7075-T6 aluminium alloy under various heat treatment conditions. It highlights how thermal exposure alters its tensile properties. All curves start with a similar linear region, indicating that the elastic modulus, thus, the alloy›s stiffness, remains mostly unchanged. Beyond the elastic limit, however, notable differences appear in yield strength, ultimate tensile strength (UTS), and elongation, reflecting the effects of different heat treatment temperatures and durations. As expected, a typical trade-off is observed: strength decreases while ductility increases with greater thermal softening.

In T6 condition, the alloy shows the highest strength but lowest ductility, characteristic of a peak-aged state (Chen et al. 2023). It yields at around 540 MPa and reaches a UTS of 600 MPa, with an elongation of about 13%, suggesting limited plastic deformation and a narrow strain-hardening region.

Heat-treated specimens, in contrast, show reduced strength but increased ductility. At 425 °C, both UTS and yield strength decline over time, dropping to 432 MPa and 243 MPa after 30 min, and to 377 MPa and 199 MPa after 60 min, respectively. Elongation improves to as much as 22.5%. These curves represent a softer, more formable material.

At 450 °C, the response is more complex. While the 30-min treatment yields a UTS of 469 MPa, it increases to 495 MPa after 60 min. Yield strength follows a similar upward trend, accompanied by improved elongation, suggesting partial recovery of strength alongside enhanced ductility. The 475 °C condition shows strong initial performance at 30 min (UTS ≈ 527 MPa, YS ≈ 352 MPa, elongation ≈ 20.7%), offering a good strength–ductility balance. However, at 60 min, strength drops significantly while elongation increases, highlighting how extended exposure can soften the alloy further.

Overall, all heat-treated samples demonstrate higher ductility than the T6 condition, with elongation ranging from 18% to 22.5%. The softest treatments offer the greatest

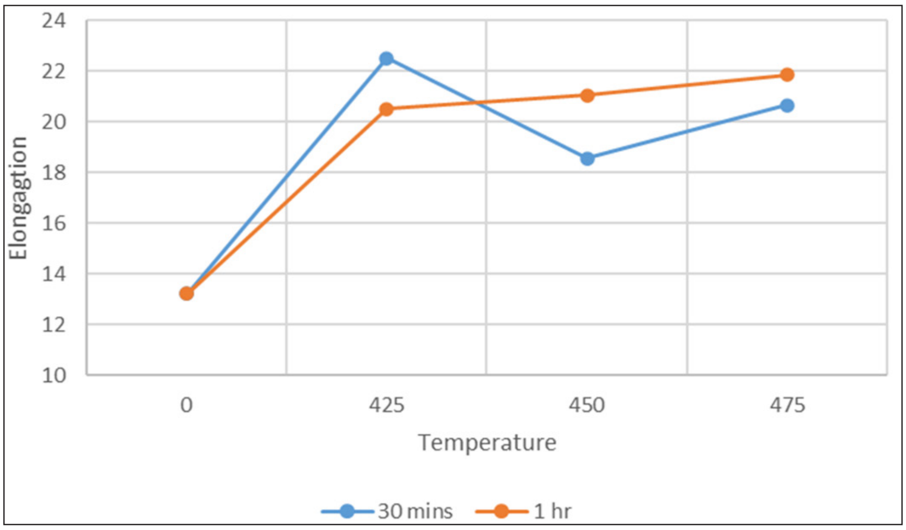


FIGURE 6. Elongation against heating temperature under different durations

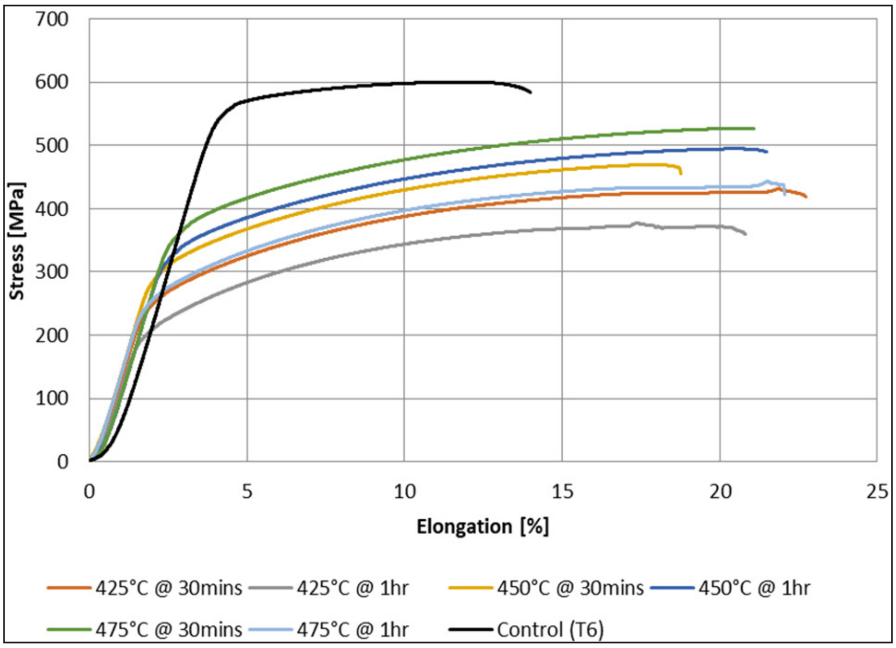


FIGURE 7. Stress against Elongation under different heating temperatures and durations

TABLE 2. Microhardness of AA7075 specimens under various heat treatment conditions

Specimen	Rockwell hardness (HRB)
Control (T6)	91.24
425-30	59.2
425-60	55.02
450-30	63.34
450-60	71.72
475-30	77.74
475-60	59.98

formability, while intermediate cases like 450 °C/60 min and 475 °C/30 min achieve a better strength–ductility compromise (Table 2). These findings illustrate how heat treatment can be used to tailor mechanical properties for specific engineering needs.

MICROHARDNESS

The hardness measurements (Figure 8 and Table 3, performed via microhardness on the Rockwell B scale) further support the tensile results. In a previous study, AA7075 samples achieved a hardness of 91.72 HRB under optimal T6 conditions involving solution treatment at 465 °C for 90 min followed by aging at 120 °C for 12 h (Freitas & Silva 2018). In another study, the base metal AA7075 exhibited a hardness of 92 HRB (Kumar, Srivastava & Singh 2020). Similarly, in the present study, the T6 temper exhibited the highest hardness, measured at approximately 91.24 HRB, indicating consistency with established T6 treatment outcomes.

All heat-treated conditions showed a drop in hardness relative to T6, confirming that exposure to 425-475 °C caused the alloy to lose some of its age-hardening. However, the hardness changes were not uniform across all conditions. At 425 °C, hardness decreased monotonically with time: from about 59 HRB after 30 min to 55 HRB after 60 min. This substantial softening at 425 °C is consistent with overaging, where prolonged heating dissolves or coarsens the strengthening precipitates. In contrast, the 450 °C treatment produced a non-monotonic hardness response. After 30 min at 450 °C the hardness dropped to ≈63 HRB, but at 60 min it increased to 72 HRB, partially recovering toward the T6 value. This behaviour aligns with the UTS/YS trends, suggesting that a longer hold at 450 °C enabled some re-precipitation or structural readjustment that restored hardness. Finally, the 475 °C condition yielded the highest hardness among the treated samples when held for 30 min: 78 HRB, which is quite close to the original hardness. A short exposure at this high temperature likely dissolved most precipitates (nearly solutionizing the alloy) and, upon quenching, resulted in a supersaturated solid solution that naturally aged, producing new fine precipitates and a high hardness. However, when the 475 °C soak was extended to 60 min, the hardness plummeted to 60 HRB. This value is one of the lowest recorded and reflects a severely overaged condition after an hour near the solvus temperature.

The microhardness trends observed in this study reflect the thermal sensitivity of AA7075 under different heat treatment conditions. At 425 °C, a steady decline in hardness with longer exposure time indicates progressive softening of the material. This suggests a reduction in strengthening effectiveness over time at this temperature. At 450 °C, the initial drop in hardness after 30 min is followed by a partial recovery at 60 min, indicating that prolonged exposure may restore some hardness, similar to industrial practices like retrogression and re-aging used to recover strength in aged alloys. Even so, the recovered value (72 HRB) remained below the original T6 hardness. At 475 °C, a short 30 min exposure produced the highest hardness among the treated samples (78 HRB), likely due to rapid transformation during quenching and natural aging, yielding a condition close to the original T6 state. However, extending the exposure to 60 min led to a significant drop in hardness (60 HRB), representing one of the softest conditions recorded. Overall, treatments above the standard aging temperature tend to reduce hardness, with short, high-temperature exposures temporarily maintaining higher values, while extended durations lead to substantial softening. From an application standpoint, lower hardness can be beneficial for improving machinability or formability, while short-duration high-temperature treatments may serve to relieve internal stresses with minimal loss in hardness, provided the process is carefully controlled.

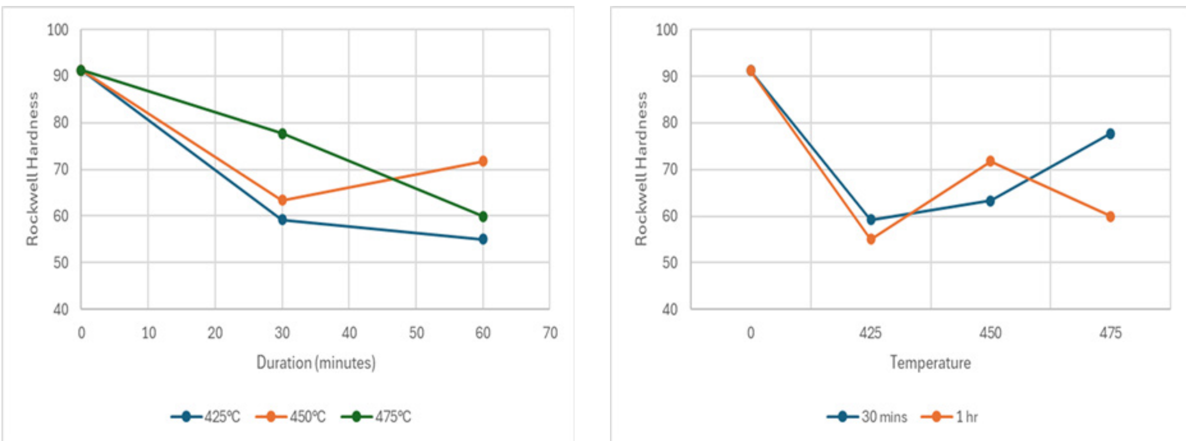


FIGURE 8. Microhardness against (a) heating temperatures and (b) heating durations

CONCLUSIONS

This study confirms that the mechanical properties of AA7075 aluminium alloy are strongly influenced by heat treatment temperature and duration. Higher temperatures and longer exposure times led to a clear reduction in tensile and yield strength, with the most significant drop observed at 425 °C for 60 min. At the same time, all heat-treated samples showed improved ductility compared to the original T6 condition, with elongation increasing by up to 70%. The treatment at 475 °C for 30 min provided the best balance between strength and ductility, making it a suitable option when both properties are important. Hardness trends closely followed strength results, reinforcing the role of thermal softening. Despite these changes, the elastic modulus remained largely constant. Overall, the findings highlight the importance of selecting appropriate heat treatment conditions to optimize the performance of AA7075 in practical applications. These insights are especially relevant for aerospace structures, automotive crash-resistant components, and lightweight sports equipment, where tailoring strength–ductility balance is critical.

A main limitation of this study is the lack of microstructural analysis using Scanning Electron Microscopy (SEM), which was not possible due to budget constraints commonly faced in final year projects. As a result, the research focused solely on mechanical testing, including hardness and tensile strength. While these tests provided useful information on how heat treatment affects the alloy's performance, the absence of SEM prevented direct observation of internal changes like precipitate behaviour or fracture patterns. Future research with access to SEM would allow a deeper understanding of the material's response to thermal treatments.

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